HGCA

PROJECT REPORT No. 191

MALTING AND BREWING TRIALS OF NEW BARLEY VARIETIES – 1998/99

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MALTING AND BREWING TRIALS OF NEW BARLEY VARIETIES – 1998/99

by

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1. EXECUTIVE SUMMARY

1.1 Samples of three new barley varieties, the winter variety Pearl, and two spring varieties Century and Decanter have been assessed for malting and brewing quality. Each variety was compared with a control grown at the same site, namely Halcyon and Chariot respectively.

1.2 All samples were malted on a small scale using identical conditions. This allowed malting performance to be compared and also indicated the most appropriate conditions for pilot scale malting.

1.3 Each barley was then malted on the pilot scale using the conditions best suited for that variety, in order to produce a malt which was as close as possible to the pilot brewery's standard specification for ale malt.

1.4 Each malt was then brewed using identical processing conditions to produce a standard pale ale.

1.5 Barleys, malts, worts and beers were analysed using standard IOB methods. Barley endosperm quality was also assessed using the Light Transflectance Meter, which is a new instrument developed at BRI as a result of HGCA-funded work (Projects 0027/1/92A and 0054/01/96.

1.6 The **Pearl** barley was of substantially lower nitrogen, with a larger corn size and mealier endosperm quality than the Halcyon grown on the same site. **Century** and **Decanter** were similar to Chariot in barley quality. There was no evidence of a tendency to dormancy with any of the new varieties. All samples displayed some water sensitivity which is probably related to the poor weather during the 1998 growing season.

1.7 **Pearl** malted significantly better than the control Halcyon. (This sample of Halcyon was atypical and did not perform as well either in malting or brewing as expected with commercial samples). Brewing performance of Pearl was also better than that of the Halcyon and it gave good extract yields. However, final attenuation was slightly poorer and the yield of ethanol was a little lower than the control. There were no off-flavours associated with the Pearl beer although some taste and aroma differences were noted.

1.8 **Century** behaved very similarly to the control Chariot during malting and gave malts of similar quality. Brewhouse performance was also identical to that of Chariot. Fermentation was faster however.

1.9 **Decanter** malted well but malts displayed significantly greater protein modification, as well as higher DPs and DUs than control malts. These differences were carried through into brewing, yielding beers with higher levels of protein and colour. Brewhouse and fermentation performance were otherwise very close to those of the control. Significant flavour differences were noted, particularly on the sulphury and estery notes.

2. SCOPE OF PROJECT

The object of the trials is to determine whether the new Winter barley variety **Pearl** and the two new Spring varieties **Century** and **Decanter** are suitable for use for malting and brewing when grown in the UK.

The trials involve malting each barley, together with the appropriate fully IOB approved variety grown on the same site, on a small scale (350g) and on the pilot scale (50 kg). For the small-scale trials, all barleys are subjected to the same conditions, so that the malting performance of the new varieties can be assessed. This information is used to adjust the pilot malting process conditions for each variety in order to produce malt of a suitable specification for pilot brewing trials. The brewing quality of each malt is then evaluated by brewing on the pilot scale (100 litres). All barleys, malts, worts and beers are analysed for standard quality parameters by IOB recommended methods. The flavour of each beer is assessed by flavour profiling.

3. BARLEY SAMPLES PROVIDED

BRI Reference	Type	Variety	Site
98/22	Winter	Halcyon Control	Morley
98/23	Winter	Fanfare Control	Morley
98/24	Winter	Pearl	Morley
98/25	Spring	Chariot Control	Dorset
98/26	Spring	Century	Dorset
98/27	Spring	Decanter	Dorset
98/28	Spring	Optic Control	Dorset

RESULTS OF MALTING AND BREWING TRIALS

A. Winter variety Pearl

1. Barley Quality

The three varieties supplied were analysed for standard barley quality parameters (**Table 1.**)

Table A. Barley Analyses - Winter Varieties

Parameter	Halcyon Control	Fanfare Control	Pearl
Barley Ref.No.	98/22	98/23	98/24
Moisture (%) (as received)	11.9	12.1	`11.8
Total Nitrogen (%)	1.71	1.61	1.46
TCW (g)	30	34	37
Sieve Analysis (g)			
> 2.8	10.7	28.9	72.7
2.5-2.8	39.4	57.4	23.0
2.2-2.5	36.3	11.4	3.6
<2.2	13.6	2.3	0.7
Germinative Capacity (%) (11.12.98)	98	96	98
Germinative Energy (%) (11.12.98)	95	90	98
Water Sensitivity (%) (11.12.98)	57	24	40

All samples were fully viable. By the beginning of December the Halcyon control and the test variety Pearl had fully recovered from dormancy. The Fanfare control was still slightly dormant and also displayed significant water sensitivity. Because of this, Halcyon was selected as the control for further work, although it too was not ideal, since the nitrogen content was significantly higher than that of the Pearl.
The sieve analysis of the Pearl indicated a preponderance of larger grains when compared with Halcyon or Fanfare. However, with a single sample it is not possible to be certain whether this is characteristic of the variety.

