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CANADIAN MALTING BARLEY TECHNICAL CENTRE

CMBTC 2016 MALTING BARLEY CROP QUALITY ASSESSMENT

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CMBTC 2016 MALTING BARLEY CROP QUALITY ASSESSMENT

Summary

The CMBTC conducted barley analysis, as well as pilot scale malting and brewing trials with the following 2016 crop malting barley varieties: AC Metcalfe, CDC Copeland, AAC Synergy, Bentley, Legacy, and a new two-row malting variety AAC Connect. These barley samples were collected and provided to the CMBTC by Richardson International, Viterra Inc., Malteurop Canada Ltd., Rahr Malting Co., Prairie Malt Ltd., Integrated Grains, and the CANTERRA SEEDS. The objectives of this work were to examine the overall quality of the barley samples, to assess their malting and brewing performance using the CMBTC's standard quality assessment procedures, and to generate process guidelines, where applicable, that can be used by end users.

The test results generated from this work indicated that the 2016 crop barley samples (AC Metcalfe, CDC Copeland, AAC Synergy, Bentley, Legacy and AAC Connect) all showed selectable quality for malting use. However there were some significant quality variations between varieties and among the samples recorded. For each of these varieties, the highlights of barley quality, as well as malting and brewing performance, in contrast to the last year's crop are summarized in the following boxes:

2016 crop AC Metcalfe (compared with 2015 AC Metcalfe)		
Barley Quality	**Malting Performance**	**Brewing Performance**
• Lower grain moisture • Lower protein content • Higher germination energy with stronger water sensitivity • Higher thousand kernel weight and higher plumpness • Significantly lower RVA values suggesting poor storability	• Faster water-uptake and more advanced growth of acrospires • Significantly higher friability and higher extract yield • Comparable levels of enzymes • Slightly higher soluble protein and higher FAN • Slightly lower malt beta-glucan	• Comparable conversion time • Slightly shorter time to clear during lautering • Slightly longer lautering time • Lower brewhouse efficiency • Lower (lighter) wort and beer colour • Comparable attenuation limit • Slightly lower foam stability • Slightly lower final beer alcohol concentration

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2016 crop CDC Copeland (compared with 2015 CDC Copeland)		
Barley Quality	**Malting Performance**	**Brewing Performance**
• Similar grain moisture • Significantly lower protein content • Comparable germination energy with stronger water sensitivity • Higher thousand kernel weight and higher plumpness • Significantly higher RVA values suggesting a better storability	• Similar water-uptake and more advanced growth of acrospires • Significantly higher friability and higher extract yield • Similar levels of enzymes • Comparable soluble protein but higher FAN • Significantly lower malt beta-glucan	• Slightly shorter conversion time • Slightly longer time to clear during lautering • Slightly longer lautering time • Comparable brewhouse efficiency • Significantly lower (lighter) wort and beer colour • Significantly greater attenuation limit • Significantly lower foam stability • Significantly greater final beer alcohol concentration

2016 crop AAC Synergy (compared with 2015 AAC Synergy)		
Barley Quality	**Malting Performance**	**Brewing Performance**
• Higher grain moisture content • Significantly lower protein content • Significantly lower germination energy and stronger water sensitivity • Significantly higher thousand kernel weight and comparable plumpness • Lower RVA values suggesting poorer storability	• Slower water-uptake and comparable growth of acrospires • Significantly higher friability and higher extract yield • Lower levels of enzymes • Lower soluble protein and FAN • Significantly lower malt beta-glucan	• Comparable conversion time • Slightly longer time to clear during lautering • Shorter lautering time • Significantly greater brewhouse efficiency • Lower (lighter) wort and beer colour • Significantly lower attenuation limit • Lower foam stability • Slightly lower final beer alcohol concentration

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2016 crop Bentley (compared with 2015 Bentley)		
Barley Quality	**Malting Performance**	**Brewing Performance**
• Same grain moisture and slightly higher protein content • Higher germination energy with similar water sensitivity • Similar thousand kernel weight and higher plumpness • Significantly higher RVA values suggesting better storability	• Significantly slower water-uptake and faster growth of acrospires • Significantly higher friability and lower extract yield • Similar levels of enzymes • Similar soluble protein and lower FAN • Significantly higher beta-glucan content	• Shorter conversion time • Slightly quicker time to clear during lautering • Significantly shorter lautering time • Significantly greater brewhouse efficiency • Comparable wort colour and higher (darker) beer colour • Comparable attenuation limit • Significantly lower foam stability • Significantly higher final beer alcohol concentration

2016 crop Legacy (compared with 2015 Legacy)		
Barley Quality	**Malting Performance**	**Brewing Performance**
• Significantly higher grain moisture and slightly lower protein content • Lower germination energy with similar water sensitivity • Lower thousand kernel weight and plumpness • Similar RVA values suggesting similar storability	• Significantly slower water-uptake and more rapid growth of acrospires • Lower friability and similar extract yield • Lower levels of enzymes • Lower soluble protein and FAN • Significantly higher beta-glucan content	• Significantly longer conversion time • Slightly longer time to clear • Longer lautering time • Significantly lower brewhouse efficiency • Comparable wort colour and significantly lower (lighter) final beer colour • Significantly lower attenuation limit • Significantly lower foam stability • Significantly lower final beer alcohol concentration

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2016 crop AAC Connect (compared 2015 AAC Connect)		
Barley Quality	**Malting Performance**	**Brewing Performance**
• Significantly higher grain moisture and slightly higher protein content • Significantly lower germination energy with stronger water sensitivity • Lower thousand kernel weight and lower plumpness • Significantly lower RVA values suggesting poorer storability	• Slightly faster water-uptake and slower growth of acrospires • Similar friability and comparable extract yield • Higher levels of enzymes • Slightly higher soluble protein and higher FAN • Higher beta-glucan content	• Slightly shorter conversion time • Similar time to clear • Shorter lautering time • Significantly higher brewhouse efficiency • Higher wort colour • Significantly lower attenuation limit • Significantly lower foam stability • Slightly lower final beer alcohol concentration

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CMBTC 2016 Crop MALTING BARLEY QUALITY ASSESSMENT

Introduction

The CMBTC conducted barley analysis, pilot scale malting and brewing trials with 2016 crop barley samples of **AC Metcalfe, CDC Copeland, AAC Synergy, Bentley and Legacy** provided by Richardson International, Viterra Inc., Prairie Malt Ltd, Canada Malting, Malteurop, Rahr Malting Canada Ltd and the Integrated Grains. These 2016 crop barley samples were collected from Alberta, Saskatchewan and Manitoba. *To some extent, these barley samples reflect the quality of the selectable malting barley of 2016 crop that are available to the customers of Canadian malting barley.* In addition, the CMBTC conducted barley analysis, pilot scale malting and brewing trials on barley samples of 2016 crop **AAC Connect** provided by CANTERRA SEEDS. Please note that the CMBTC was not involved in the selection of any of barley samples.

1. Barley Quality Analysis

Quality of the 2016 crop barley samples was examined prior to the malting trials, and the test results are summarized in Tables 1.1 through 1.6. Please note the test results were generated from a single test except for germination.

AC Metcalfe barley samples from the 2016 crop showed, on average, acceptable grain moisture content, good protein content, and good germination energy, but exhibited significant water sensitivity. Additionally the barley showed very good thousand kernel weight and plumpness (Table 1.1). AC Metcalfe barley samples from the 2016 harvest also showed some staining.

Table 1.1. Analysis of 2016 crop barley samples of AC Metcalfe received at the CMBTC

2016 Crop AC Metcalfe	Moisture, %	Protein, %	Germination, % (4ml, n=2)	Germination, % (8ml, n=2)	1000 Kernel wt, g	Sizing, %		RVA
						>6/64 sieve	>5/64 sieve	
B-16-044	13.3	12.0	95.0	75.5	46.4	94.6	4.3	14
B-16-105	10.5	11.4	99.0	71.5	45.3	91.7	6.2	29
B-16-125	10.1	12.2	90.0	62.0	44.3	92.7	6.8	49
B-16-126	11.5	12.0	95.5	67.0	48.2	97.2	2.5	91
B-16-127	12.9	10.3	98.5	80.5	48.6	94.0	3.6	20
Average of 2016 crop (n=5)	**11.66**	**11.58**	**95.6**	**71.3**	**46.6**	**94.0**	**4.7**	**40.6**
Std Dev	**1.42**	**0.78**	**3.6**	**7.2**	**1.8**	**2.1**	**1.8**	**31.1**
Average of 2015 crop (n=9)	**11.6**	**12.8**	**95.1**	**82.9**	**45.4**	**92.86**	**5.34**	**61**
Average of 2014 crop (n=13)	**11.7**	**12.1**	**95.5**	**77.7**	**45.6**	**92.92**	**5.46**	**71.8**

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RVA values for these samples were significantly lower than the desired level (which is >100). Please note that for the five 2016 crop AC Metcalfe barley samples that were tested, no samples reported RVA values higher than 100. Low RVA values suggested that these barley samples had suffered from pre-harvest sprouting; therefore, a decrease in germination energy during long-term storage could be expected from the 2016 crop AC Metcalfe.

In comparison with 2015 crop, **2016 crop AC Metcalfe** barley on average showed similar grain moisture content, significantly lower protein content and slightly higher germination energy with significantly stronger water sensitivity. Thousand-kernel weight and plumpness for 2016 crop AC Metcalfe was significantly higher than the 2015 crop. However RVA values were significantly lower than the average for 2015 crop AC Metcalfe

CDC Copeland barley samples from the 2016 harvest exhibited acceptable grain moisture content, good protein content, and good germination energy but with significant water sensitivity. In addition, the new crop barley samples exhibited very good thousand kernel weight and plumpness (Table 1.2). RVA values of the 2016 crop tended to be better than last year with two of three 2016 crop CDC Copeland barley samples reporting RVA values higher than 100. CDC Copeland barley samples from the 2016 harvest showed noticeable signs of staining.

