ARDI PROJECT

Project title: Pilot malting and brewing
Project number: 00-407

Background and objectives

The Canadian Malting Barley Technical Centre (CMBTC) is a newly established, non-profit organization. CMBTC's mandate is to provide technical support to the marketing of Canadian barley and malt to offshore customers.
The objectives of this project are:

- Commissioning and standardizing pilot malting and pilot brewing systems and establishing CMBTC's ability to produce malt and beer with commercial quality
- To establish as soon as possible after the 2001 harvest the optimal malting conditions for each variety, given the market they are likely to be used in, and the type of malting facility they might be processed in.
- Since brewhouse performance cannot necessarily be predicted from finished malt analysis, pilot brewing will be used to evaluate the brewing characteristics of malt produced from these varieties. Brewing will be carried out using standardized methods developed during phase 1 of the project.

Research activities

Pilot Malting

1. Commissioning and standardizing pilot malting system

Installation and startup of the malting units was delayed until the end of July, 2001, due to site preparation problems. Once the equipment was in operation, we commenced our work on establishing the ability of the malting equipment. Given the fact that this malting plant represents new technology and is quite unique, a lot of work was required before we could adjust the equipment to produce malt of the required standard. For standardizing the malting system, we did comparative studies by simulating (repeating) commercial malting schedules and by processing the barley sampled from the same lot of barley for commercial malt production. The quality of the malt produced from the pilot malting system was compared with the commercial malt. The test results indicate that the pilot system is able to simulate commercial scale malting conditions and produce commercial type malt. Based on the test results, a poster presentation titled "Evaluating the malting and brewing characteristics of new Canadian malting barley varieties under the simulated commercial processing conditions**"** has been prepared. The poster

has been accepted, and will be presented at the annual meeting of the American Association of Brewing Chemists in Tuscon, Arizona during June 8-12, 2002.

2. Study of water uptake of the major Canadian malting barley varieties

Water uptake rates of CDC Copeland, AC Bountiful, AC Metcalfe, CDC Kendall, CDC Stratus, Stein, Merit, Excel, CDC Sisler and Legacy, as well as three breeding lines at the late breeding stage were examined with Harrington as control. Barley's water uptake rate at steeping is one of the very important quality characteristics of malting barley because it affects the requirements of processing conditions and the quality of the finished malt. In this study we examined the effects of crop year (growing conditions) and barley protein content on barley water uptake and chitting rates at steep, as well as the quality of the finished malt. We observed that in addition to the varietal differences in water uptake, crop year (growing conditions) and barley protein content significantly affected barley water uptake, chitting rate and finished malt quality. The high barley protein content elevated by last year's dry growing conditions slowed down barley water uptake significantly. Therefore, we tried different steeping cycles for the different varieties mentioned above and for the same variety with different protein content to achieve a desirable steep out moisture, chitting rate and to improve malt quality. Some of the preliminary results from this study were presented to our malting barley end users in China during the CIGI and CWB's 2001 malting barley technical mission, which took place during Nov. 30 through Dec. 9, 2001. The more detailed results will be presented to the District Western Canada 2002 MBAA convention in Winnipeg during May 23-25, 2002.

3. Optimization of the malting conditions of new Canadian malting barley varieties

In this study we focused on two aspects: (1) develop practical malting schedules for the newly developed barley varieties and transfer these schedules to our domestic and international barley users, which enable them to utilize the quality potential of these barley varieties; (2) develop malting schedules which enable the malting barley users to fully utilize the quality potential of some of our existing varieties with less desirable protein content (>13.0 %). The activities related to this study are summarized in Table 1.

Table 1.

	Commercial processing conditions developed	Malt quality evaluated	Recommendations to members and clients	Current status
New varieties				
AC Metcalfe	√	√	√	
CDC Kendall	√	√	√	
CDC Stratus	√	√	√	
Merit	√	√	√	
CDC Copeland	√	√	√	Did plant scale test with the customer
AC Bountiful	√	√	√	Feed back results to seed company
CDC Sisler	√	√	√	
Excel	√	√	√	

Legacy	√	√		
Existing varieties				
Harrington	√	√	√	Continuing study
Stein	√	√	√	Continuing study, plant trials in progress
Breeding lines				
AB2482-M	√	√	√	Fed back results to breeder
AB-2482-1	√	√	√	
AB2482-4	√	√	√	

Up to date we have conducted 37 pilot malting trials with all the varieties listed in Table 1. Some of the processing conditions generated from these tests have been given to domestic and off-shore malting barley customers to be used as guidelines in processing the new Canadian malting varieties, and existing varieties with higher protein content caused by last year's dry growing conditions. Foreign customers are gradually accepting the new varieties. At present time we are working with a malting company in China to process one malting barley variety with a protein content above13%. We are attempting to overcome and minimize the negative effect of the high barley protein content. According to traditional malting and brewing practice, barley with a protein content of > 13% is not desirable and not welcomed by maltsters and brewers. Barley with high protein content produces lower extract and has a tendency toward poor modification and undesirable soluble protein.

Our test results indicate that all the tested new barley varieties can produce quality malt with quality comparable to or better than Harrington barley. For malting condition requirements, there are some similarities to Harrington, but every new variety requires processing conditions to be fine-tuned in order to fully utilize its malting quality potential.

Based on our pilot malting and plant scale trials, we have generated technical data sheets for our members for the new malting barley varieties. Those data sheets will help barley traders and barley users gain a better understanding of new Canadian malting barley varieties.

Pilot brewing

1. Commissioning and standardizing the pilot brewing system

The pilot brewing system was commissioned in November 2001 due to some unexpected delays in site preparation. Since the commissioning, we have processed 20 brews. The first 15 brews were used to start up and to standardize the brewing system. Therefore, only brewing analysis was performed for these 15 brews, not beer analysis. For the rest of the brewing trials we performed both brewing and beer analysis (Table 2).

Table 2

Varieties	Brewing trials	Beer packaged and evaluated
New		
AC Metcalfe	2	X

CDC Kendall	1	X
CDC Stratus	1	
Merit	1	X
CDC Copeland	2	
AC Bountiful	1	X
CDC Sisler	1	X
Excel		
Legacy		
Existing		
Harrington	1	
Stein	1	

2. Brewing tests with new Canadian malting barley varieties

As we know, the acceptance of the barley varieties by customers is not only affected by the malting quality and brewing characteristics of a particular variety, but also the understanding of how to process the new varieties and to fully utilize their quality potential.

In addition to the start up brewing trials, we did a comparative study with 4 new varieties. The study was focused on brew-house performance and beer quality. The varieties we tested were AC Metcalfe, CDC Kendall, Merit, AC Bountiful, and CDC Sisler (Table 2). The malt for the brewing trials was produced by our pilot-malting system. As a control, we used a standard commercial 2-row malt blend produced by a major Canadian malting company. All beers were produced using 100% malt (no adjuncts), and no aroma hops were used, in order not to mask any malt characters.