Endosperm structure was examined used light transflectance. This technique has been developed at BRI as a result of an HGCA funded projects (0027/1/92 and 0054/01/96). It relies upon the fact that a glassy or steely endosperm structure (in which the starch granules and matrix protein are tightly packed with few air spaces) is more translucent to light than is a mealy or floury endosperm (which is much less densely packed with many air spaces). Mealy endosperm modifies more readily during malting and generally gives a better quality product. The BRI Light Transflectance Meter measures the extent to which light can pass through the endosperm and expresses this as the proportion of mealy and steely grains in a sample.

As shown in **Table 2**, the sample of Pearl was much more mealy than the Halcyon sample grown under the same environmental conditions. As noted before, the nitrogen content was also lower than that of the Halcyon. If these traits are reproducible they would generally be considered advantageous for malting, although very low nitrogen contents could mean that Pearl was less suitable for making certain types of lager malts.

Table 2. Barley Endosperm Structure using Light Transflectance

Parameter	Halcyon	Pearl	Chariot	Century	Decanter
Light transflectance meter index (%)	66	84	72	62	73
Mealy grains (%)	77	93	85	71	88

2. Micro-malting

Each barley was malted on a small (350g scale) using two schedules, with or without added gibberellic acid. Both schedules involved three steeps and 4 days germination. Results are shown in **Table 3.** In general, Pearl malted better than the Halcyon control. This can be seen in the higher Extract, Soluble Nitrogen Ratio and Friability, and the lower viscosity of the Pearl sample. The Cold Water Extract and the non-routine measurements of Fine/Concentrated Mash Difference and Viscosity of 70° mash, which are all measurements of the extent of endosperm degradation – particularly cell wall degradation – during malting, all indicate an improved degree of modification for the Pearl compared with the Halcyon. The difference between the two is not, however, as marked as might be expected from the differences in mealiness. Also, the indices of amylose activity (fermentability, DP and DU) are similar for the two varieties. Given that the overall malting performance of the Pearl was better than that of

the Halcyon, one might have expected the DP and DU values for Pearl to be higher also.

Table 3. Malt Analyses, small scale malting[1],

Parameter	No added Gibberellic Acid		With Gibberellic Acid	
Barley Ref. No.	98/22	98/24	98/22	98/24
Variety	Halcyon	Pearl	Halcyon	Pearl
Hot Water Extract (litre°/kg) fine grind coarse grind	 301 293	 315 311	 306 303	 318 314
Total Soluble Nitrogen (%)	0.57	0.54	0.67	0.65
Total Nitrogen (%)	1.60	1.37	1.59	1.40
Soluble Nitrogen Ratio	36	39	42	46
Free Amino Nitrogen (%)	0.10	0.10	0.13	0.12
Fermentability (%)	84	85	83	84
Viscosity (mPa/s)	1.69	1.63	1.62	1.58
Cold Water Extract (%)	14.9	14.2	17.1	17.2
DP °IOB	95	94	121	107
DU	41	46	55	55
Wort Clarity	clear	clear	clear	clear
Fine/Concentrated Mash Difference	9	13	13	9
Viscosity of 70°Mash	10.47	7.01	8.14	6.54
Filtration Time[2] (minutes)	7	6	7	8
Friability (%)	81	98	84	99
Homogeneity (%)[3]	98	99	98	100

[1] *malting schedules: 7h wet/17h air/7h wet/ 17h air/3h wet + 4 days at 16°C +/- gibberellic acid (0.2ppm)*
[2] *for IOB laboratory mash, coarse grind*
[3] *from friability measurement*

As expected, both barleys displayed an improvement in malting performance when gibberellic acid was applied. This was especially marked for the Halcyon.

It must be noted that the malting performance of this Halcyon sample was significantly poorer than for typical commercial samples of this variety, which makes it more difficult to gauge the true performance of the Pearl in absolute terms.

3. Pilot malting

The malting performance of the two barleys on the small scale was used to select appropriate malting pilot conditions for each sample. The aim was to produce a malt from each barley as close as possible to the specifications of the BRI pilot brewery's stock ale malt. This allows the actual brewing performance of each variety to be evaluated under similar conditions.

The conditions selected are shown in **Table 1** of the **ANNEX.** Both the Pearl and the control Halcyon were steeped with a similar schedule comprising three wet periods and both were germinated for three days. The main difference was the amount of gibberellic acid (GA) applied. This poor quality Halcyon sample required twice as much GA as the Pearl.

Kilning conditions were identical for each variety.

Process data, shown in **Table 4,** indicates that there was little difference between the varieties in moisture take-up, in spite of the mealiness of the Pearl endosperm, which might have been expected to improve water absorption. The yield of malt from the Halcyon was slightly lower than from Pearl, probably because of the smaller grain size, resulting in a greater proportion of roots.

Table 4. Pilot Malting, Process data

Variety	Halcyon Control	Pearl
Barley Number	98/22	98/24
Malt Batch Number	780P	781P
Moisture after 1st steep	33.9	33.8
Casting moisture (%)	46.2	45.3
Moisture at end of germination (%)	43.2	43.5
Time to break point (hr)	12	11.5
Total kilning time (hr)	21	19.5
Root weight (kg)	1.5	1.1
Malt yield (%)	85.6	86.6

Malt analyses are shown in **Table 5.** For the Pearl, most parameters were within specification except for the Soluble Nitrogen Ratio, which was a little low. The colour was also low, but this was the same for the control. The coarse/fine difference was higher than specification. This is partly because of the high extract obtained with a fine grind. The Halcyon control did not malt well, even with the higher level of added GA, giving poor extract, limited protein modification and poorer friability.