Table 1.2. Analysis of 2016 crop barley samples of CDC Copeland received at the CMBTC

2016 Crop CDC Copeland	Moisture, %	Protein, %	Germination, % (4ml, n=2)	Germination, % (8ml, n=2)	1000 Kernel wt, g	Sizing, %		RVA
						>6/64 sieve	>5/64 sieve	
B-16-064	12.0	12.0	97.0	85.5	47.1	92.2	6.0	107
B-16-110	13.2	10.5	98.0	86.0	47.0	92.9	5.9	37
B-16-128	13.8	11.1	98.5	79.0	53.3	96.5	2.3	126
Average of 2016	**13.00**	**11.20**	**97.83**	**83.50**	**49.13**	**93.87**	**4.73**	**90**
Std Dev	**0.92**	**0.75**	**0.76**	**3.91**	**3.61**	**2.31**	**2.11**	**47**
Average of 2015 (n=7)	**11.0**	**12.1**	**96.6**	**86.1**	**47.5**	**92.59**	**5.72**	**63.8**
Average of 2014 (n=8)	**13.1**	**11.1**	**93.9**	**76.3**	**47.1**	**94.56**	**3.98**	**42.4**

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In comparison with the 2015 crop CDC Copeland, on average **2016 crop CDC Copeland** barley showed significantly higher grain moisture content, significantly lower protein content, significantly higher germination energy and stronger water sensitivity. In addition, thousand kernel weight and plumpness for 2016 crop CDC Copeland were slightly higher than the 2015 crop average. RVA values for 2016 crop CDC Copeland were significantly higher than the 2015 crop average.

AAC Synergy barley samples of 2016 crop showed significant variations in grain moisture and germination energy (Table 1.3). Two out of the three samples showed moisture marginally higher than the level for safe storage (≤13.5%), and one out of the three samples showed germination energy lower that required for malting use (≥95%), and all the three samples exhibited water sensitivity. However, all the samples showed acceptable protein content, good thousand kernel weight and very good plumpness. Note that all the AAC Synergy samples showed very low RVA values, which suggested they had suffered from pre-harvest sprouting, As a result poor storability could be expected from 2016 AAC Synergy barley with low RVA values.

Table 1.3. Analysis of 2016 crop barley samples of AAC Synergy received at CMBTC

2016 Crop AAC Synergy	Moisture, %	Protein, %	Germination, % (4ml, n=2)	Germination, % (8ml, n=2)	1000 Kernel wt, g	Sizing, %		RVA
						>6/64 sieve	>5/64 sieve	
B-16-045	13.8	10.9	98.0	91.5	51.3	96.8	2.2	42
B-16-219	13.8	11.6	92.0	74.5	50.9	96.6	2.4	40
B-16-215	12.7	9.6	99.0	87.5	48.5	97.5	1.6	71
Average of 2016 (n=3)	**13.43**	**10.70**	**96.3**	**84.5**	**50.2**	**97.0**	**2.1**	**51.0**
Std Dev	**0.64**	**1.01**	**3.8**	**8.9**	**1.5**	**0.5**	**0.4**	**17.3**
Average of 2015 (n=4)	**11.85**	**11.95**	**98.63**	**91.00**	**47.58**	**95.91**	**3.04**	**54.75**
Average of 2014 (n=1)	**10**	**11.4**	**93.0**	**73.0**	**48.49**	**96.0**	**2.60**	**33**

In comparison with the 2015 crop AAC Synergy, on average **2016 crop AAC Synergy** barley showed significantly higher grain moisture content, significantly lower protein content, significantly lower germination energy and stronger water sensitivity. Thousand kernel weight and plumpness for 2016 crop AAC Synergy were higher than the 2015 crop. RVA values for 2016 crop AAC Synergy were slightly lower than the 2015 crop.

Bentley barley sample of 2016 crop showed normal appearance and exhibited no noticeable signs of mould infection or severe staining. The Bentley barley sample showed moisture

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content within the required range for safe storage (≤ 13.5%), and exhibited acceptable protein content, good germination energy with insignificant water sensitivity, very good thousand kernel weight and plumpness (Table 1.4). This barley showed very good RVA values, which suggested that it did not experience pre-harvest sprouting, therefor, good storability could be expected from this 2016 crop Bentley barley.

Table 1.4. Analysis of 2016 crop barley sample of Bentley received at the CMBTC

2016 Crop Bentley	Moisture, %	Protein, %	Germination, % (4ml, n=2)	Germination, % (8ml, n=2)	1000 Kernel wt, g	Sizing, %		RVA
						>6/64 sieve	>5/64 sieve	
B-16-143	13.1	11.6	99.0	90.0	52.7	98.0	1.2.0	143
2015 crop (B-16-013)	13.1	11.4	96.5	89.0	52.2	96.3	1.75	20
Average of 2014 (n=3)	12.67	11.80	81.17	58.5	47.64	90.0	8.73	52.0

In comparison with the 2015 crop Bentley, **2016 crop Bentley** barley sample showed comparable grain moisture content, slightly higher protein content, significantly higher germination energy, comparable water sensitivity, similar thousand kernel weight and higher plumpness, as well significantly higher RVA value.

The CMBTC received one **Legacy** barley sample from the 2016 harvest which showed normal appearance and exhibited no noticeable signs of mould infection. The barley sample had moisture content higher than that required for safe storage (≤13.5%), good protein content, and very good germination energy but with significant water sensitivity (Table 1.6). In addition, this barley sample showed good thousand kernel weight and very good plumpness. Its RVA value was low which suggested that it has suffered some pre-harvest sprouting damage. Therefore some decrease in germination during a long-term storage could be expected.

Table 1.6. Analysis of 2016 crop barley sample of Legacy received at the CMBTC

2016 Crop Legacy	Moisture, %	Protein, %	Germination, % (4ml, n=2)	Germination, % (8ml, n=2)	1000 Kernel wt, g	Sizing, %		RVA
						>6/64 sieve	>5/64 sieve	
B-16-063	14.4	11.7	98.5	75.5	39.9	93.7	3.9	63
2015 crop (n=1)	12.1	12.6	99.5	74.0	40.97	94.56	3.69	64
2014 crop Legacy GRL Harvest Survey	9.9	12.0	93.0	73.0	37.9	93.5	4.9	N/A

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In comparison to 2015, the **2016 crop Legacy** barley sample showed significantly higher grain moisture content, lower protein content, lower germination energy and comparable water sensitivity. Its thousand-kernel-weight and plumpness were lower than the 2015 crop.

AAC Connect barley samples of 2016 crop showed normal appearance and exhibited no noticeable signs of mold infection or staining. The barley samples showed acceptable moisture content, acceptable protein content, as well as very good thousand kernel weight and plumpness (Table 1.5). One sample showed very good germination however the other had germination energy lower than level required for malting use (≥95%), and both samples showed strong water sensitivity. The two AAC Connect barley samples showed very low RVA values, which suggested they had experienced pre-harvest sprouting, therefor, poor storability could be expected from the 2016 crop AAC Connect barley with low RVA values.

Table 1.5. Analysis of 2016 crop barley samples of AAC Connect received at the CMBTC

2016 Crop AAC Connect	Moisture, %	Protein, %	Germination, % (4ml, n=2)	Germination, % (8ml, n=2)	1000 Kernel wt, g	Sizing, %		RVA
						>6/64 sieve	>5/64 sieve	
B-16-122	11.8	11.8	98.5	67.5	45.3	94.2	5.2	82
B-16-123	10.8	12.4	93.0	68.5	50.6	90.4	8.5	5
Average of 2016 (n=2)	**11.3**	**12.1**	**95.8**	**68.0**	**48.0**	**92.3**	**6.9**	**43.5**
Std Dev	**0.7**	**0.4**	**3.9**	**0.7**	**3.7**	**2.7**	**2.3**	**54.4**
Average of 2015 (n=3)	**10.1**	**11.7**	**98.3**	**96.0**	**50.6**	**96.8**	**2.30**	**110**

In comparison with the 2015 crop AAC Connect, **2016 crop Connect** barley on average showed significantly higher grain moisture content, slightly higher protein content, significantly lower germination energy, significantly strong water sensitivity, lower thousand kernel weight and lower plumpness, as well significantly lower RVA values.

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Pilot Malting Trials

Pilot malting trials were conducted with 2016 crop barley samples; AC Metcalfe, CDC Copeland, AAC Synergy, Bentley, AAC Connect and Legacy. Depending on the quantity of the barley samples received at the CMBTC, one or multiple pilot malting trials on each of these barley varieties were conducted using the CMBTC's pilot malting systems with a batch size of 50-60kg of cleaned barley. The malting trial results are reported in Tables 2.1 through 2.12, respectively.

AC Metcalfe

In the malting trials, under the processing conditions given in Box 2.1 these 2016 crop AC Metcalfe barley samples did not show any processing difficulties. At the end of steep, the barley samples obtained satisfactory steep-out moisture content and achieved very good chitting rate (Table 2.1). During germination, AC Metcalfe barley samples showed normal growth of acrospires and good modification progress.

Box 2.1. Malting conditions used for processing AC Metcalfe barley samples of 2016 crop

AC Metcalfe
STEEPING CYCLES **42.5 hours (6 hrs Wet – 13 hrs Dry - 9 hrs Wet -14 hrs Dry - 0.5 hr Wet) at 15°C** **GERMINATION CONDITIONS** **Day 1 @ 15°C, Day 2, Day 3 @ 14.5°C & Day 4 @ 14.0°C** **KILNING CONDITIONS** **A 21-hour cycle with a 4-hour curing phase at 82°C**

In comparison with the 2015 crop average, on average, 2016 crop AC Metcalfe barley showed slightly lower steep-out moisture content than the 2015 crop trial average. However, considering the 2016 new crop samples were processed using a short steeping cycle (4.5 hrs shorter than that used for processing last year crop) the actual water-uptake rate for the new crop would be faster than the 2015 crop. The new crop AC Metcalfe also obtained a slightly lower chitting rate than the 2015 crop at the end of steep. During germination, these 2016 AC Metcalfe samples showed good growth of acrospires, which were more advanced than 2015 crop AC Metcalfe.

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Table 2.1. Steep-out moisture content, chitting rate and growth profile of acrospires for 2016 AC Metcalfe barley samples

2016 crop AC Metcalfe (n=5)					
Steep-out moisture, % (average) **42.99 – 45.34 (44.1)**			Chitting rate, % (average) **95.0-100 (97.0)**		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0.0	0.0	5.0	59.0	36.0
2015 crop AC Metcalfe (n=7)					
Steep-out moisture (%) **43.38**			Chitting rate (%) **96.42**		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0	0	4.3	80	15.7

Complete malt analysis was carried out for the pilot malting trials with the 2016 crop AC Metcalfe barley samples, and the analytical results for the trials are given in Table 2.2. For comparison, the table also includes the average analysis of AC Metcalfe malts generated from the pilot-malting trials carried out at the CMBTC with the 2015 and 2014 crop AC Metcalfe barley samples.