As the malt analysis indicates (Table 3), all the varieties were well modified, with commercially acceptable levels of extract, enzymes, and soluble protein. One area where the malts were different, reflecting the barley analysis, was total protein. Merit, at 11.7%, was quite low, reflecting barley that would be obtained from a season with ideal growing conditions. However, problems in the malting plant resulted in malt with a high level of soluble protein, resulting in a Kolbach Index that was very high, and would be out of specification to many customers. We did not have enough barley to process another batch of malt, so the results have to be viewed with this in mind. CDC Kendall, with a protein of 13.56, reflected the high protein barley that is typical of the Canadian 2001 crop. This is significant in that we had an opportunity to evaluate both low and high protein malt in the same trial. Many customers of Canadian barley would consider 13.5% protein unacceptably high.

Table 3

	AC Metcalfe	Merit	CDC Kendall	AC Bountiful	CDC Sisler	Commercial
Moisture %	4.0	4.0	4.3	4.2	3.7	4.6
Friability %	90.5	92.1	92.9	92.2	93.6	
Fine Extract %	81.2	80.9	80.6	80.3	77.9	81.7
Coarse Extract %	80.9	80.5	80.2	80.2	77.8	79.9
F/C difference	0.3	0.4	0.4	0.1	0.1	1.8
Soluble Protein %	5.54	5.82	5.47	5.65	5.23	4.83
Total Protein %	12.5	11.7	13.6	13..2	12.2	12.1
Kolbach index*	44.32	49.74	40.34	42.90	42.90	39.70
β–Glucan - ppm	76	97	52	82	63	
Viscosity centipoises	1.45	1.41	1.42	1.43	1.43	1.44
Runoff time - min	83	70	70	73	83	88
Diastatic PowerP ^{0}L	164	163	175	166	165	128
α–Amalyse- dextrinizing units	69.4	70.6	61.3	68.6	62.7	59.7
Free Amino Nitrogen - ppm	228	247	248	233	246	
malt colour - ^{0}ASBC	1.70	2.80	2.00	2.57	1.78	1.5

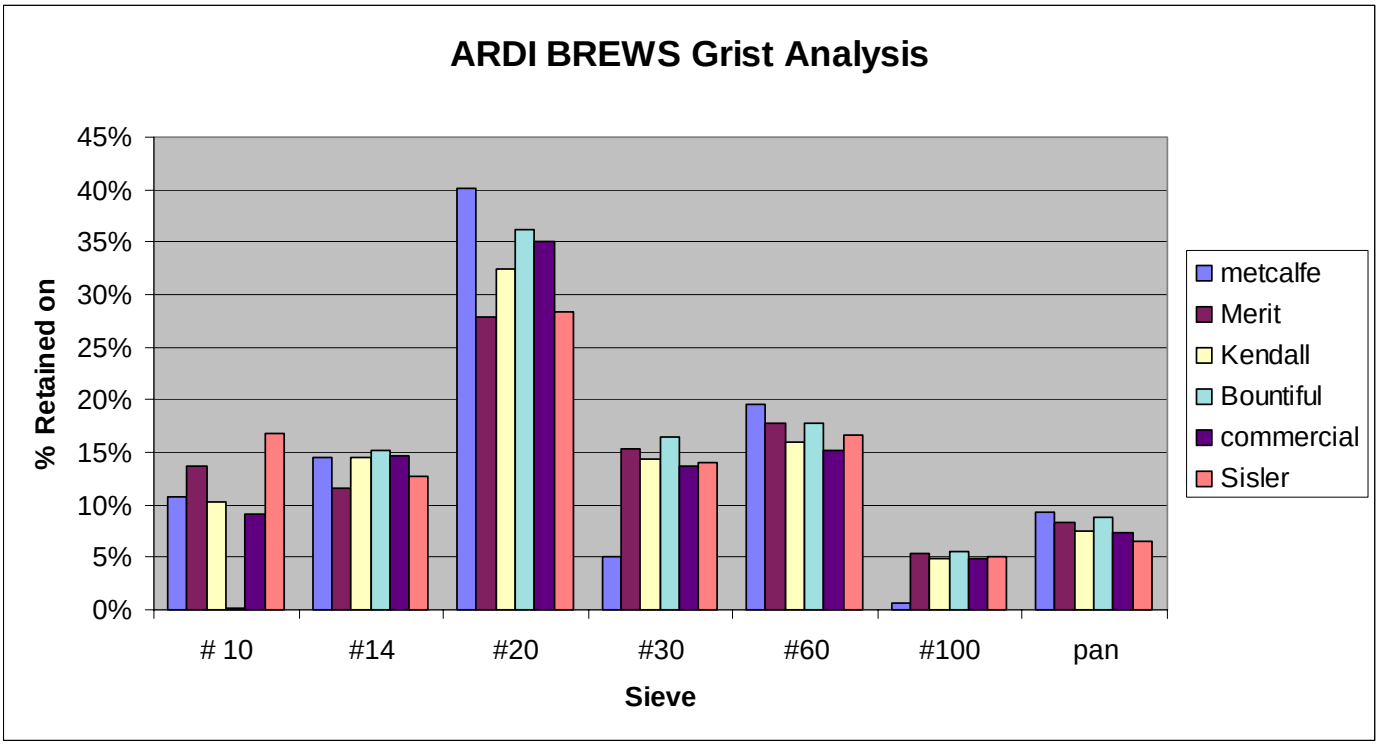
* the Kolbach index for Merit was abnormally high due to malting problems

Brewing Results

Milling

All the malts were ground using the CMBTC 4-roll malt mill with identical mill settings, and produced remarkably similar grist, as measured by particle size distribution on standard sieves, although there were some differences (Fig. 1). This is very important, as breweries do not like to have to adjust their mills, and often use a blend of varieties. In our trials, AC Metcalfe tended to produce a slightly coarser grist overall, while AC Bountiful seemed to have less large husk fraction. CDC Sisler had a higher fraction of husk on the #10 sieve, which could be expected for six-row malt.