Table 5. Pilot malting, malt analyses

Parameter	Halcyon Control	Pearl	BRI Pilot Brewery Specification for ale malt
Barley Ref No	98/22	98/24	
Malt batch No.	780P	781P	
Hot Water Extract (litre°/kg) **fine grind** **coarse grind**	 305 297	 316 312	 310 -314 308 - 312
Coarse/fine Difference	8	4	1.0 - 1.5
Colour (EBC)	4.1	4.1	4.5 - 5.5
Total Soluble Nitrogen (%)	0.58	0.58	0.5 - 0.7
Total Nitrogen (%)	1.65	1.41	< 1.7
Soluble Nitrogen Ratio	35	41	45
Free Amino Nitrogen (%)	0.10	0.11	
pH	5.83	5.88	5.5 - 6.0
DP (°IOB)	64	67	
Fermentability (%)	70	73	70 - 75
Viscosity (mPa/s)	1.63	1.55	1.55 - 1.65
Friability (%)	82	96	>90

4. Pilot Brewing

The Halcyon and Pearl malts were brewed in the pilot brewery, using standard process conditions for BRI Pale Ale. These are shown in **Table 3** of the **ANNEX.**

Process data, given in **Table 6,** shows that, as expected from the malt analysis, the Pearl malt performed better in the brewery than did the Halcyon control, giving a higher yield of extract with no processing difficulties.

Table 6. Pilot brewing, process data

Variety	Halcyon Control	Pearl
Brew No.	19/99	20/99
Barley No.	98/22	98/24
Malt No.	780P	781P
Lauter time (min)	76 recirculation needed prior to run-off	77
Wort Clarity	initially poor	satisfactory
Trub settling time (min)	30	30
Final wort gravity pre-fermentation	1037.9	1036.5
Total volume wort (litres)	112.8	128
Yeast viability at harvest (%)	94	90
Final gravity (°)	1009.2	1010
Gravity drop (° of gravity)	28.7	26.5

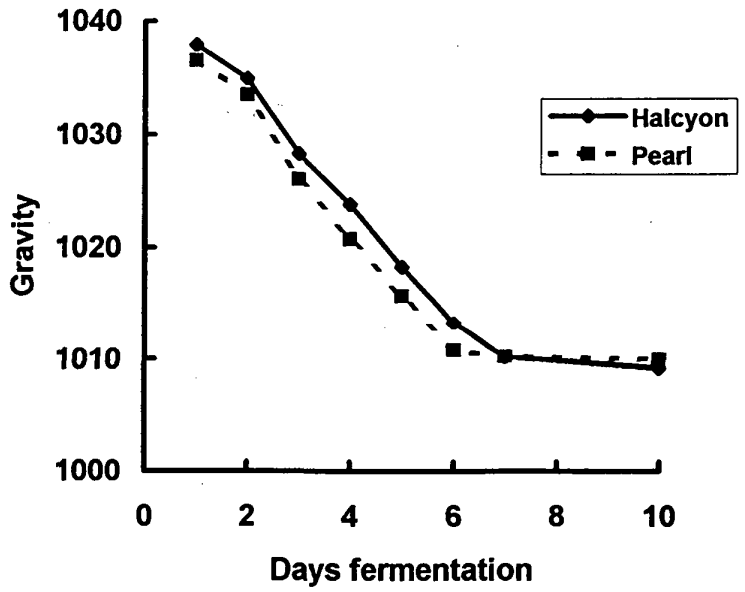
Standard wort analyses are shown in **Table 7.** The control Halcyon was within specification for OG and nitrogenous materials (both free amino and total soluble nitrogen). Surprisingly, the Pearl gave a lower wort OG, but this may be related to the higher volume collected. The variations in wort bitterness are not unusual at the wort stage and do not carry through to the final beer.

Table 7. Wort Analyses

Parameter	Halcyon Control	Pearl	BRI Pale Ale Wort specification
Barley No.	98/22	98/24	
Brew No.	19/99	20/99	
pH	5.15	5.28	5.4 +/- 0.2
Colour (°EBC)	25.4	26.0	30 +/- 3
Original Gravity (°)	1037.22	1034.76	1038 +/- 1
Bitterness (BU)	46	33	37 +/- 3
Free Amino Nitrogen (mg/litre)	105	97.2	100 +/- 20
Total Soluble Nitrogen (mg/litre)	622	571	600 +/- 50
Fermentability (%)	65	67	2

Figure 1 shows the rate of drop of gravity during fermentation for the two beers. Pearl fermented slightly faster than the Halcyon, but final attenuation was marginally poorer than that of the control.

Figure 1. Fermentation profile for Halcyon and Pearl beers



5. Beer Quality

Results for the final beer analyses are given in **Table 8.** Nitrogen parameters (FAN and TSN), bitterness and pH are within specifications for both varieties. However, the final gravity is relatively high for both varieties compared with the target values. This is partially a characteristic of malts produced in the pilot plant compared with commercial malts. However, Pearl gave a slightly higher gravity than Halcyon and the ethanol content for Pearl was significantly lower than that of the control. This tends to support the earlier indications from the micro-malting data that amylolytic activity could be potentially be limiting in Pearl.