Table 2.2. Malt Analysis for 2016 crop AC Metcalfe barley samples

Parameter	**2016 Crop AC Metcalfe**	**2015 QS**	**2014 QS**
	Mean (n=5)	**Mean (n=7)**	**Mean (n=3)**
Friability, %	83.02	72.7	82.6
Fine-extract, %	81.94	80.9	81.3
F/C Difference, %	0.80	1.03	0.8
Soluble protein, %	5.56	5.27	5.48
Total protein, %	11.49	12.66	12.4
Kolbach Index, %	48.34	41.6	44.0
Beta-Glucan, ppm	151	158	120
Diastatic power, °L	150	156	154
α-Amylase, D.U.	79.54	82.6	60.4
Wort colour, ASBC	2.80	2.34	2.30
Fan, mg/L	241.2	220	216

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Malting Summary

- **General modification:** Under the given process conditions, 2016 crop AC Metcalfe samples produced malts with satisfactory overall quality. The values for friability, F/C difference, and soluble protein and beta-glucan content suggested that these 2016 crop AC Metcalfe barley samples produced malts with acceptable modification.

- **Extract yield and enzyme levels:** The malts produced from 2016 crop AC Metcalfe samples exhibited very good extract yield, on average, the extract yield was significantly higher than the 2015 crop average and slightly higher than the 2014 crop average. The malts developed good levels of enzymes; the diastatic power was lower than both the 2015 and 2014 crop averages, while the α-amylase was significantly lower than the 2015 crop average but higher than 2014 crop average.

- **Soluble protein, free amino nitrogen (FAN) and malt colour:** The malts produced from 2016 crop AC Metcalfe samples exhibited good protein solubilisation. On average, the soluble protein was slightly higher than the 2015 and 2014 crop averages, but the Kolbach Index was significantly higher overall. The malts also developed adequate levels of FAN that were significantly higher than the 2015 and 2014 crop averages. Malt colour for 2016 crop AC Metcalfe was good, which was significantly higher than 2015 and 2014 crop averages.

- ***Comments on the malting process:*** No difficulties during the malting process were recorded for the 2016 crop AC Metcalfe barley samples. They were processed under the normal processing conditions used at the CMBTC for quality evaluation of Canadian two-row malting barley. However, special attention should be given to processing conditions that affect malt beta-glucan content and excessive growth of acrospires. At steep, steep-out moisture of 44-45% and over 85% of chitting rate are the targets. The steeping cycle should consist of two or three wet periods at 14-15°C. In germination, avoid a high temperature and excessive watering to control the growth of acrospires and protein breakdown. In kilning a lower curing temperature (80-82°C) should be considered to avoid excessive malt color formation.

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CDC Copeland

In the malting trials, 2016 crop CDC Copeland barley samples did not show any processing difficulties under the processing conditions given in Box 2.2. CDC Copeland barley samples obtained satisfactory steep-out moisture content and excellent chitting rate at the end of steep (Table 2.3). During germination, Copeland barley samples showed good growth of acrospires.

Box 2.2. Malting conditions used for processing CDC Copeland barley samples of 2016 crop

CDC Copeland
STEEPING CYCLES 41.25 hours (7 hrs Wet - 12 hrs Dry - 10 hrs Wet -12 hrs Dry -0.25 hr Wet) at 15°C **GERMINATION CONDITIONS** Day 1 @ 15°C, Day 2, Day 3 @ 14.5°C & Day 4 @ 14.0°C **KILNING CONDITIONS** A 21-hour cycle with a 4-hour curing phase at 82°

In comparison with the 2015 crop CDC Copeland samples, on average, 2016 crop CDC Copeland barley displayed slightly slower water uptake and higher chitting rate at the end of steep. During germination, 2016 crop CDC Copeland barley showed growth of acrospires but more advanced than 2016 crop CDC Copeland.

Table 2.3. Steep-out moisture content, chitting rate and growth profile of acrospires of 2016 crop CDC Copeland barley samples

2016 Crop CDC Copeland (n=3)					
Steep-out moisture, % (average) 41.94 -44.79 (43.56)			Chitting rate, % (average) 90-100 (96.67)		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0.00	0.00	0.00	61.67	38.33
2015 crop CDC Copeland (n=5)					
Steep-out moisture (%) 44.3			Chitting rate (%) 95		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0	0	13	66	21

Complete malt analysis was carried out for the pilot malting trials, and the analytical results for these trials are given in Table 2.4. For comparison, the table also includes the average malt

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analysis of CDC Copeland malting trials carried out at the CMBTC with the 2015 and 2014 crop CDC Copeland barley samples.

Table 2.4. Malt analysis for 2016 CDC Copeland barley samples

Parameter	2016 New Crop CDC Copeland	2015 Crop	2014 QS
	Mean (n=3)	Mean (n-5)	Mean (n=2)
Friability, %	**94.57**	76.7	83.2
Fine-extract, %	**81.53**	80.4	81.5
F/C Difference, %	**0.57**	1.2	1.25
Soluble protein, %	**5.12**	5.05	4.89
Total protein, %	**10.97**	12.09	10.98
Kolbach Index, %	**46.67**	41.8	44.6
Beta-Glucan, ppm	**82.67**	211	226
Diastatic power, °L	**133**	134	107
α-Amylase, D.U.	**63.6**	61.7	40.1
Wort colour, ASBC	**2.29**	2.42	2.49
Fan, mg/L	**215**	208	205

Malting Summary

- **General modification:** The values for friability, F/C difference, soluble protein and beta-glucan content suggested that these 2016 crop CDC Copeland barley samples produced malts with very good modification, though some variations in overall modification between the samples were recorded.

- **Extract yield and enzyme levels:** The malts produced from the 2016 crop CDC Copeland samples exhibited good extract yield; on average, the extract yield was significantly higher than the 2015 crop average but comparable to 2014 crop average. The 2016 crop Copeland malts developed good levels of enzymes; their diastatic power was similar to the 2015 crop average but significantly higher than the 2014 crop average; while their α-amylase levels were close to 2015 crop average and significantly higher than the 2014 crop average.

- **Soluble protein, free amino nitrogen (FAN) and malt colour:** The malts produced from 2016 crop CDC Copeland samples exhibited good protein modification, on average, their soluble protein was slightly higher than the 2015 and 2014 crops averages, while their Kolbach Index were significantly higher. To some extent this was due to the lower

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barley protein for 2016 crop Copeland. The malts also developed adequate levels of FAN, which were significantly higher than the 2015 and 2014 crop averages. Malt colour for 2016 crop CDC Copeland was good, on average, the colour was comparable to the samples of last two crop years.

- ***Comments on the malting process:*** During the malting process, no difficulties were recorded for 2016 crop CDC Copeland barley samples. 2016 crop CDC Copeland barley can be processed under the normal processing conditions for Canadian two-row malting barley. Steep-out moisture of 44-45% and over 85% chitting rate are the targets. The steeping cycle should consist of two or three wet periods at 14-15°C. In germination, avoid high temperature and excessive watering to control acrospires growth and protein breakdown. In kilning the curing temperature can be similar to those used for AC Metcalfe (80-82°C).

AAC Synergy

In the malting trials under the given processing conditions given in Box 2.3, 2016 crop AAC Synergy barley did not show any processing difficulties. At the end of steep, the barley samples obtained satisfactory steep-out moisture content of 42.6 % and excellent chitting rate of 97% (Table 2.5). During germination, AAC Synergy barley showed normal growth of acrospires and good progress of modification.

Box 2.3. Malting conditions used for processing AAC Synergy of 2016 crop

AAC Synergy
STEEPING CYCLES 42.25 hours (8 hrs Wet - 13 hrs Dry - 8 hrs Wet -13 hrs Dry -0.25 hr Wet) at 14°C **GERMINATION CONDITIONS** Day 1 & Day 2 @ 14.5°C, Day 3 & Day 4 @ 15°C **KILNING CONDITIONS** A 21-hour cycle with a 4-hour curing phase at 82°

In comparison with the 2015 crop, 2016 crop AAC Synergy displayed slower water-uptake and lower chitting rate at the end of steep, but showed more advanced growth of acrospires during germination.

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Table 2.5. Steep-out moisture content, chitting rate and growth profile of acrospires for 2016 crop AAC Synergy barley sample

2016 crop AAC Synergy (n=3)					
Steep-out moisture, % (average) 42.25 – 43.20 (42.58)			Chitting rate (%) 96.67		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0.00	0.00	3.33	73.33	23.33
2015 crop AAC Synergy (n=2)					
Steep-out moisture (%) 44.79			Chitting rate (%) 98.3		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0.00	0.00	1.67	73.33	25.00

Complete malt analysis was carried out for the pilot malting trials, and the analytical results are given in Table 2.6. For comparison, the table also includes the average malt analysis of the pilot-malting trial conducted by the CMBTC with the 2015 and 2014 crop AAC Synergy samples.

Table 2.6. Malt analysis for 2016 new crop AAC Synergy barley sample

Parameter	**2016 Crop**	**2015 Crop**	**2014 Crop**
	Mean (n=3)	**Mean (n=2)**	**Mean (n=1)**
Friability, %	93.3	85.2	73.7
Fine-extract, %	82.6	82.1	81.2
F/C Difference, %	0.7	0.6	1.4
Soluble protein, %	5.25	5.57	4.57
Total protein, %	10.15	11.86	11.46
Kolbach Index, %	51.8	47.10	39.9
Beta-Glucan, ppm	100	64	358
Diastatic power, °L	116	136	124
α-Amylase, D.U.	70.6	72.2	54.2
Wort colour, ASBC	2.61	2.43	1.78
Fan, mg/L	219	247	166

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Malting Summary

- **General modification:** Under the given process conditions, the 2016 crop AAC Synergy barley produced malts with very good modification as indicated by the values for friability, F/C difference, soluble protein and beta-glucan content.

- **Extract yield and enzyme levels:** The 2016 crop AAC Synergy malts showed very good extract yield, which was significantly higher both the 2015 and 2014 crop averages. The 2016 crop malts developed good levels of enzymes; the DP was lower than the 2015 and 2014 crop averages, while the α-amylase was comparable to 2015 crop but significantly higher than 2014 crop AAC Synergy.