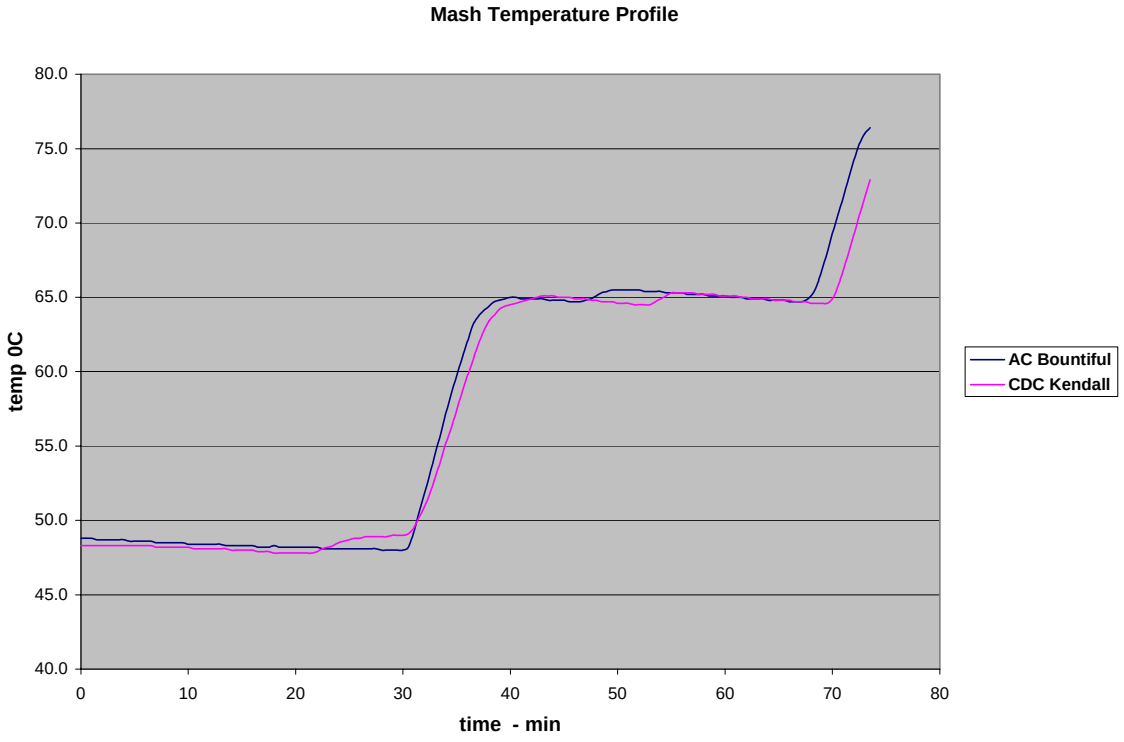
Fig.1



Mashing

All brews were processed using a standard mashing cycle. The ground malt was mixed with water at 48^0 C and held for 30 minutes for protein and β-glucan breakdown. The temperature was then raised to 65^0C and held for 30 minutes for enzymatic conversion of starches. A starch test using iodine was done to ensure that no residual starch was present before proceeding to the next step, mash off to inactivate the enzymes, at 76^0C. The mash profile graph (Fig. 2) demonstrates not only the ability of the brewing system to replicate processing conditions, but the accuracy with which the brews were processed.

Fig. 2



Lautering

The mash was transferred to the lauter tun, and filtration of wort to the kettle took place. Filtration time and wort clarity (Fig. 3) were monitored. Slow runoff, and/or poor wort clarity could be indications of inadequate malting or a problem with the variety (high β-glucan, etc.). In the case of the malts studied, there were slight differences, but these were probably within tolerances for the process being used, and are not cause for concern. Merit exhibited high initial wort turbidity, but it cleared up quickly. The most surprising result was that the "control" commercial malt had the poorest level of wort clarity. This is a result that will be confirmed as soon as we have time.

Runoff times were somewhat variable (Fig. 4), with the commercial malt taking the longest to run off, but there were no obvious problems with any of the malts. The commercial malt was not as fully modified as the CMBTC malts, and this could account for the difference. An interesting insight was provided by the relationship between wort viscosity, as measured in the "congress wort" during malt analysis, and lautering time (Fig. 5). Wort viscosities were all within a fairly narrow range, and well within normal specifications, but the correlation between viscosity and runoff time, at R=0.71 was quite high. While the results of our brews might indicate that Merit, CDC Kendall, and AC Bountiful have superior lautering characteristics, this conclusion would be premature, as the malting process determines many of the characteristics of the malt. As well, since the lautering process is manually controlled, and the operator exercises his judgment as to speed of liquid flow, positioning of the lautering rakes, etc., it would be improper to draw any conclusions on the basis of one trial. Over time, as we process more brews with each variety, we will be able to accumulate enough data to demonstrate whether the results of this trial are valid.

Although the levels of β-glucan are traditionally associated with high viscosity and slow runoffs, we actually had a slight negative correlation between β-glucan and viscosity (R=-0.2), and β-glucan and runoff time (R= -0.27). These are not significant values, but we would have expected a positive correlation. It could be because the levels of β-glucan were very low in all of the malts, but it may be worthy of study in the future.
Brewing materials efficiency, or brewhouse yield, was again very similar for all the malts tested (Fig. 6), with CDC Kendall and AC Bountiful having slightly higher yields, although with only one trial, this may not be a significant result.