Table 8. Pilot brewing, beer analyses, standard parameters

Parameter	Halcyon Control	Pearl	BRI Pale Ale Beer Specification
Barley No.	98/22	98/24	
Brew No.	19/99	20/99	
pH	3.99	3.96	4.0 +/- 0.2
Colour (°EBC)	20.4	20.7	25 +/- 2
Present Gravity (°)	9.62	10.29	6 +/- 2
Attenuation limit (°)	7.68	6.62	5.0 +/- 1
Head Retention Value (Nibem) (sec)	92/172/249	89/164/242	-/-/250
Bitterness (BU)	27	27	25 +/- 2
Free Amino Nitrogen (mg/litre)	37.2	35.9	30 +/- 10
Total Soluble Nitrogen (mg/litre)	419	423	425 +/- 50
Ethanol (% v/v)	3.94	3.53	4.0 +/- 0.2

Table 9 gives the values for flavour volatiles in the two beers. Values were largely within the ranges expected for BRI Pale Ale . Differences between Pearl and the Halcyon control were not significant.

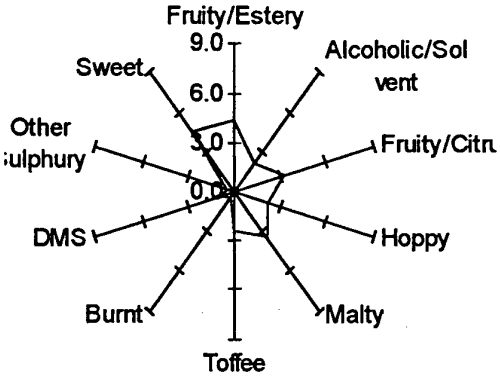
Table 9. Pilot brewing. Beer analyses. Flavour volatiles

Parameter	Halcyon Control	Pearl
Barley No.	98/22	98/24
Brew No.	19/99	20/99
Diacetyl (mg/litre)	0.11	0.08
Pentanedione (mg/litre)	0.01	0.02
DMS (µg/litre)	19	23
Acetaldehyde (mg/litre)	2.6	2.5
Ethyl Acetate (mg/litre)	23.3	21.7
***i*-Butyl acetate (mg/litre)**	<0.06	<0.06
***n*-Propanol (mg/litre)**	16.4	14.5
***i*-Butanol (mg/litre)**	16.3	13.1
***i*-Amyl acetate (mg/litre)**	1.4	1.3
***i*-Amyl alcohol (mg/litre)**	49.8	43.8
Ethyl hexanoate (mg/litre)	0.13	0.14

The flavour and aroma of both beers was assessed by BRI's trained flavour profile panel. No off-flavours were detected in either beer. For aroma, Pearl was scored as significantly less sweet, and slightly less estery and alcoholic than the control. For taste, Pearl was scored as significantly less estery , hoppy and sweet, and significantly more astringent than the control. The analytical difference in DMS concentration was not apparent. These results are displayed visually as "spider diagrams" in **Figures 2 and 3.**

Figure 2. Aroma and Taste scores for Halcyon beer

Aroma



Taste

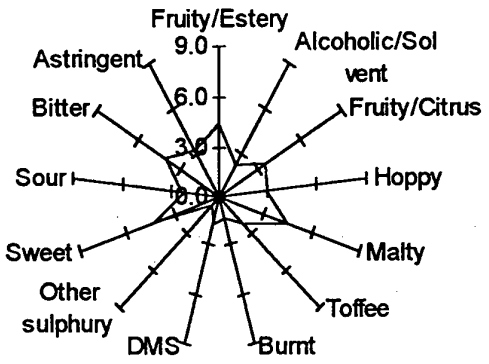
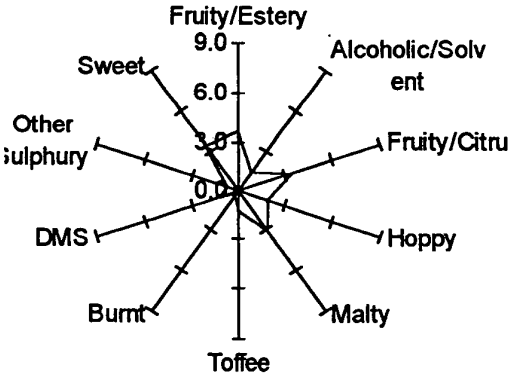
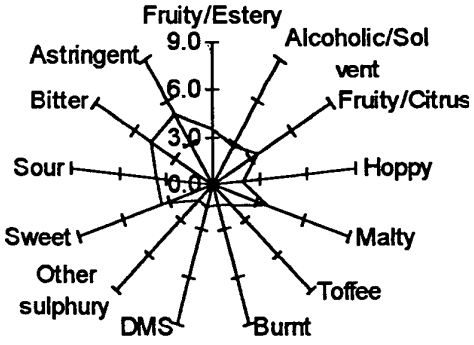


Figure 3. Aroma and Taste scores for Pearl beer

Aroma



Taste



B. Spring Varieties, Century and Decanter

1. Barley Quality

Results of analyses for standard barley quality parameters are shown in **Table 10.** Nitrogen contents and sieve analyses were similar for each of the varieties. All had largely recovered from dormancy by early October. Some residual water sensitivity was apparent even in November, probably as a result of the poor weather conditions during the 1998 growing season. However, there was no evidence that either Century or Decanter was significantly more prone to water sensitivity than the control.