- **Soluble protein, free amino nitrogen (FAN) and malt colour:** The malts produced from 2016 crop AAC Synergy exhibited good protein solubilisation; on average its soluble protein was slightly lower than 2015 crop but comparable to the 2014 crop, however, its Kolbach Index was significantly higher than both the 2015 and 2014 crops. The malt also developed adequate levels of FAN, which were significantly lower than the 2015 crop but significantly higher than 2014 crop. Malt colour for 2016 crop AAC Synergy was good, which was slightly lower than 2015 crop but significantly higher than 2014 crop.

- ***Comments on the malting process:*** At steeping, target a steep-out moisture content of 43-44% and over 85% chitting rate. The steeping cycle should consist of 2 or 3 wet periods at 14-16°C. In germination avoid high temperature and excessive watering to control growth of acrospires and protein breakdown. In kilning a lower curing temperature (80-82°C) should be considered to avoid excessive malt color formation.

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Bentley

In the trial, this 2016 crop Bentley barley sample did not show any processing difficulties under the conditions given in Box 2.4.

Box 2.4. Malting conditions used for processing Bentley barley sample of 2016 crop

Bentley
STEEPING CYCLES 44 hours (8 hrs Wet - 13 hrs Dry - 9 hrs Wet -13 hrs Dry -1 hr Wet) at 15°C **GERMINATION CONDITIONS** Day 1 & Day 2 @ 15°C, Day 3 & Day 4 @ 15.5°C **KILNING CONDITIONS** A 21-hour cycle with a 4-hour curing phase at 82°

At the end of steep, it obtained satisfactory steep-out moisture content of 40.88 % and a chitting rate of 80% (Table 2.9). During germination, this barley sample showed normal growth of acrospires and good progress of modification.

Table 2.7. Steep-out moisture content, chitting rate and growth profile of acrospires for 2016 crop Bentley barley sample

2016 crop Bentley (n=1)					
Steep-out moisture (%) 40.88			Chitting rate (%) 80		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0	0	5	65	30
2015 crop Bentley (n=1)					
Steep-out moisture (%) 44.75			Chitting rate (%) 95		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0	0	5	70	25

In comparison with the 2015 crop, 2016 crop Bentley displayed significantly slower water up-take and significantly lower chitting rate at the end of steep. During germination, this 2016 crop barley sample showed more advanced growth of acrospires than the 2015 crop Bentley.

Complete malt analysis was carried out for the pilot malting trial, and the analytical results for the trial is given in Table 2.8. For comparison, the table also includes the average malt analysis of the pilot-malting trials conducted by the CMBTC with the 2015 and 2014 crop Bentley barley samples.

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Table 2.8. Malt analysis for 2016 new crop Bentley barley sample

Parameter	2016 crop	2015 crop	2014 crop
	Mean (n=1)	Mean (n=1)	Mean (n=3)
Friability, %	**90.6**	88.2	75.1
Fine-extract, %	**83.7**	81.7	81.1
F/C Difference, %	**1.3**	0.8	1.1
Soluble protein, %	**4.75**	4.85	5.09
Total protein, %	**9.18**	10.6	11.53
Kolbach Index, %	**51.7**	45.8	44.1
Beta-Glucan, ppm	**229**	100	231
Diastatic power, °L	**133**	131	129
α-Amylase, D.U.	**70.4**	60.5	48.3
Wort colour, ASBC	**1.99**	1.89	2.93
Fan, mg/L	**202**	213	205

Malting Summary

- **General modification:** Under the given process conditions, this 2016 crop Bentley produced malt with acceptable modification as indicated by the values for friability, F/C difference and soluble protein, however, some further modification is needed to lower its beta-glucan content.

- **Extract yield and enzyme levels:** In comparison with the trial results of 2015 crop, the malt produced from the 2016 crop Bentley sample exhibited significantly higher extract yield and developed good levels of enzymes. Its DP was slightly than that in the 2015 and 2014 crop sample, while its α-amylase was significantly higher than the last two years.

- **Soluble protein, free amino nitrogen (FAN) and malt colour:** The malt produced from 2016 crop Bentley sample exhibited good protein solubilisation. Its soluble protein was comparable to the 2015 crop but lower than the 2014 crop while its Kolbach Index was significantly higher than the last two crop years (due to low total protein). The malt also developed adequate levels of FAN, which were lower than the 2015 crop sample and comparable to the 2014 crop. Malt colour for 2015 crop Bentley was good, which was slightly higher than the 2015 crop sample but significantly lower than the 2014 crop.

- ***Comments on the malting process:*** At steeping, target a steep-out moisture content of 44-45% and over 85% chitting rate. The steeping cycle should consist of 2 or 3 wet

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periods at 14-16°C. In germination avoid high temperature and excessive watering to control growth of acrospires and protein breakdown. In kilning a lower curing temperature (80-82°C) should be considered to avoid excessive malt color formation. Please note that under the given conditions, the 2016 crop sample did not obtain the targeted steep-out moisture, which might contribute the high malt beta-glucan content.

AAC Connect

In the trials, 2016 crop AAC Connect barley samples did not show any processing difficulties. At the end of steep, the barley sample obtained satisfactory steep-out moisture content of 45% and an excellent chitting rate of 100% (Table 2.9). During germination, this barley showed normal growth of acrospires and good progress of modification.

Box 2.5. Malting conditions used for processing 2016 AAC Connect crop

AAC Connect
STEEPING CYCLES 42 hours (6 hrs Wet - 13 hrs Dry - 9 hrs Wet -14 hrs Dry) at 15°C **GERMINATION CONDITIONS** Day 1 & Day 2, Day 3 @ 14°C, & Day 4 @ 14.5°C **KILNING CONDITIONS** A 21-hour cycle with a 4-hour curing phase at 82°

In comparison with the 2015 crop, 2016 crop AAC Connect displayed comparable water uptake and chitting rate at the end of steep. During germination, this 2016 crop barley sample showed less advanced growth of acrospires than 2015 crop AAC Connect.

Table 2.9. Steep-out moisture content, chitting rate and growth profile of acrospires for 2016 crop Bentley barley sample

2016 crop AAC Connect (n=2)					
Steep-out moisture (%) 45.0			Chitting rate (%) 100		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0.0	0.0	2.5	80.0	17.5
2015 crop AAC Connect (n=3)					
Steep-out moisture (%) 44.5			Chitting rate (%) 100		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0.0	0.0	3.3	68.3	28.3

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Complete malt analysis was carried out for the two pilot malting trials, and the analytical results for the trials are given in Table 2.10. For comparison, the table also includes the average malt analysis of the pilot-malting trials conducted by the CMBTC with the 2015 crop AAC Connect barley samples.

Table 2.10. Malt analysis for 2016 new crop AAC Connect barley samples

Parameter	2016 Crop	2015 crop
	Mean (n=2)	Mean (n=3)
Friability, %	86.9	86.9
Fine-extract, %	82.4	82.6
F/C Difference, %	0.9	0.9
Soluble protein, %	5.71	5.67
Total protein, %	11.27	12.12
Kolbach Index, %	50.7	46.90
Beta-Glucan, ppm	134	122
Diastatic power, °L	150	144
α-Amylase, D.U.	84.1	72.3
Wort colour, ASBC	2.62	2.25
Fan, mg/L	237	228

Malting Summary

Overall modification: Under the given process conditions, 2016 crop AAC Connect produced malts with very good modification as indicated by the good values for friability, F/C difference, soluble protein content and beta-glucan content. Compared to the 2015 crop AAC Connect, 2016 crop AAC Connect malts showed comparable degree of modification.

Extract yield and enzyme levels: The 2016 crop AAC Connect produced malts with very good extract yield, which was slightly lower than the 2015 crop AAC Connect. The 2016 crop malts developed adequate levels of enzymes; both the diastatic power and alpha-amylase were significantly higher the 2015 crop.

Soluble protein, free amino nitrogen (FAN) and malt color: The 2016 crop AAC Connect malts exhibited good protein modification; the soluble protein was comparable to 2015 crop, while Kolbach Index were higher than 2015 crop. The malts developed good malt color, which was slightly higher than the 2015 crop. In addition, 2016 crop AAC Connect malts showed adequate levels of FAN, the levels were higher than 2015 crop AAC Connect.

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Comments on the malting process: some optimization on the processing conditions is needed, though AAC Connect barley produced malting with acceptable quality, however, its Kolbach Index was significantly higher than the desired.

Legacy

Legacy was the only six-rowed barley variety included in the new crop quality evaluation. Under the given processing conditions (Box 2.6), this 2016 crop Legacy barley sample did not show any processing difficulties. At the end of steep, the it obtained satisfactory steep-out moisture, 41.7 % and good chitting rate of 85% (Table 2.12). During germination, this barley sample showed good growth of acrospires.

Box 2.6. Malting conditions used for processing Legacy of 2016 crop

Legacy
STEEPING CYCLES 42 hours (8 hrs Wet - 12 hrs Dry - 10 hrs Wet - 10 hrs Dry - 2 hrs Wet) at 15°C **GERMINATION CONDITIONS** Day 1 & Day 2 @ 15°C, Day 3 @ 15.5°C, Day 4 @ 16°C **KILNING CONDITIONS** A 21-hour cycle with a 4-hour curing phase at 82°

In comparison with the trial of 2015 crop Legacy barley samples, 2016 crop Legacy sample showed significantly slower water up-take and lower chitting rate at the end of steep. During germination, this Legacy barley sample showed more even growth of acrospires than the 2015 crop Legacy average.

Table 2.11. Steep-out moisture content, chitting rate and growth profile of acrospires for 2016 crop Legacy barley sample

2016 crop Legacy (n=1)					
Steep-out moisture (%) 41.74			Chitting rate (%) 85		
Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0	0	5	35	60
2015 crop Legacy (n=1)					
Steep-out moisture (%) 43.5			Chitting rate (%) 100		

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Acrospire growth					
Process Time	0-¼ (%)	¼-½ (%)	½-¾ (%)	¾-1 (%)	>1 (%)
96 hours	0	0	15	75	10

Complete malt analysis for this pilot malting trial is given in Table 2.12. For comparison, the table also includes the average malt analysis of Legacy malting trials carried out at CMBTC with 2015 crop Legacy barley sample.