Fig. 3

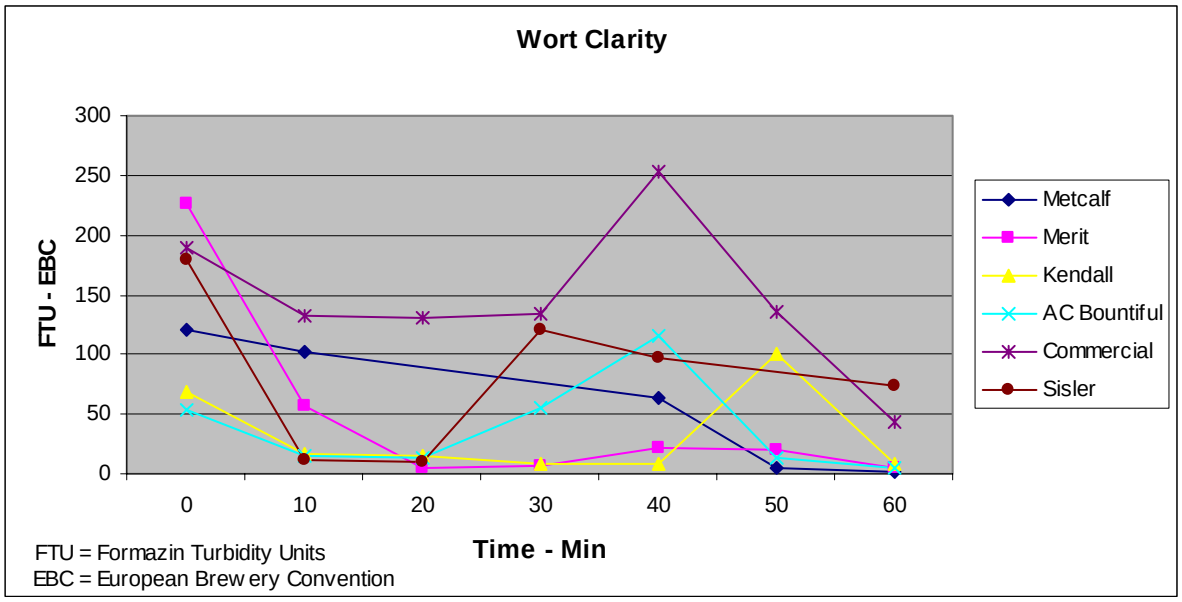


Fig.4

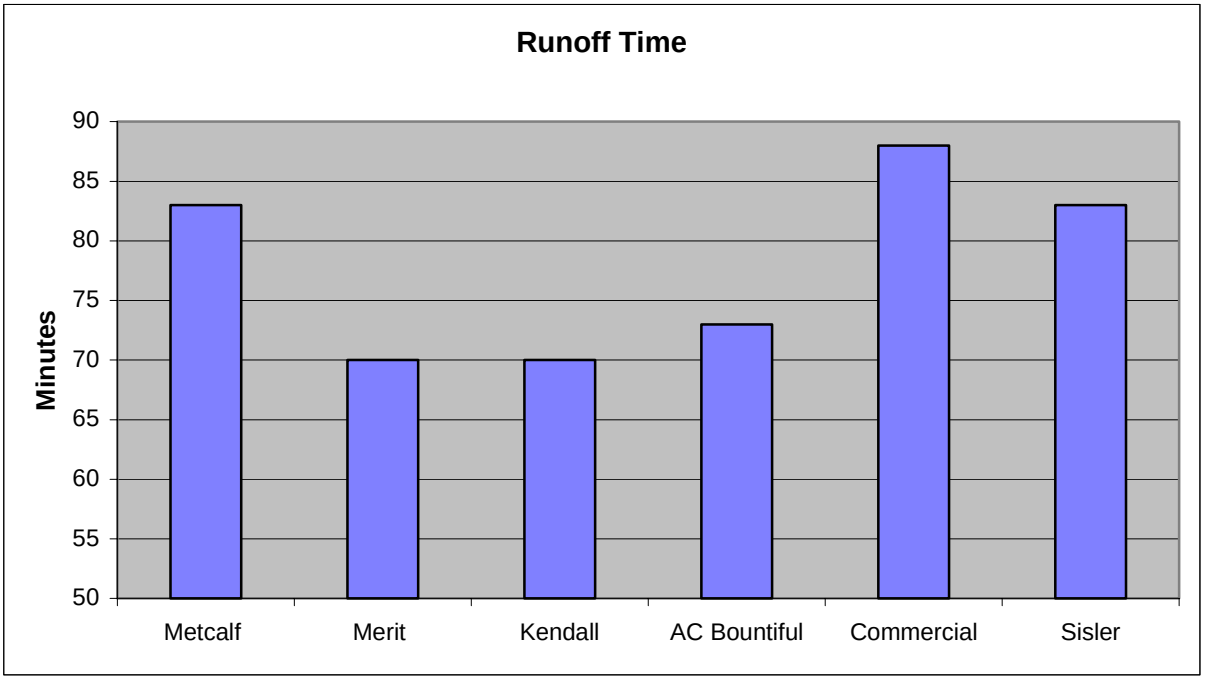

Runoff Time
Minutes
90
85
80
75
70
65
60
55
50
Metcalf
Merit
Kendall
AC Bountiful
Commercial
Sisler

Fig. 5

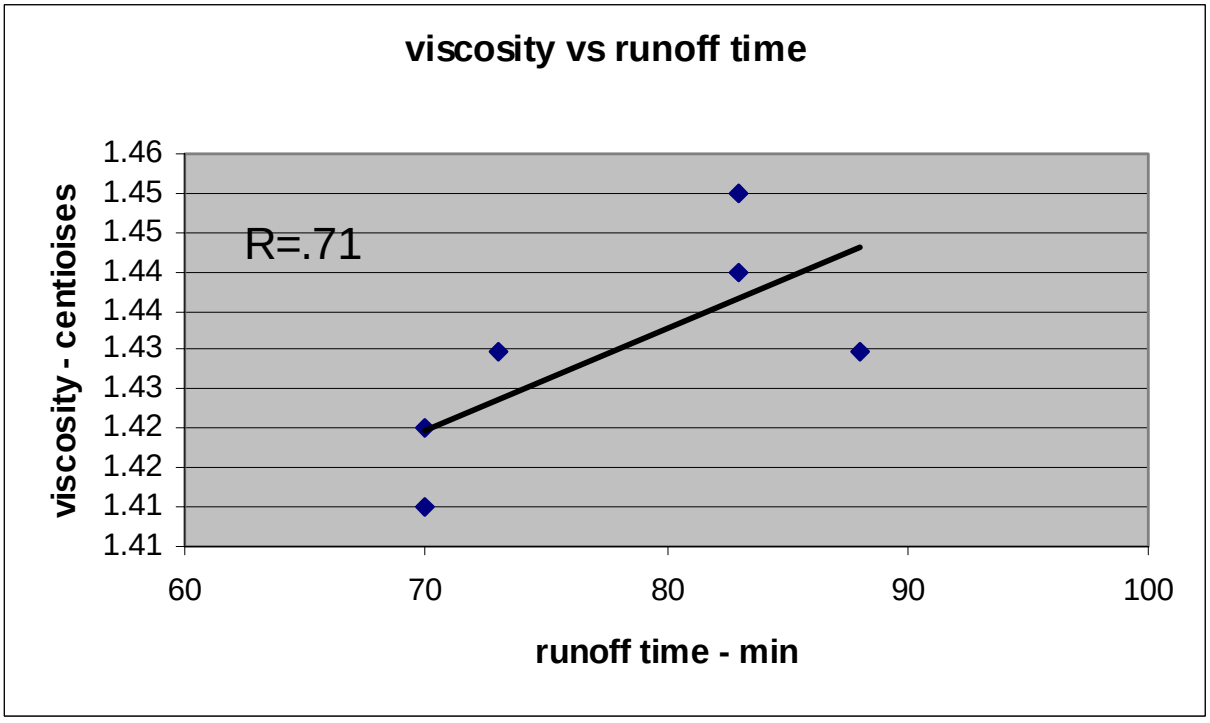
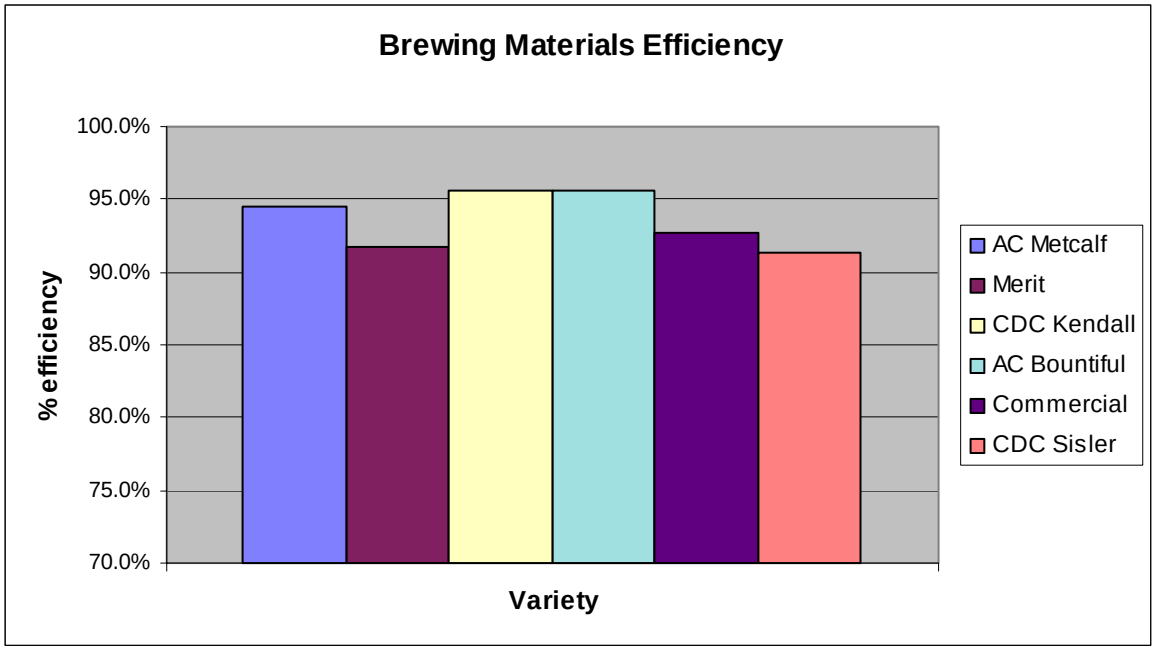