Table10. Barley Analyses - Spring Varieties

	Chariot Control	Century	Decanter	Optic Control
Barley Ref.No.	98/25	98/26	98/27	98/28
Moisture (%) (after drying)	11.6	11.8	11.6	11.4
Total Nitrogen (%)	1.69	1.64	1.65	1.67
TCW (g)	35	36	37	37
Sieve Analysis (g)				
> 2.8	49.6	49.2	33.7	46.5
2.5-2.8	34.2	34.3	48.4	39.1
2.2-2.5	11.7	12.2	14.0	10.8
<2.2	4.5	4.3	3.9	3.6
Viability (%)	99	99	100	99
Germinative Energy (%) (5.10.98)	97	96	98	100
Water Sensitivity (%) (16.11.98)	47	36	45	60

Endosperm quality was examined using the Light Transflectance Meter as before (**Table 2**). This suggested that the Century grains were somewhat less mealy than the Decanter and Chariot samples grown under the same conditions.

2. Micro-malting

Each sample was micro-malted using similar conditions to the winter varieties in order to compare malting performance (**Table 11**).

Table 11. Malt Analyses, small scale malting[1],

Parameter	No added Gibberellic Acid			With Gibberellic Acid		
Barley Ref. No.	98/25	98/26	98/27	98/25	98/26	98/27
Variety	Chariot	Century	Decanter	Chariot	Century	Decanter
Hot Water Extract (litre°/kg)						
fine grind	313	310	310	314	312	312
coarse grind	311	307	309	312	310	311
Total Soluble Nitrogen (%)	0.54	0.54	0.69	0.59	0.61	0.75
Total Nitrogen (%)	1.61	1.67	1.56	1.64	1.62	1.65
Soluble Nitrogen Ratio	34	32	44	36	38	45
Free Amino Nitrogen (%)	0.10	0.10	0.15	0.12	0.12	0.16
Fermentability (%)	84	84	84	83	84	83
Viscosity (mPa/s)	1.46	1.49	1.46	1.47	1.50	1.48
Cold Water Extract (%)	14.3	14.3	17.8	15.4	15.6	18.6
DP °IOB	128	113	151	143	136	158
DU	56	47	82	62	56	78
Wort Clarity	slightly cloudy	slightly cloudy	clear	slightly cloudy	slightly cloudy	clear
Fine/ Concentrated Mash Difference	14	15	11	6	9	13
Viscosity of 70°Mash	4.49	6.10	4.89	4.18	5.38	4.91
Filtration Time[2] (minutes)	10	18	19	10	19	22
Friability (%)	93	82	93	97	85	92
Homogeneity (%)[3]	98	95	99	98	96	99

[1] *Malting schedules: 7h wet/17h air/7h wet/17h air/1h wet + 4 days at 16°C +/- gibberellic acid (0.2ppm).*
[2] *for IOB laboratory mash, coarse grind*
[3] *from friability measurement*

Results for both Century and Decanter were generally very similar to, but no better than, the control Chariot, with those for Decanter being slightly better than those for Century. Friability scores for Century were significantly lower than those of the control. The most noticeable difference between the three varieties was in protein modification, where it was apparent from the TSN, SNR and FAN values that protein modification both with and without gibberellic acid was significantly more advanced for Decanter than for either Century or the control Chariot. Measures of amylolytic activity (DU and DP) were also higher for Decanter.

3. Pilot Malting

The three spring samples were malted in the pilot plant using similar conditions (a three steep schedule followed by four days germination) except that less GA was used for the Decanter than for the Chariot and the Century. Exact details of the malting conditions are given in the **Annex, Table 2.** Process data, given in **Table 12,** suggests that both Century and Decanter were slightly better at taking up water during steeping than the control. Decanter yielded less malt than Century or Chariot, probably because of the increased root growth.

Table 12. Pilot Malting, Process data

Variety	Chariot Control	Century	Decanter
Barley Number	98/25	98/26	98/27
Malt Batch Number	776P	777P	779P
Casting moisture (%)	45	47.0	48.4
Moisture at end of Germination (%)	43.6	44.2	46
Time to break point (hr)	13	13	12.5
Total kilning time (hr)	24	24	21
Root weight (kg)	1.7	1.7	2.3
Malt yield (%)	85	84.2	82

Malt analysis data is given in **Table 13.** Again, Decanter showed evidence of higher protein modification (and consequently a higher colour) than either the control Chariot or Century. Other parameters were generally similar for all three varieties, although, as with the micro-malts, DP values for Decanter were a little higher than for the other two varieties.