Table 2.12. Malt analysis for 2016 new crop Legacy barley sample

Parameter	**2015 New Crop**	**2015 Crop**
	(n=1)	**(n=1)**
Friability, %	**73.3**	81.3
Fine-extract, %	**79.2**	79.0
F/C Difference, %	**0.7**	0.2
Soluble protein, %	**5.15**	5.77
Total protein, %	**11.68**	12.26
Kolbach Index, %	**44.1**	47.1
Beta-Glucan, ppm	**487**	200
Diastatic power, °L	**170**	194
α-Amylase, D.U.	**76.3**	71.9
Wort colour, ASBC	**2.60**	2.67
Fan, mg/L	**225**	266

Malting Summary

- **General modification:** Under the given process conditions, this 2016 crop Legacy produced under-modified malt as indicated by low friability and high beta-glucan content though its F/C difference and soluble protein were acceptable. This suggested Some further modification was needed to lower beta-glucan content.

- **Extract yield and enzyme levels:** In comparison with the trial of 2015 crop Legacy, the malt developed good levels of enzymes; its DP was lower than the 2015 crop, while its α-amylase was higher than in 2015 crop.

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- **Soluble protein, free amino nitrogen (FAN) and malt colour:** The malt produced from 2016 crop Legacy sample exhibited good protein solubilisation; its soluble protein was slightly lower than the 2015 crop, while its Kolbach Index was significantly lower. The malt also developed adequate levels of FAN, which were significantly lower than the 2015 crop. Malt colour for 2016 crop Legacy barley was good, which was comparable to 2015 crop.

- ***Comments on the malting process:*** some optimization on the processing conditions is needed, under the given conditions, the Legacy barley produced malt with unbalance quality. The malt had extremely high malt beta-glucan content, but its extract yield, soluble protein and enzymes were satisfactory.

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PILOT BREWING TRIALS

AC Metcalfe, CDC Copeland, AAC Synergy, Bentley, Legacy and AAC Connect malts from the pilot malting trials were brewed in the CMBTCs 250L Pilot Brewery. The following are the brewing and fermentation conditions for the pilot brewing trials:

1) 100% all malt brew with water to malt ratio of 3.75:1.

2) Mash in at 48˚C; 30-minute hold; temperature raise at 1.5˚C per minute to 65˚C; 30-minute hold (iodine conversion test every minute); temperature raise at 1.5˚C to 77˚C; one-minute hold. Transfer mash to lauter tun with 25L underlet water.

3) 10-minute rest in lauter tun followed by a vorlauf (wort clarification) until wort clarity reading is less than 100 FTU. First wort collected into kettle followed by a hot water sparge of the grain bed using 125L of water at 77˚C to a total volume of 275L in brew kettle.

4) Boil for 90 minutes with 9% evaporation rate. Hop additions of Nugget at 0 minutes into boil time and Mt. Hood at 85 minutes into boil time.

5) Cooled wort to 12˚C, pitched with lager yeast at 1.25 million cells per ml. Fermented at 13.5˚C until 6 ˚P, then increased to 15˚C until finish. Cooled to -1˚C for 7 days.

6) Filtered through a 1 µm pad filter system, carbonated to 2.5 volumes CO_2. Stored 2 days at 1˚C, packaged and pasteurized to 15 PU

Pilot Brewing Trials with AC Metcalfe

AC Metcalfe brewing results are given in Tables 3.1 through 3.4.

Table 3.1. Brewhouse observations for AC Metcalfe pilot brewing trials.

Parameter	2016 AC Metcalfe Average (n=3)	2015 AC Metcalfe Average	2014 AC Metcalfe Average
Conversion time (min.)	12	12	17
Time to clear (min.)	6	7	7
Lautering time (min.)	49	45	41
Brewhouse efficiency (%)	87.5	88.5	87.9
Wort pH	5.32	5.37	5.38
Wort Colour (SRM)	3.99	5.57	4.91

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The 2016 crop AC Metcalfe malt recorded a comparable average conversion time than the 2015 crop AC Metcalfe (Table 3.1). Lautering time was slightly longer than the last two years. Average wort color was significantly lower in the 2016 crop Metcalfe than its previous two crop years. Average wort pH was comparable to last two years' Metcalfe average. 2016 crop AC Metcalfe average time to clear was good and comparable to its previous two crop year's averages. Lautering time was comparable to its previous two crop years' averages. Brewhouse efficiency was also good and lower than last year's crop average.

Table 3.2. AC Metcalfe wort sugar concentrations (g/L).

Carbohydrate	2016 AC Metcalfe Average (n=3)	2015 AC Metcalfe Average	2014 AC Metcalfe Average
Maltotetraose	2.55	2.76	3.00
Maltotriose	14.07	13.95	14.06
Maltose	57.71	58.00	61.36
Glucose	14.27	12.62	13.24
Fructose	2.43	1.91	3.01

Normal and generally comparable wort sugar spectra were recorded for all the samples (Table 3.2). The 2016 crop AC Metcalfe recorded slightly lower levels of unfermentable Maltotetraose than the average of the 2015 crop AC Metcalfe wort samples.

Table 3.3. AC Metcalfe fermentation observations.

Parameter	2016 AC Metcalfe Average (n=3)	2015 AC Metcalfe Average	2014 AC Metcalfe Average
Attenuation Limit (%)	85.3*	85.0	89.2

*Yeast with an overall lower attenuation than the yeast used for previous crop years was utilized for attenuation limit testing.

Average attenuation limit of the 2016 AC Metcalfe wort was comparable to the 2015 crop year AC Metcalfe average (Table 3.3). Although, it should be noted that the yeast used for attenuation limit testing was known to have a lower overall attenuation compared to the yeast used for previous crop year's attenuation testing.

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Table 3.4. AC Metcalfe final beer analysis.

Parameter	2016 AC Metcalfe Average (n=3)	2015 AC Metcalfe Average	2014 AC Metcalfe Average
Apparent Ext. (Plato)	1.87	1.51	1.37
Real Ext. (Plato)	3.71	3.43	3.27
Alcohol (v/v %)	5.05	5.26	5.20
Color (ASBC)	3.19	4.82	3.99
pH	4.38	4.35	4.25
Foam (NIBEM)	222	269	144

The 2016 crop AC Metcalfe produced beer with acceptable quality (Table 3.4). Final average beer colour for 2016 crop AC Metcalfe beer was significantly lower (lighter) than its previous two crop year averages.

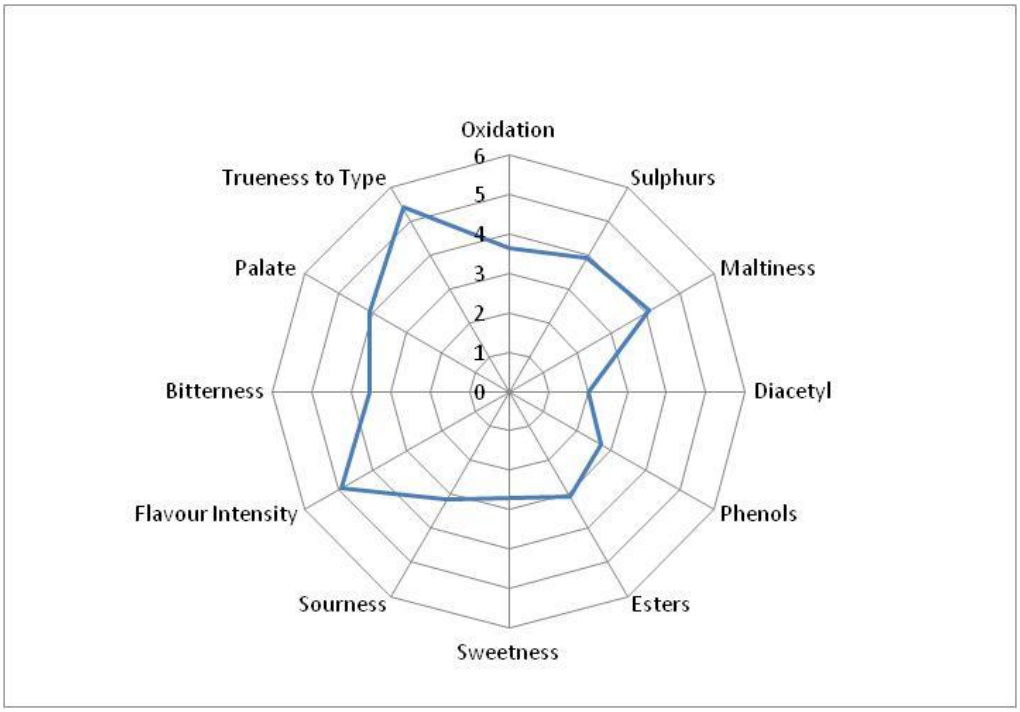

Figure 1. Average 2016 AC Metcalfe beer organoleptic properties.

Rating Scale

0 Less ←OXIDATION→ More 10
0 Less ←Diacetyl→ More 10
0 Less ←Phenols→ More 10
0 Less ←Esters→ More 10
0 Less ←Sulfurs→ More 10
0 Less ←Flavour Intensity→ More 10
0 Less Pleasant ←Palate→ More Pleasant 10
0 Less ←Bitterness→ More 10
0 Less ←Sweetness→ More 10
0 Less ←Sourness→ More 10
0 Less ←Maltiness→ More 10

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The 2016 crop AC Metcalfe average beer scored satisfactorily overall with no major defects apparent during sensory analysis (Figure 1).

Pilot Brewing Trials with CDC Copeland

CDC Copeland brewing results are given in Tables 3.5 through 3.8.

Table 3.5. Brewhouse observations for CDC Copeland pilot brewing trials.

Parameter	2016 CDC Copeland Average (n=2)	2015 CDC Copeland Average	2014 CDC Copeland Average
Conversion time (min.)	14	16	35
Time to clear (min.)	7	5	13
Lautering time (min.)	49	46	46
Brewhouse efficiency (%)	87.7	87.3	71.3
Wort pH	5.40	5.51	5.28
Wort Colour (SRM)	3.85	6.26	5.06

The 2016 crop CDC Copeland averages showed a shorter conversion time and longer time to clear than the previous crop year's average (Table 3.5). Lautering time was slightly longer than the last two years. Brewhouse efficiency was also comparable to the 2015 crop CDC Copeland average. Average wort pH was comparable than the averages of the previous two crop years. 2016 CDC Copeland average wort color was significantly lower than its previous three crop averages.

Table 3.6. CDC Copeland wort sugar concentrations (g/L).