viscosity vs runoff time
viscosity - centioises
1.46
1.45
1.45
1.44
1.44
1.43
1.43
1.42
1.42
1.41
1.41
R=.71
60
70
80
90
100
runoff time - min

Fig. 6



FERMENTATION

All worts were cooled to 12^{o} C, aerated using pure oxygen to approximately 12 ppm dissolved oxygen, and fermented at 15^{o} C. Yeast was obtained from a local microbrewery, and pitched at approximately 11 million cells per ml.
Fermentation curves were very similar (fig.7), and the beers all fermented to an end gravity that was very similar (Fig.8), producing an alcohol level between 5.1 and 5.3 % by volume. This is a very important result, because it confirms two hypotheses

- The basic nature of the new varieties, and indeed Canadian malts, to produce similar fermentable carbohydrate profiles given the same brewhouse processing conditions
- The ability of the CMBTC brewery to produce consistent and repeatable worts.

A failure of the cooling system during the AC Bountiful fermentation resulted in the temperature rising 5 degrees above the set point. This would not affect the degree to which the beer fermented, but could have affected the flavour profile of the finished beer

Fig. 7

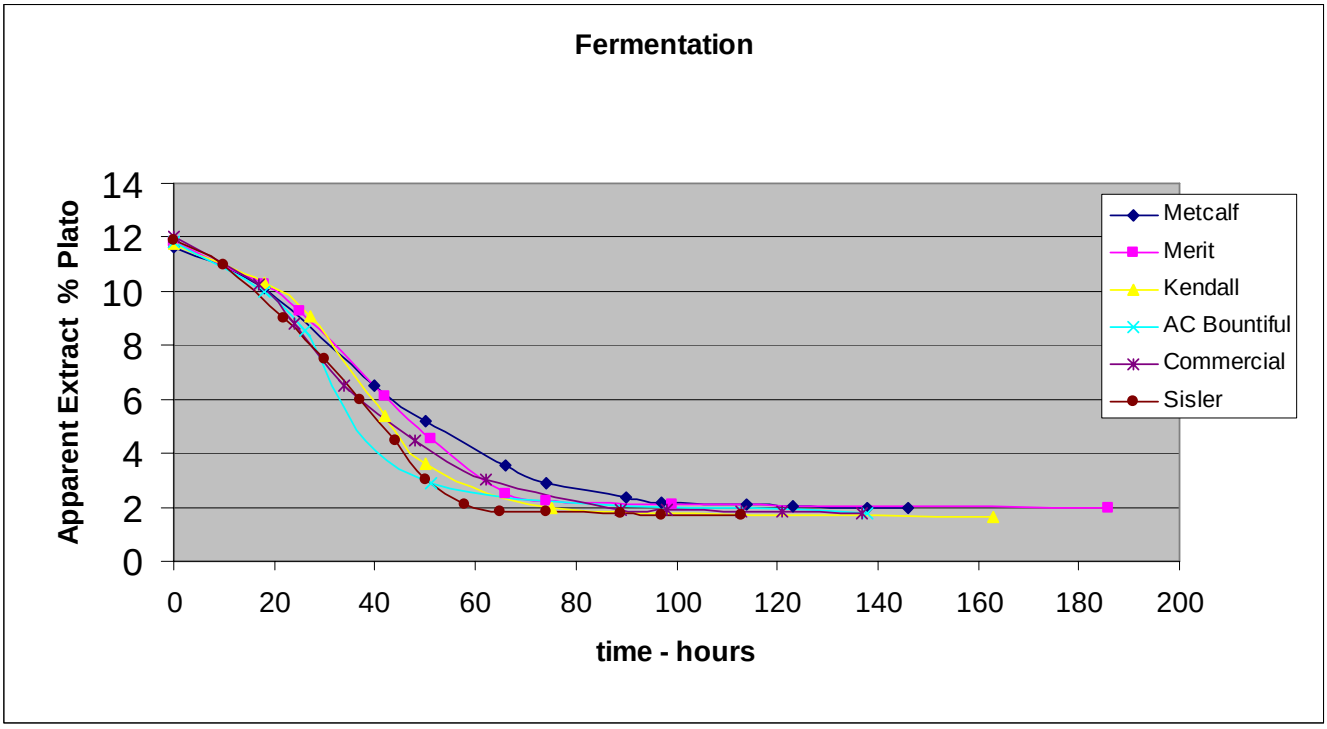
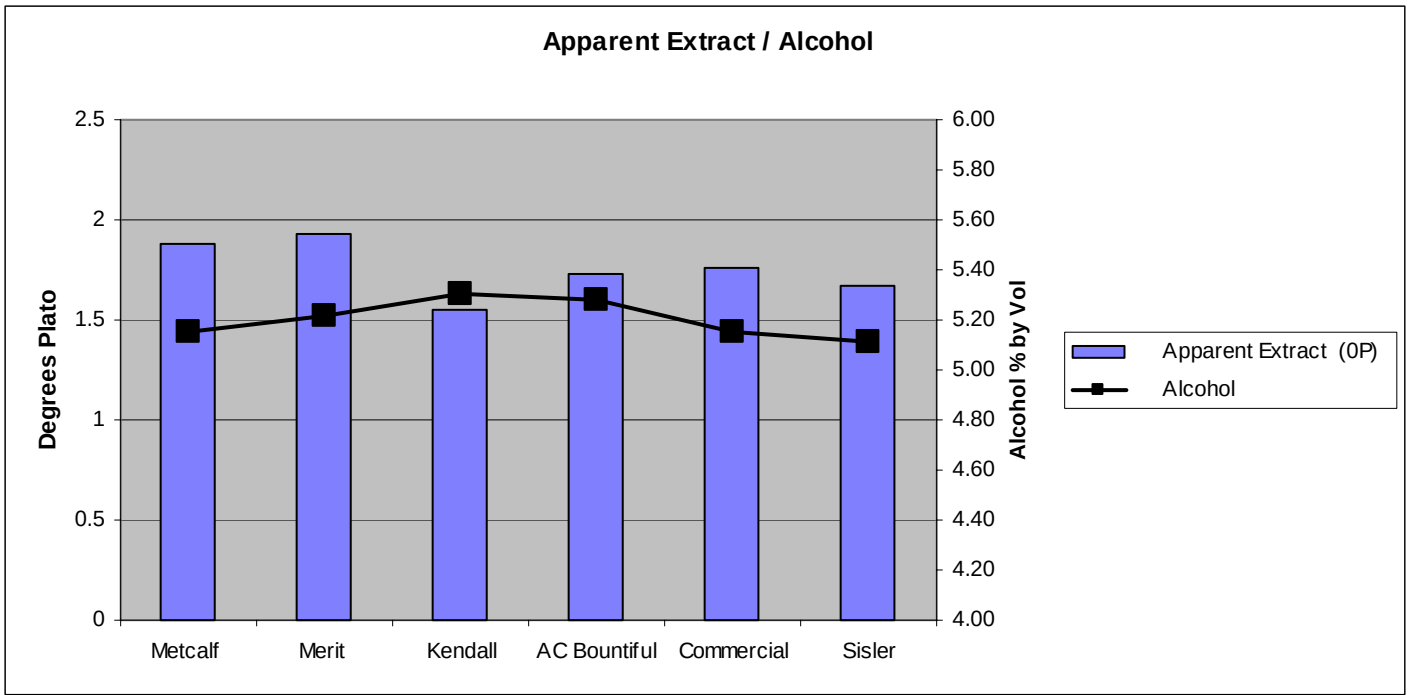