Table 13. Pilot malting, malt analyses

Parameter	Chariot Control	Century	Decanter
Barley Ref No	98/25	98/26	98/27
Malt batch No.	776P	781P	779P
Hot Water Extract (litre°/kg) fine grind coarse grind	 312 309	 311 306	 312 309
Coarse/fine Difference	3	5	3
Colour (EBC)	3.6	4.1	6.8
Total Soluble Nitrogen (%)	0.62	0.65	0.76
Total Nitrogen (%)	1.61	1.62	1.66
Soluble Nitrogen Ratio	38	40	46
Free Amino Nitrogen (%)	0.12	0.12	0.17
pH	5.8	5.81	5.59
DP (°IOB)	82	80	91
Fermentability (%)	74	73	76
Viscosity (mPa/s)	1.55	1.56	1.47
Homogeneity (%)	99	97	100
Friability (%)	94	96	97

4. Pilot Brewing

The Chariot, Century and Decanter pilot malts were used for brewing in the pilot brewery, using standard process conditions for BRI pale ales. Details of these are given in the **ANNEX, Table 3.** Process data for each brew is given in

Table 14. This shows that brewing performance was similar for each of the varieties, with no processing problems being encountered. The yield of extract from each of the test varieties was equal to that from the control.

Table 14. Pilot brewing, process data

Parameter	Chariot Control	Century	Decanter
Brew No.	16/99	17/99	18/99
Barley No.	98/25	98/26	98/27
Malt No.	776P	777P	779P
Lauter time (min)	77	76	77
Gravity of last runnings (°gravity)	1005.9	-	1003.8
Wort clarity	good	good	good
Trub settling time (min)	30	30	30
Final wort gravity pre-fermentation	1038.4	1038.3	1038
Total volume wort (litres)	116.4	119	119.5
Yeast viability at harvest (%)	84	91	89
Final gravity (°)	1009.4	1009.4	1009.9
Gravity drop (° of gravity)	28.5	28.9	28.1

Wort analyses are shown in **Table 15.** Values for Century are close to those of the control Chariot, and mainly within target ranges (except for colour, which is lower than specification, as expected from the low values for colour in the malt). Decanter, however, gave high levels of total and soluble nitrogen, confirming the indications of excess protein modification in the malts. The colour was higher than that of Chariot and Century worts, no doubt due to the higher protein levels. Gravity and fermentability, however, were similar to the control values.

Table 15. Wort Analyses

Parameter	Chariot Control	Century	Decanter	BRI Pale Ale Wort specification
Barley No.	98/25	98/26	98/27	
Brew No.	16/99	17/99	18/99	
pH	5.27	5.28	5.26	5.4 +/- 0.2
Colour (°EBC)	23.6	25.6	28.4	30 +/- 3
Original Gravity °	1037.85	1037.61	1037.58	1038 +/- 1
Bitterness (BU)	42	45	42	37 +/- 3
Free Amino Nitrogen (mg/litre)	117	124	151	100 +/- 20
Total Soluble Nitrogen (mg/litre)	662	689	803	600 +/- 50
Fermentability (%)	67	67	67	73 +/- 2

Figure 4. Fermentation profiles for Century and Decanter beers

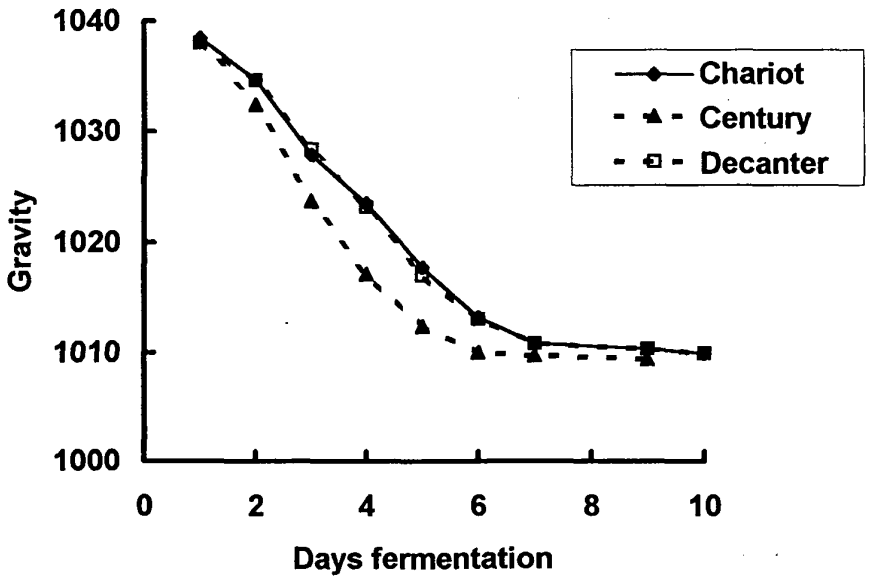


Figure 4 shows the rate of fermentation for each variety. The rate of fermentation and the extent of attenuation for Decanter was almost identical to that for the control Chariot. Century, however, fermented slightly faster in spite of having a lower DP in laboratory analysis.

5. Beer Quality and Flavour

Results for standard beer quality analyses are shown in **Table 16.** As predicted from the wort analyses, Century was similar to the control Chariot for most parameters, and both were mainly within target specifications, except for final gravities, which were higher than the target, indicating an incomplete fermentation. However, as explained earlier, this is a characteristic of malts prepared in the pilot maltings and is not considered to be related to barley quality. With Decanter, levels of amino and total nitrogen were significantly higher than the control, and well outside specifications. Both of these results would be expected from the corresponding malt and wort values. The yield of ethanol was also slightly lower for Decanter than for the other varieties.