Carbohydrate	2016 CDC Copeland Average (n=2)	2015 CDC Copeland Average	2014 CDC Copeland Average
Maltotetraose	2.09	2.74	5.13
Maltotriose	13.43	14.55	18.71
Maltose	57.03	55.61	72.61
Glucose	13.13	12.05	13.84
Fructose	3.68	2.86	1.67

The 2016 crop CDC Copeland exhibited slightly higher levels of fermentable sugars as well as a significantly lower concentration of unfermentable maltotetraose sugars compared to the 2015 crop CDC Copeland average (Table 3.6).

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Table 3.7. CDC Copeland fermentation observations

Parameter	2016 CDC Copeland Average (n=2)	2015 CDC Copeland Average	2014 CDC Copeland Average
Attenuation Limit (%)	89.1*	84.0	88.3

*Yeast with an overall lower attenuation than the yeast used for previous crop years was utilized for attenuation limit testing.

Average attenuation limit of the 2016 CDC Copeland wort samples was significantly greater than its previous two CDC Copeland crop years' averages (Table 3.7). Although, it should be noted that the yeast used for attenuation limit testing was known to have a lower overall attenuation compared to the yeast used for previous crop year's attenuation testing.

Table 3.8. Beer analysis for CDC Copeland brewing trials

Parameter	2016 CDC Copeland Average (n=2)	2015 CDC Copeland Average	2014 CDC Copeland Average
Apparent Ext. (Plato)	1.58	1.72	1.70
Real Ext. (Plato)	3.42	3.40	3.53
Alcohol (v/v %)	5.05	4.60	5.01
Color (ASBC)	3.08	5.13	2.95
pH	4.39	4.42	4.44
Foam (NIBEM)	163	257	181

The 2016 crop CDC Copeland samples produced beer with a significantly lower (lighter) final average beer colour than the 2015 crop CDC Copeland average (Table 3.8). 2016 crop CDC Copeland beers had comparable average pH readings to last year's crop average.

During sensory analysis, the beer produced from the 2016 crop CDC Copeland wort was considered normal with no defects (Figure 2 below).

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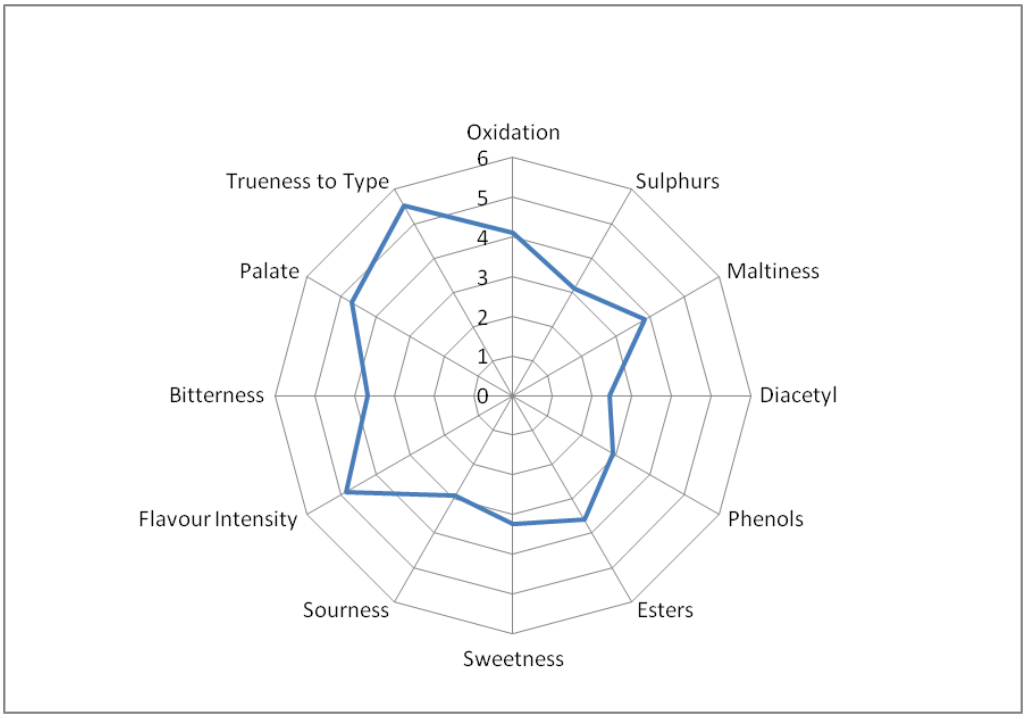

Figure 2. Average 2016 CDC Copeland beer organoleptic properties.

Rating Scale

0 Less ←OXIDATION→ More 10
0 Less ←Diacetyl→ More 10
0 Less ←Phenols→ More 10
0 Less ←Esters→ More 10
0 Less ←Sulfurs→ More 10
0 Less ←Flavour Intensity→ More 10
0 Less Pleasant ←Palate→ More Pleasant 10
0 Less ←Bitterness→ More 10
0 Less ←Sweetness→ More 10
0 Less ←Sourness→ More 10
0 Less ←Maltiness→ More 10

Pilot Brewing Trials with AAC Synergy

AAC Synergy brewing results are given in Tables 3.9 through 3.12.

Table 3.9. Brewhouse observations for AAC Synergy pilot brewing trials

Parameter	2016 AAC Synergy Average (n=2)	2015 AAC Synergy Average	2014 AAC Synergy Average
Conversion time (min.)	12	12	15
Time to clear (min.)	9	8	8
Lautering time (min.)	43	47	49
Brewhouse efficiency (%)	89.6	88.1	88.2
Wort pH	5.31	5.35	5.38
Wort Colour (SRM)	4.34	5.43	4.19

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The 2016 crop AAC Synergy showed average conversion time, average time to clear and average pH values which were comparable to the 2015 crop AAC Synergy average (Table 3.9). Average lautering time was shorter than last two crop years.
Brewhouse efficiency was significantly greater in the 2016 crop average than its previous two years' crop averages. Average wort color was lower (lighter) in the 2016 crop compared to the 2015 crop.

Table 3.10. AAC Synergy wort sugar concentrations (g/L).

Carbohydrate	2016 AAC Synergy Average (n=2)	2015 AAC Synergy Average	2014 AAC Synergy Average
Maltotetraose	2.72	2.35	2.13
Maltotriose	15.49	18.67	14.16
Maltose	58.44	60.65	63.03
Glucose	14.11	13.57	11.49
Fructose	2.20	2.10	1.35

The 2016 crop AAC Synergy exhibited slightly lower levels of total fermentable sugars and a slightly greater concentration of unfermentable maltotetraose sugar compared to the 2015 crop AAC Synergy average (Table 3.10).

Table 3.11. AAC Synergy fermentation observations.

Parameter	2016 AAC Synergy Average (n=2)	2015 AAC Synergy Average	2014 AAC Synergy Average
Attenuation Limit (%)	86.2*	91.1	89.3

*Yeast with an overall lower attenuation than the yeast used for previous crop years was utilized for attenuation limit testing.

Average attenuation limit of the wort samples was significantly lower in the 2016 AAC Synergy crop average than its previous two crop year's averages (Table 3.11). Although, it should be noted that the yeast used for attenuation limit testing was known to have a lower overall attenuation compared to the yeast used for previous crop year's attenuation testing.

Table 3.12. Beer analysis for AAC Synergy brewing trials.

Parameter	2016 AAC Synergy Average (n=2)	2015 AAC Synergy Average	2014 AAC Synergy Average
Apparent Ext. (Plato)	1.98	1.23	1.36
Real Ext. (Plato)	3.85	3.18	3.26

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Alcohol (v/v %)	5.14	5.34	5.21
Color (ASBC)	3.33	6.36	3.42
pH	4.57	4.38	4.37
Foam (NIBEM)	192	260	148

The 2016 crop AAC Synergy samples produced beer with a lower average final alcohol concentration than the 2015 crop AAC Synergy average. (Table 3.12). Final average beer colour for 2016 crop AAC Synergy was significantly lower (lighter) than both the 2015 and 2014 crop AAC Synergy averages. 2015 crop AAC Synergy beers had a higher average pH than its previous two years' crop averages.

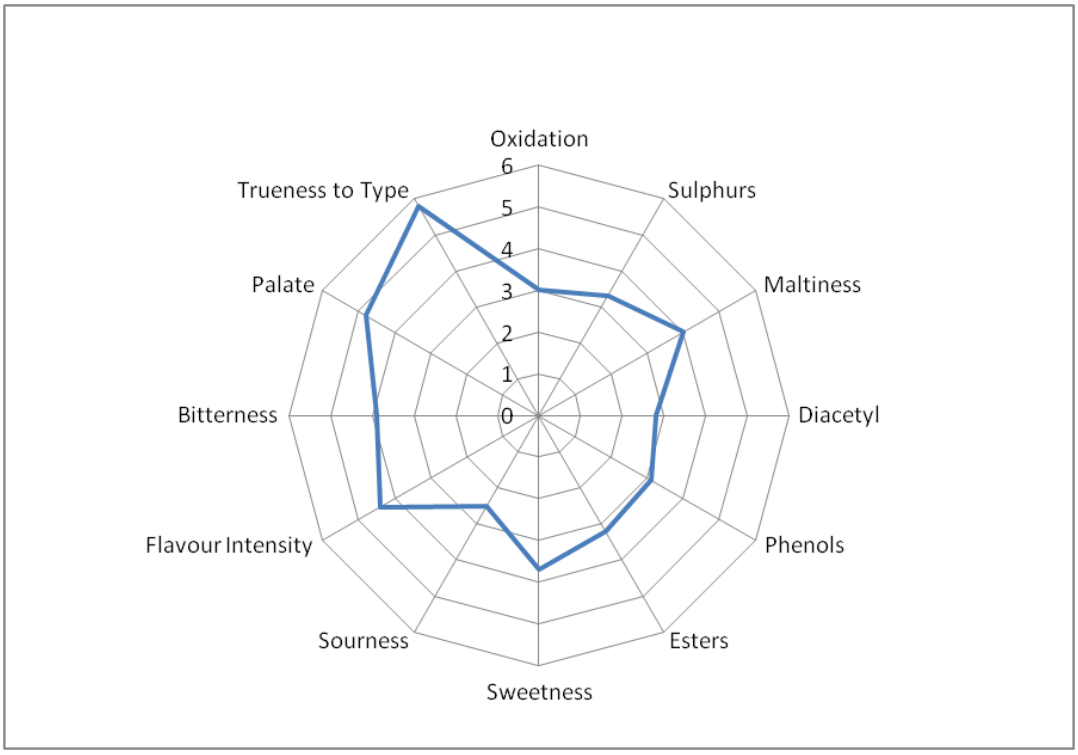

Figure 3. Average 2016 AAC Synergy beer organoleptic properties.