Fermentation
Apparent Extract % Plato
14
12
10
8
6
4
2
0
0
20
40
60
80
100
120
140
160
180
200
time - hours
Metcalf
Merit
Kendall
AC Bountiful
Commercial
Sisler

Fig. 8



ANALYTICAL RESULTS

The results of beer analysis indicate that all the four varieties produced quality beer under the trial conditions (table 4). It is important to note that these observations are based on very limited trials, so we were unable to draw definitive conclusions. One conclusion that is safe to make is that all the varieties tested will produce good quality beer. This is not surprising considering the pedigree of the barleys, and the fact that a variety that becomes registered has never been shown to produce unacceptable beer.

Things worth noting included

- The difference in beer colour. This is directly related to the malt colour (Fig. 9), which in turn is related to the malt soluble protein (Fig 10), as kilning conditions were the same for all varieties, and boiling time for the worts was the same. Also, higher levels of soluble protein will cause greater colour development during boiling. The relationship between soluble protein and malt and beer colour is very important, as many customers of Canadian barley do not want malt with high colour. Too much modification of the barley will result in high soluble protein, which in turn results in high malt colour. This is a bit of a “catch 22” for the maltster, as the extract level of the malt and modification are directly related.
- The Dissolved Oxygen values in the in-process and bottled beer were variable, as we were still in the “commissioning” phase for our bottling and filtration equipment. Acceptable levels for commercial bottled beer using the latest equipment and good brewing technique would be <0. 25 ppm. By the end of the trials, we were well under this figure.

- CO2 levels in the finished beer were variable as well, another commissioning issue that will resolve itself with experience.
- HPLC analysis for carbohydrates (Fig 11) showed that the residual carbohydrate profiles were very similar, suggesting that a brewery would meet its internal specifications with any of the varieties without having to make any significant process changes