Table 16. Pilot brewing, beer analyses, standard parameters

Parameter	Chariot Control	Century	Decanter	BRI Pale Ale Beer Specification
Barley No.	98/25	98/26	98/27	
Brew No.	16/99	17/99	18/99	
pH	3.95	4.02	4.09	4.0 +/- 0.2
Colour (°EBC)	21.5	21.4	23.1	25 +/- 2
Present Gravity (°)	10.15	9.59	10.37	6 +/- 2
Attenuation limit (°)	7.09	6.92	6.89	5.0 +/- 1
Head Retention Value (Nibem) (sec)	73/159/240	98/178/248	73/145/213	-/-/250
Bitterness (BU)	25	28	26	25 +/- 2
Free Amino Nitrogen (mg/litre)	47.9	37.8	77.6	30 +/- 10
Total Soluble Nitrogen (mg/litre)	471	430	565	425 +/- 50
Ethanol (% v/v)	3.88	3.82	3.75	4.0 +/- 0.2

Flavour volatile analyses are shown in **Table 17.** Dimethyl sulphide (DMS) values are higher for Decanter than for the other varieties, probably related to the increased degree of protein modification in this variety, but the difference is not significant. Otherwise there is little difference between the three varieties in concentrations of flavour-active volatile compounds.

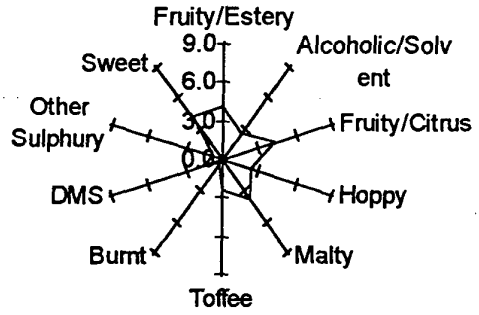
Table 17. Beer analyses. Flavour volatiles

Parameter	Chariot Control	Century	Decanter
Barley No.	98/25	98/26	98/27
Brew No.	16/99	17/99	18/99
Diacetyl (mg/litre)	0.11	0.10	0.11
Pentanedione (mg/litre)	0.02	0.02	0.01
DMS (µg/litre)	29.9	29	32
Acetaldehyde (mg/litre)	4.9	3.6	2.9
Ethyl Acetate (mg/litre)	22.8	25.2	22.1
***i*-Butyl acetate (mg/litre)**	<0.06	0.07	<0.06
***n*-Propanol (mg/litre)**	15.4	17.1	12.8
***i*-Butanol (mg/litre)**	15.7	17.5	11.1
***i*-Amyl acetate (mg/litre)**	1.3	1.9	1.2
***i*-Amyl alcohol (mg/litre)**	47.3	56.6	45.8
Ethyl hexanoate (mg/litre)	0.15	0.18	0.15

The aroma and taste of each beer was assessed by BRI's trained flavour profile panel. No off-flavours were detected for either beer. With the Century beer, no significant differences, compared with the control Chariot, were scored for either aroma or taste. These results are presented as "spider diagrams" in **Figures 5 and 6.**

Figure 5. Aroma and Taste scores for Chariot beer

Aroma



Taste

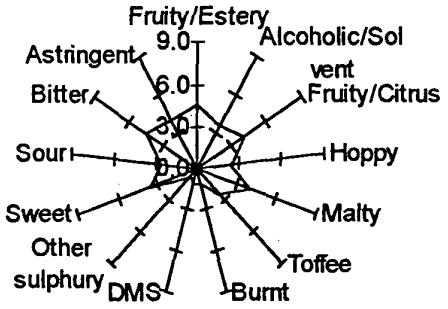
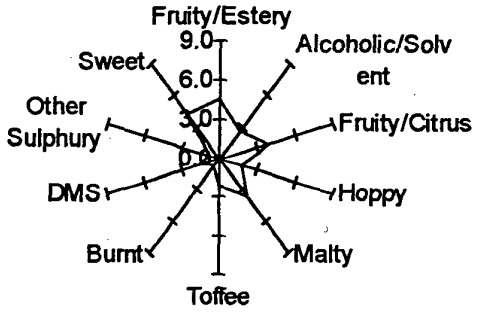
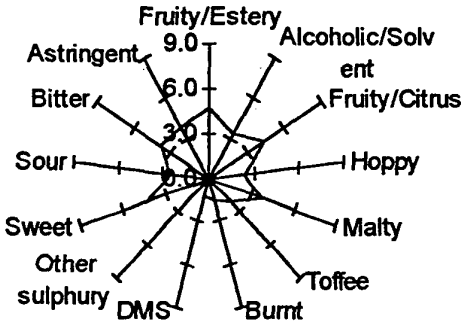