Rating Scale

0 Less ←OXIDATION→ More 10
0 Less ←Diacetyl→ More 10
0 Less ←Phenols→ More 10
0 Less ←Esters→ More 10
0 Less ←Sulfurs→ More 10
0 Less ←Flavour Intensity→ More 10
0 Less Pleasant ←Palate→ More Pleasant 10
0 Less ←Bitterness→ More 10
0 Less ←Sweetness→ More 10
0 Less ←Sourness→ More 10
0 Less ←Maltiness→ More 10

During sensory analysis, the beer produced from the 2016 crop CDC Copeland wort was considered normal with no defects (Figure 3).

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Pilot Brewing Trials with Bentley

Bentley brewing results are given in Tables 3.13 through 3.16.

Table 3.13. Brewhouse observations for Bentley pilot brewing trials

Parameter	2016 Bentley (n=1)	2015 Bentley Average	2014 Bentley Average
Conversion time (min.)	10	13	14
Time to clear (min.)	7	8	12
Lautering time (min.)	43	54	46
Brewhouse efficiency (%)	88.7	86.4	87.1
Wort pH	5.24	5.26	5.13
Wort Colour (SRM)	4.15	3.86	5.89

The 2016 crop Bentley showed a shorter conversion time, time to clear and lautering time compared to its 2015 and 2014 averages (Table 3.13). Average lautering time was shorter than its two-previous year's crop. the A comparable wort colour and greater brewhouse efficiency was observed in the 2016 crop Bentley compared to its 2015 and 2014 crop averages.

Table 3.14. Bentley wort sugar concentrations (g/L)

Carbohydrate	2016 Bentley (n=1)	2015 Bentley Average	2014 Bentley Average
Maltotetraose	2.38	2.59	3.96
Maltotriose	15.57	13.77	14.48
Maltose	64.94	56.54	53.52
Glucose	13.62	12.48	13.20
Fructose	2.44	2.90	2.00

The 2016 crop Bentley exhibited a greater concentration of total wort sugars with significantly higher concentrations of fermentable maltose and maltotriose sugars compared with its 2015 and 2014 crop averages (Table 3.14). As well, a lower concentration of unfermentable maltotetraose sugars was observed in the 2016 crop Bentley wort compared with its 2015 and 2014 crop wort averages.

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Table 3.15. Bentley fermentation observations

Parameter	2016 Bentley (n=1)	2015 Bentley Average	2014 Bentley Average
Attenuation Limit (%)	86.3*	85.8	88.1

*Yeast with an overall lower attenuation than the yeast used for previous crop years was utilized for attenuation limit testing.

Average attenuation limit of the 2016 Bentley wort sample was slightly greater than the 2015 Bentley crop year average (Table 3.15). Although, it should be noted that the yeast used for attenuation limit testing was known to have a lower overall attenuation compared to the yeast used for previous crop year's attenuation testing.

Table 3.16. Beer analysis for Bentley brewing trials

Parameter	2016 Bentley (n=1)	2015 Bentley Average	2014 Bentley Average
Apparent Ext. (Plato)	1.86	1.70	1.67
Real Ext. (Plato)	3.92	3.52	3.53
Alcohol (v/v %)	5.71	5.0	5.09
Color (ASBC)	3.28	4.6	5.26
pH	4.57	4.33	4.45
Foam (NIBEM)	209	253	172

Compared with its previous two crop year averages, the 2016 crop Bentley sample produced beer with a significantly higher concentration of alcohol and higher pH (Table 3.16). A higher pH and lower (lighter) colour were also observed in the 2016 crop Bentley beer.

During sensory analysis, the 2016 crop Bentley beer was considered normal without major defects (Figure 4 below).

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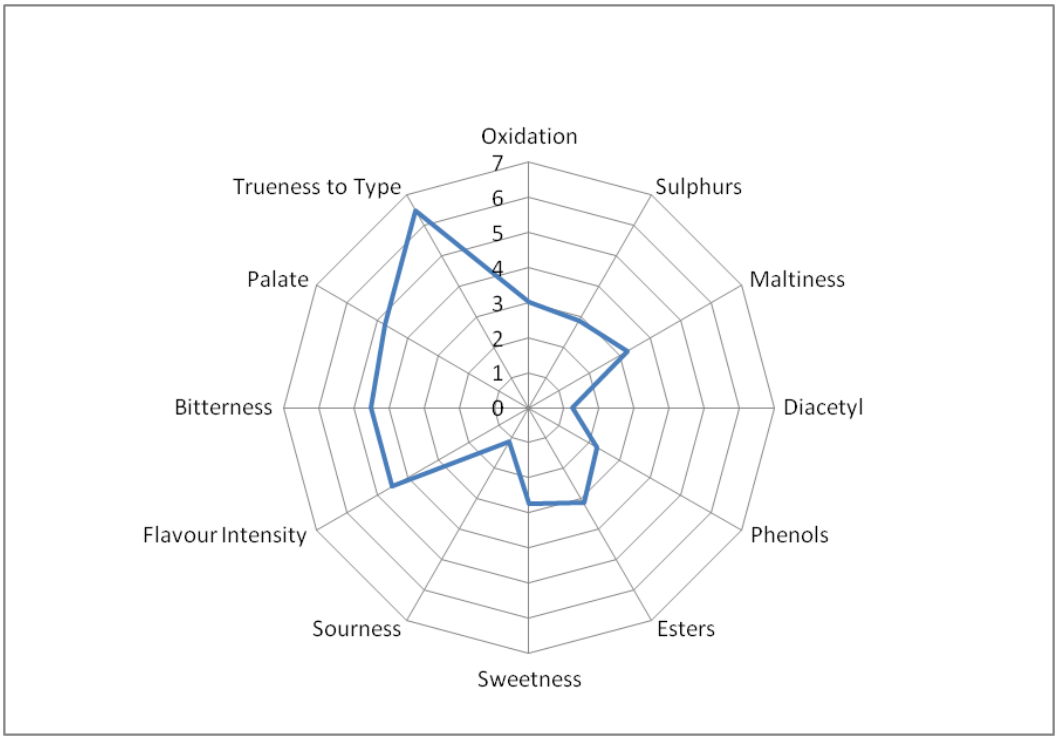

Figure 4. Average 2016 Bentley beer organoleptic properties.

Rating Scale

0 Less ←OXIDATION→ More 10
0 Less ←Diacetyl→ More 10
0 Less ←Phenols→ More 10
0 Less ←Esters→ More 10
0 Less ←Sulfurs→ More 10
0 Less ←Flavour Intensity→ More 10
0 Less Pleasant ←Palate→ More Pleasant 10
0 Less ←Bitterness→ More 10
0 Less ←Sweetness→ More 10
0 Less ←Sourness→ More 10
0 Less ←Maltiness→ More 10

Pilot Brewing Trials with Legacy

Legacy brewing results are given in Tables 3.21 through 3.24. Note that only the 2015 crop Legacy average was used for comparison.

Table 3.21. Brewhouse observations for Legacy pilot brewing trial

Parameter	2016 Legacy (n=1)	2015 Legacy Average
Conversion time (min.)	18	10
Time to clear (min.)	11	9
Lautering time (min.)	51	45
Brewhouse efficiency (%)	85.9	87.8
Wort pH	5.36	5.33
Wort Colour (SRM)	4.34	4.85

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In the brewhouse, the 2016 crop Legacy malt recorded a significantly longer average conversion time than its previous crop year average (Table 3.21). The average time for wort to clear to less than 100 FTU in lautering of the 2016 crop Legacy was longer than the 2015 crop average, while the average lautering time was slightly longer. The 2016 crop Legacy showed significantly lower brewhouse efficiency than the 2015 average. Its average wort pH and wort colour were comparable to its 2015 averages.

Table 3.22. Legacy wort sugar concentrations (g/L).

Carbohydrate	2016 Legacy (n=1)	2015 Legacy Average
Maltotetraose	2.64	3.32
Maltotriose	12.92	15.45
Maltose	55.36	60.63
Glucose	12.56	15.34
Fructose	2.16	2.99

Lower concentrations of total sugars were observed in the 2016 Legacy crop compared with the 2015 Legacy crop average (Table 3.23). Overall, comparable average wort sugar spectra were recorded for the 2016 and 2015 Legacy crop.

Table 3.23. CDC Legacy fermentation observations.

Parameter	2016 Legacy (n=1)	2015 Legacy Average
Attenuation Limit (%)	83.6*	91.2

*Yeast with an overall lower attenuation than the yeast used for previous crop years was utilized for attenuation limit testing.

The 2016 crop Legacy had a significantly lower attenuation limit than the 2015 crop Legacy average (Table 3.23). Although, it should be noted that the yeast used for attenuation limit testing was known to have a lower overall attenuation compared to the yeast used for previous crop year's attenuation testing.

Table 3.24. Beer analysis for Legacy brewing trials.

Parameter	2016 Legacy (n=1)	2015 Legacy Average (n=1)
Apparent Ext. (Plato)	1.91	1.20
Real Ext. (Plato)	3.65	3.10
Alcohol (v/v %)	4.75	5.21
Color (ASBC)	3.42	5.42
pH	4.39	4.31
Foam (NIBEM)	196	252

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The 2016 crop Legacy samples produced beer with a higher final apparent extract and lower final alcohol concentration than the 2015 crop Legacy average (Table 3.24). Final average beer colour for the 2016 crop Legacy was lower (lighter) than the 2015 crop Legacy average.