Fig.9

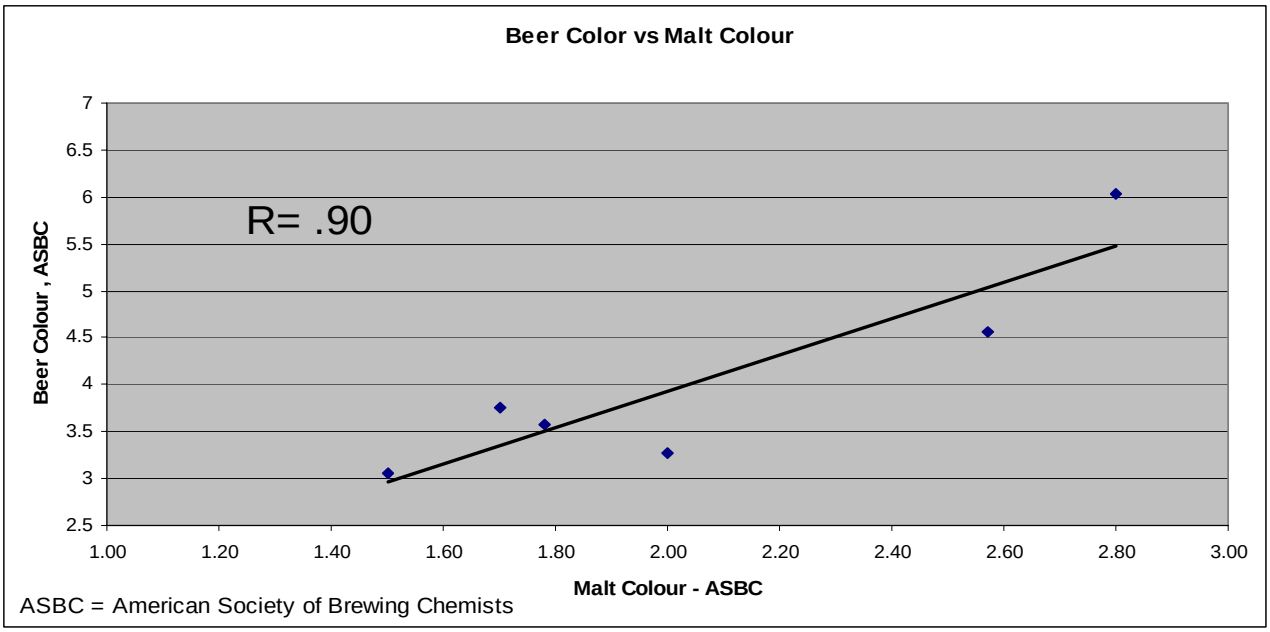


Fig. 10

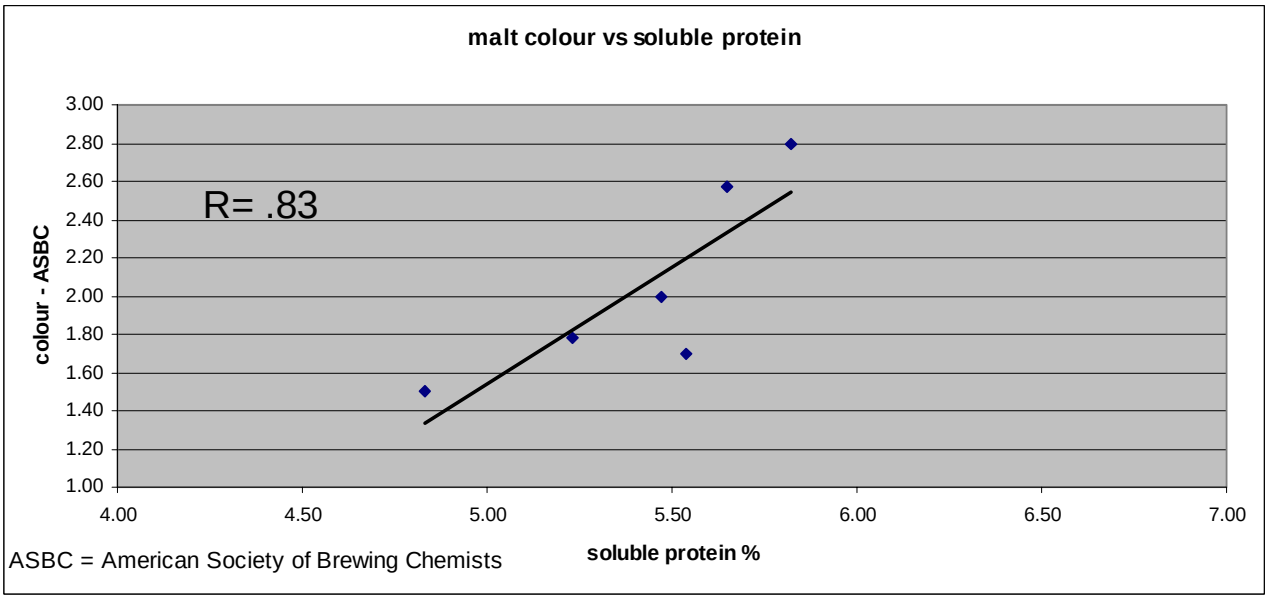
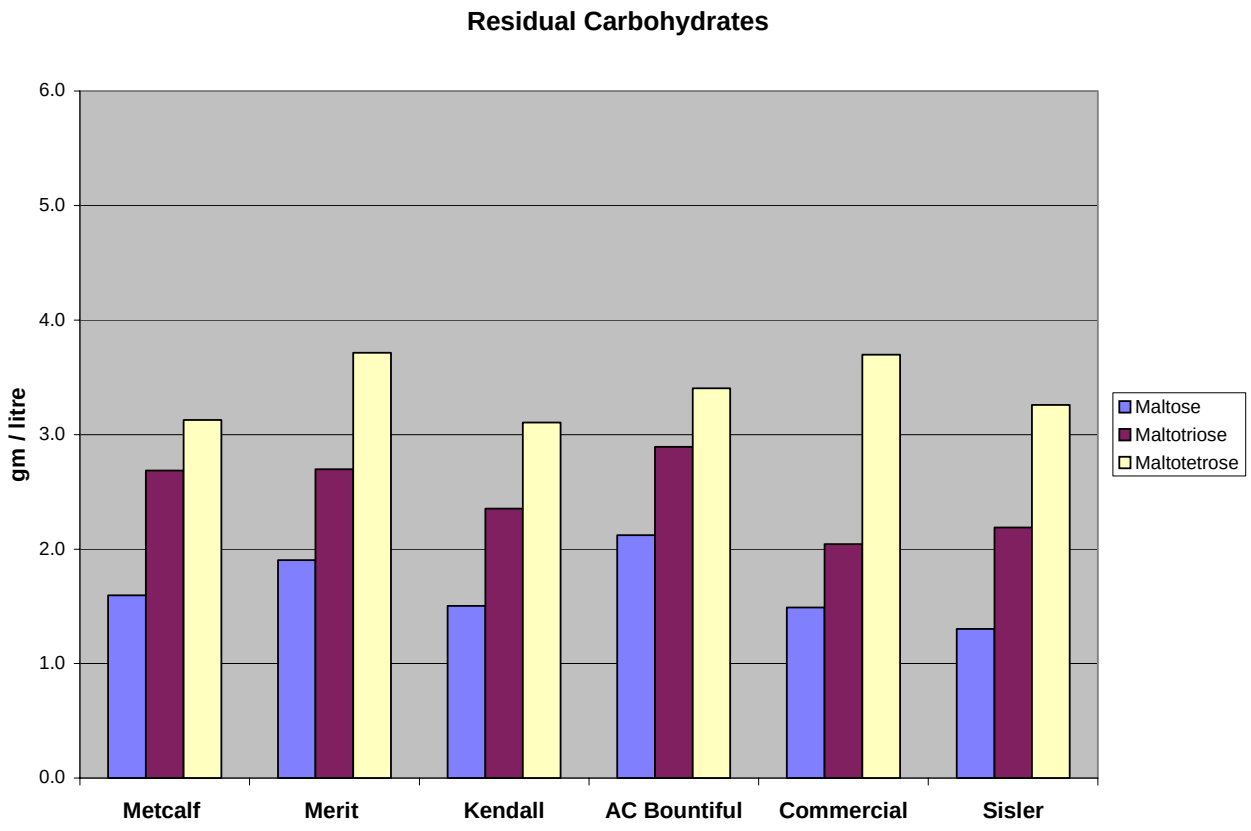