Figure 6. Aroma and Taste scores for Century beer

Aroma



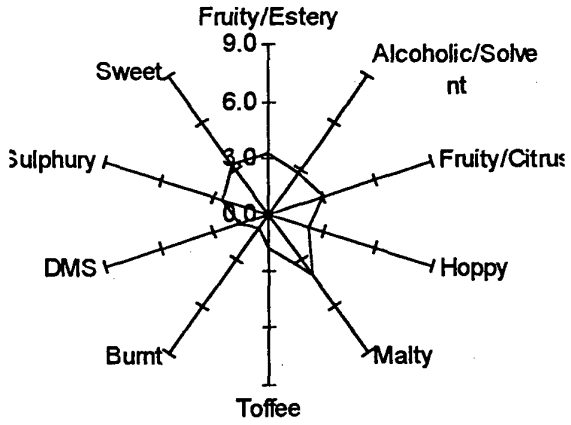
Taste



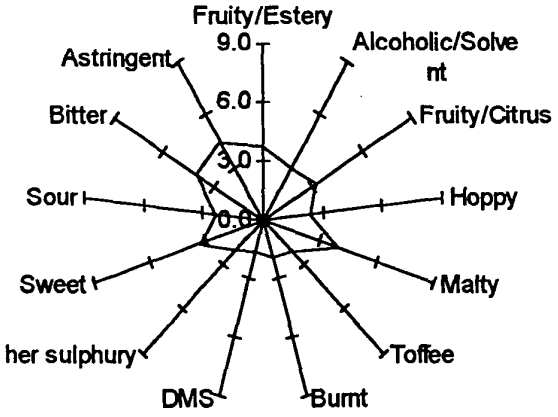
The Decanter beer however was scored as significantly different from the control for both aroma and taste (**Figure 7**). The aroma of Decanter beer was considered to be less fruity, estery and sweet and more sulphury than the control, while the taste was also considered to be more sulphury and less estery although there was no significant difference between the beers in ester content. A non-significant difference in DMS was noted, in line with the slightly higher DMS content of the Decanter beer.

Figure 7. Aroma and Taste scores for Decanter beer

Aroma



Taste



6. Conclusions

Pearl
This variety appears to be a large corned, low nitrogen variety with good endosperm structure. Malting performance was significantly better than the Halcyon, although it must be noted that this sample of Halcyon was atypical in its performance and had a significantly higher nitrogen content. Brewhouse performance and extract yield of Pearl were also good. The higher final attenuation and lower yield of ethanol suggest that amylolytic activity could be limiting, at least in this low nitrogen sample.
There were some flavour differences from the control but no overt off-flavours.

Century
This variety performed in a very similar manner to the control Chariot, both in malting and in the brewhouse. It fermented significantly faster than the control, although malt DPs and DUs were no higher than those of the control. Beer flavour and aroma was very close to that of the control.

Decanter
This variety behaved quite differently from the control. Protein modification was significantly higher than that of either the control or of Century. This was associated with higher colours for malts, worts and beers. DP and DU values were also elevated, suggesting that Decanter is a high enzyme variety. Behaviour in the brewhouse was very similar to that of the control and there was a good yield of extract. Fermentation performance likewise was identical to that of the control. Although there were no overt off-flavours, both aroma and taste of the Decanter beer differed significantly from the control, particularly in the estery (lower than control) and sulphury (higher than control) notes. This may be related to the slightly higher DMS levels in the Decanter.
If these findings prove reproducible with other samples it suggests that Decanter could be useful for particular types of malt but would be less suitable as a direct replacement for Chariot.

ANNEX

Table 1. Pilot Malting Conditions – Winter Varieties

STEEPING:

Parameter	Halcyon Control	Pearl
Steep schedule (hours)	3 steep: 8 wet / 14 air / 6 wet / 12 air / 6 wet / 2 air	
Temperature (°C)	15 +/- 1	17 +/- 2
Duration (hours)	48	
Aeration	Yes	
Gibberellic Acid (ppm)	0.2 at cast	0.1 at cast

GERMINATION:

Parameter	Halcyon Control	Pearl
Temperature (°C)	15 – 18	18
Duration	4 days	

KILNING:

Ale schedule, air-on 45°C rising to 95°C over 20 - 21 hours. Recirculation of warm air post-break.

Table 2. Pilot Malting Conditions: Spring varieties

STEEPING:

Parameter	Chariot Control	Century	Decanter
Steep schedule (hours)	3 steeps: 8 wet / 14 air /6 wet / 12 air / 3 wet / 2 air		
Temperature (°C)	16 °C +/- 2°C		
Duration (hours)	45		
Aeration	yes		
Gibberellic Acid (ppm)	0.25	0.25	0.1

GERMINATION:

Parameter	Chariot Control	Century	Decanter
Temperature (°C)	15 °C rising to 18 °C		
Duration	4 days		

KILNING:

Ale schedule, air-on 45°C rising to 95°C over approximately 24 hours. Recirculation of warm air post-break.

Table 3. Pilot Brewing, Process Conditions

Brewing Stage	Conditions
Grist:	12.25 kg test malt 1.75 kg Crystal malt liquor/grist ratio 3:1
Mashing	Infusion mash at 64°C for 60 mins. Sparge temperature 78°C 3.5 kg Fermentose syrup
Kettle Boil	Boil time 60 mins Hop grist; 25 g $HOPCO_2N$
Fermentation	18°C for 6 days or until PG < 1010° gravity Yeast strain NCYC 1681
Maturation	3 days at 13° 1-2 days cold rest at 3°C minimum of 7 days cold maturation at 0°C
Packaging	DE filter sheets, type XE 200 275 ml bottles
Pasteurisation	15 min at 60°