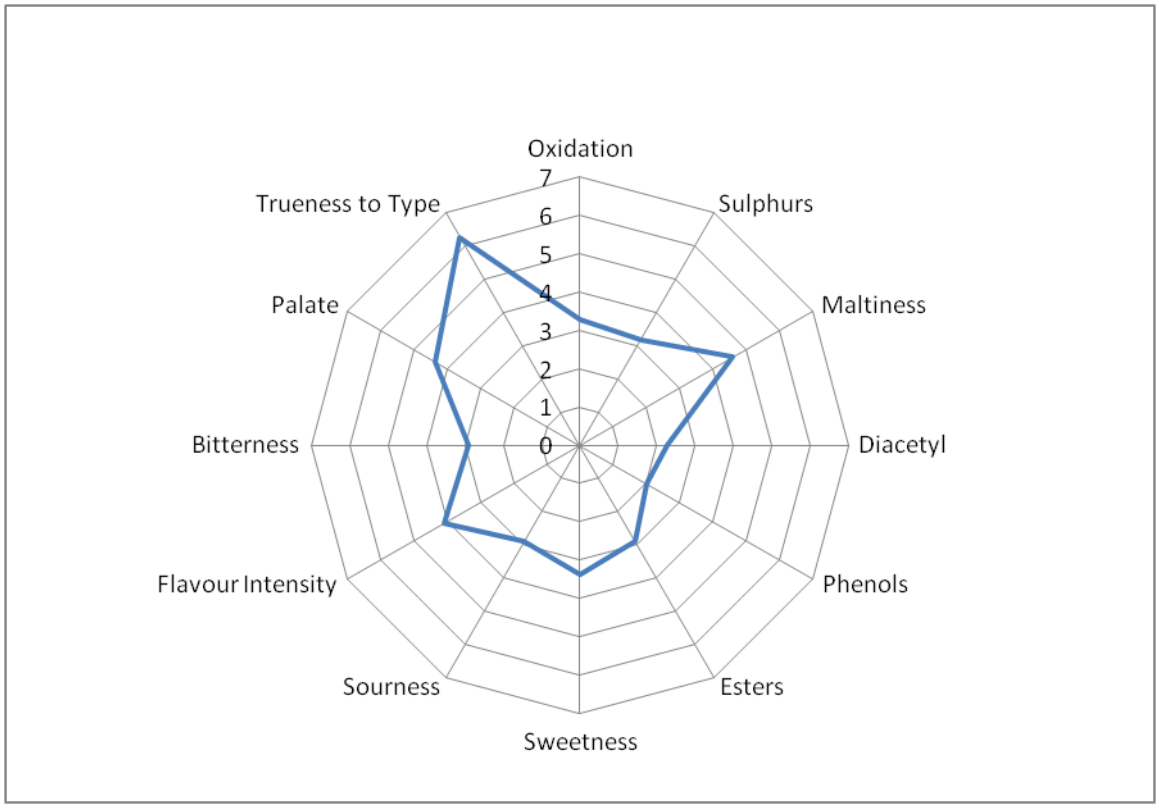

Figure 5. Average 2016 Legacy beer organoleptic properties.

Rating Scale

0 Less ←OXIDATION→ More 10
0 Less ←Diacetyl→ More 10
0 Less ←Phenols→ More 10
0 Less ←Esters→ More 10
0 Less ←Sulfurs→ More 10
0 Less ←Flavour Intensity→ More 10
0 Less Pleasant ←Palate→ More Pleasant 10
0 Less ←Bitterness→ More 10
0 Less ←Sweetness→ More 10
0 Less ←Sourness→ More 10
0 Less ←Maltiness→ More 10

During sensory analysis, the 2016 crop Legacy beer was considered normal without any major defects (Figure 5).

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Pilot Brewing Trials with AAC Connect

AAC Connect brewing results are given in Tables 3.17 through 3.20.

Table 3.17. Brewhouse observations for AAC Connect pilot brewing trials

Parameter	2016 AAC Connect Average (n=2)	2015 AAC Connect Average (n=3)
Conversion time (min.)	9	12
Time to clear (min.)	8	7
Lautering time (min.)	46	49
Brewhouse efficiency (%)	86.0	72.5
Wort pH	5.29	5.39
Wort Colour (SRM)	5.50	4.50

In the brewhouse, the 2016 AAC Connect malts did not exhibit any processing difficulties (Table 3.17). The 2016 crop AAC Connect on averages displayed a quick conversion time and good Lautering time and a satisfactory time to clear, which were comparable to 2015 crop. Its wort pH was lower than 2015 crop, while its color was significantly higher. In addition, 2016 crop AAC Connect showed significantly higher brewhouse efficiency than the 2015 crop.

Table 3.18. AAC Connect wort sugar concentrations (g/L).

Carbohydrate	2016 AAC Connect Average (n=2)	2015 AAC Connect Average (n=3)
Maltotetraose	2.33	2.59
Maltotriose	13.97	14.58
Maltose	55.31	56.98
Glucose	13.40	14.86
Fructose	2.36	2.09

A normal average wort sugar spectrum was recorded from the 2016 crop AAC Connect worts (Table 3.18). The worts exhibited a lower concentration of total wort sugars with significantly lower concentrations of fermentable maltose and maltotriose sugars compared with its 2015 crop average. As well, a lower concentration of unfermentable maltotetraose sugars was observed in the 2016 crop Connect wort compared with its 2015 crop wort averages.

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Table 3.19. AAC Connect fermentation observations.

Parameter	2016 AAC Connect Average (n=2)	2015 AAC Connect Average (n=3)
Attenuation Limit (%)	85.8*	91.1

*Yeast with an overall lower attenuation than the yeast used for previous crop years was utilized for attenuation limit testing.

Average attenuation limit of the 2016 AAC Connect wort sample was significantly lower than the 2015 crop year average (Table 3.19). Although, it should be noted that the yeast used for attenuation limit testing was known to have a lower overall attenuation compared to the yeast used for previous crop year's attenuation testing.

Table 3.20. Final beer analysis for AAC Connect brewing trials.

Parameter	2016 AAC Connect Average (n=2)	2015 AAC Connect Average (n=3)
Apparent Ext. (Plato)	1.76	1.28
Real Ext. (Plato)	3.62	3.20
Alcohol (v/v %)	5.10	5.28
Color (ASBC)	4.56	5.10
pH	4.39	4.46
Foam (NIBEM)	216	268

The 2016 crop AAC Connect produced beer with acceptable quality (Table 3.20).
Compared with its 2015 crop year averages, the 2016 crop AAC Connect sample produced beer with a significantly lower concentration of alcohol (Table 3.20). A lower pH and significantly lower (lighter) colour were also observed in the 2016 crop Connect beer.

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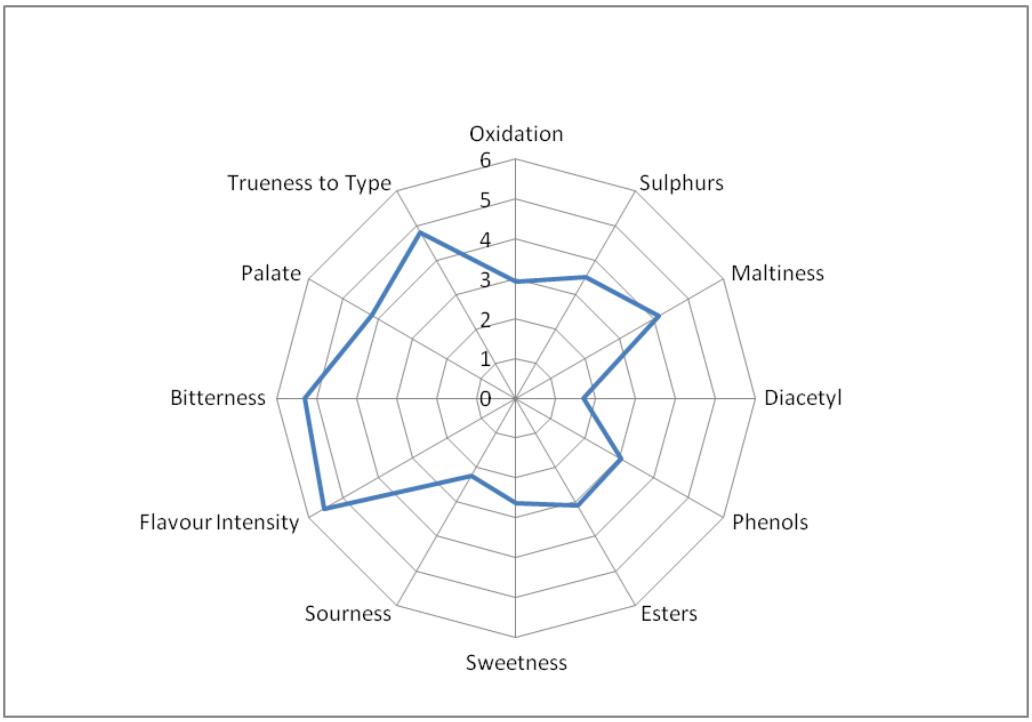

Figure 5. Average 2016 AAC Connect beer organoleptic properties.

Rating Scale

0 Less ←OXIDATION→ More 10
0 Less ←Diacetyl→ More 10
0 Less ←Phenols→ More 10
0 Less ←Esters→ More 10
0 Less ←Sulfurs→ More 10
0 Less ←Flavour Intensity→ More 10
0 Less Pleasant ←Palate→ More Pleasant 10
0 Less ←Bitterness→ More 10
0 Less ←Sweetness→ More 10
0 Less ←Sourness→ More 10
0 Less ←Maltiness→ More 10

The 2016 crop AAC Connect average beer scored satisfactorily overall with no major defects apparent (Figure 5). Slight bitterness and flavour intensity were observed.

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Glossary

Attenuation limit: Attenuation limit or Fermentability is important in that it is a measure of the amount of beer that can be produced from the original malt; the higher the better.

Brewhouse material efficiency: Brewhouse material efficiency is a metric to determine the ease of obtaining the extract from the mash.

Conversion time: Conversion time is a metric that is important for the brewer in regards to the economics of his brewhouse. Longer conversion times could translate into higher operating costs in more energy requirement, higher labour costs or decreased capacity. Conversion time is related to the enzyme content of the malt, and can be manipulated by changing malt: water ratio and temperature.

Attenuation limit: A measure of the fermentability or amount of beer that can be produced from the original malt. Typically, a higher value is desired.

Runoff time: Time to complete the runoff is a metric that is important for the brewer in regards to the economics of his brewhouse. Longer times could translate into higher operating costs in more energy requirement, higher labour costs or decreased capacity. Runoff time is related to the beta-glucan content of the malt as well as the friability and milling of the malt.

Time to clear*:* Time required for the wort to clear is a metric that is important for the brewer in regards to the economics of his brewhouse as well as the quality of the finished beer. Most brewers want clear wort, it provides better quality beer and also allows for better capacity utilization in fermentation. The time to obtain wort that is clear (less than 100 FTU) is therefore related to capacity and manpower utilization.

Wort color: Most international brewers are looking for a lower pale colour to be derived from the malt, so the lower the better.

Wort pH: Wort pH is related to beer flavour stability, the higher the pH the more flavour stable the beer is through time. However, the pH cannot be too high or else the possibility of flavour changes and microbiological infection can occur.

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