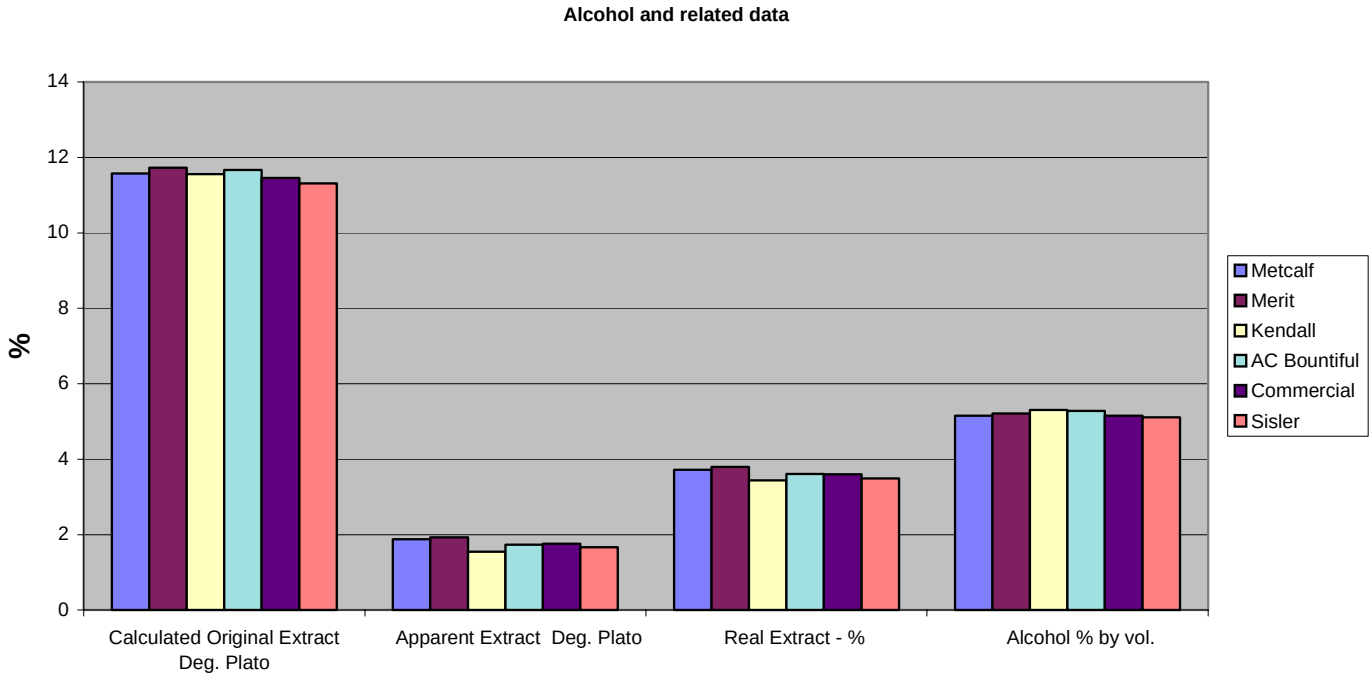
Fig. 11


Residual Carbohydrates
gm / litre
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Metcalf
Merit
Kendall
AC Bountiful
Commercial
Sisler
Maltose
Maltotriose
Maltotetrose

	AC Metcalfe	Merit	CDC Kendall	AC Bountiful	Commercial	CDC Sisler
Calculated Original Extract ^{0}Plato	11.57	11.73	11.56	11.67	11.46	11.31
Apparent Extract. ^{0}Plato	1.88	1.93	1.55	1.73	1.759	1.669
Apparent Degree of Fermentation %	83.8%	83.5%	86.6%	85.2%	84.7%	85.2%
Real Extract %	3.72	3.79	3.44	3.61	3.6	3.49
Real Degree of Fermentation %	69.2	69.04	71.45	70.34	69.92	69.92
Alcohol % by Vol.	5.15	5.21	5.31	5.28	5.15	5.11
Alcohol Vol / Real Extract	1.38	1.38	1.54	1.46	1.43	1.46
Specific Gravity	1.007340	1.007540	1.006050	1.006750	1.006855	1.006503
Alcohol % by Wt.	4.04	4.09	4.17	4.15	4.05	4.02
Alcohol Wt./Real Extract	1.09	1.08	1.21	1.15	1.13	1.15
Color (ASBC)	3.76	6.04	3.27	4.57	3.05	3.57
pH	4.53	4.42	4.39	4.46	4.4	4.34
IBU – ppm	18.31	23.47	23.37	21.6	19.1	18.3
VDK, ppm	0	0	0	0	0	0.048
CO2 v/v	2.65	2.3	2.09	2.69	3.2	3.05
Dissolved Oxygen (mg/L)	0.36	0.758	0.76	0.39	0.08	0.08
Formazin Turbidity Units - ASBC	35	24	22	31	14	14
Foam, Nibem	139	138	146	156	148	140
Glucose gm/litre	0	0	0	0	0	0
Maltose gm/litre	1.6	1.9	1.5	2.1	1.5	1.3
Maltotriose gm/litre	2.7	2.7	2.4	2.9	2.0	2.2
Maltotetrose gm/litre	3.1	3.7	3.1	3.4	3.7	3.3

Table. 3

Fig. 12



SENSORY EVALUATION

The packaged beer was submitted to sensory analysis on two separate occasions. While there were minor differences, the beers were rated as good, and very similar in character. It was clear from the panel results that any of the malts would make quality beer.

CONCLUSIONS – ECONOMIC IMPLICATION OF THE MALTING AND BREWING PROJECT

- With the assistance of the ARDI grant, the CMBTC has established its ability to malt and brew to commercial standards, and has validated the ability of the equipment we purchased.
- The CMBTC has malted 2001 crop barley from all the new varieties, and has provided our members, and their clients with information on how to process the barley.
- The CMBTC has demonstrated that beer brewed from the new varieties will meet the standards of commercial brewers.

CMBTC's establishment, and work to date for its members, is helping to enhance the image of the Canadian malting barley industry in general and we are gradually achieving our goal of establishing technical relations with our major barley and malt users, both domestically and internationally. During the last few months CMBTC has played host to numerous visitors from major international malting and brewing companies on behalf of its members. In the summer of 2002, the CMBTC, in conjunction with CIGI is going to provide a technical training program to our major malting barley and malt users from China. China currently is Canada's 2nd largest malting barley buyer with the potential for major increases in malting barley and malt importation.

This project has helped CMBTC to establish its database and to facilitate customer technical support By providing technical support to our barley users, we can build up customers' trust and confidence in pursuing and using the new Canadian malting barley varieties and to help Canadian grain companies to expand their market share.

ACKNOWLEDGEMENT

The CMBTC wishes to express its appreciation to ARDI for providing the funding to make this project possible.