A Guide to the Use of Pre-Isomerized Hop Pellets, Including Aroma Varieties

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ABSTRACT

The use of modern hop products requires careful consideration and certain aspects can only be determined by practical application in specific products and in the brewing plant pertinent to individual companies and their intrinsic operating procedures.

Some practical guidelines are presented that have been found to be valuable in maintaining product consistency and ease of use for pre-isomerized hop pellets including the use of products derived from hop varieties usually regarded for use as aroma hops (with consequent gain of bittering potential from the utilized alpha acids of these aroma varieties).

Keywords: preisomerized hop pellets, hop utilization, perceived bitterness

INTRODUCTION

The development of modern hop products has allowed more efficient use of those hop fractions that are important contributors to beer flavor and quality.

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After several years of Post-Doctoral research in Medical Biochemistry at the University of Birmingham, through the offices of the late Professor Jim Hough, David joined the brewing industry as Senior Chemist with Watney Mann & Truman Brewers, Ltd. in 1977. Subsequently, he held several technical brewing positions within WMTH, (which became Grand Metropolitan Brewing and later Courage, Ltd.) prior to joining Ushers in September, 1993. He is a regular contributor to the Institute of Brewing’s training programs, and takes and active interest in the industry’s research and development projects. In 1995, he was elected a Fellow of the IBC, and has been an international member of the MBAA since September, 1991.

David has published and lectured on a wide range of brewing technology topics, including three previous MBAA Conventions. His paper on “Uses of Nitrogen in Brewing,” written in conjunction with Dr. Jim Murray, and presented to the 1991 convention, received the MBAA Presidential Award for an outstanding paper on brewing technology in September, 1992.

Email:
Modern hop processing technology has allowed more efficient and cost-effective use of the hop fractions; for example, separate oil-rich fractions and purified resins can be introduced into the product stream at the optimum time to ensure enhanced efficiency. However, the use of these materials may require installation of relatively sophisticated dosing equipment in order to achieve the necessary degree of process control to ensure accurate additions.

One category of hop products that is produced by relatively simple technology, without high processing costs and requiring no additional process handling, is Pre-Isomerized Hop Pellets.[2]

Pre-isomerized hop pellets are genuinely “value added” products in that they provide the brewer with reduced production costs and enhanced beer quality.

At Ushers of Trowbridge in the UK, we have been using pre-isomerized hops (notably “Wye Target” variety) for several years as the sole source of the bitterness character in our ales and in some lagers and we have identified much improved utilizations (far in excess of conventional hops or ‘Type 90’ pellets), leading to increased cost effectiveness in that the additional processing cost is more than offset by the cost benefits attained. All this is consistent with beer quality in no way being compromised, rather in fact, enhanced and, more recently, we have discovered that using aroma hops in the form of pre-isomerized pellets is similarly cost effective and can provide unique new product opportunities.

EXPERIMENTAL AND DISCUSSION

1. Production of Pre-Isomerized Pellets

Pre-isomerized hop pellets are produced commercially[3,4] by mixing intimately milled hops with magnesium oxide (at up to 3% by weight) prior to pelletizing in the standard manner. This process involves pressing through a die and packaging in an oxygen-free environment, usually under partial vacuum (after flushing with inert gas). The boxes of hop pellets are then held at approximately 50°C for 8 to 13 days to effect isomerization (Figure 1).

![FIGURE 1](image-url) Isomerization of α-acid.

The efficiency of this conversion of alpha acid to iso-alpha can be in excess of 95% and provides a very stable form of iso-alpha acid provided the storage packs are intact (i.e. as long as oxygen is excluded). In this way, a very efficient conversion of labile alpha acid to stable iso-alpha is achieved at low cost, especially if the isomerization process is carried out immediately after harvest.

2. Analytical Guidelines

The use of purified iso-alpha acids requires adoption of the standard method of bitterness determination, unless HPLC equipment is to be considered for routine brewery analyses. The following considerations have been established and confirmed in our use of iso-alpha acid materials at Ushers.

The traditional method[5] for measuring beer bitterness involves extraction into acidified iso-octane, with the absorbance of this extract determined at 275nm (in a 1cm cuvette), multiplied by the factor 50 to express the result in Bitterness Units (BU).

Where bitterness is achieved by conventional hopping (viz. whole hops or ‘Type 90’ pellets), the iso-octane extract contains a variety of materials, also absorbing at 275nm, in addition to iso-alpha acids. HPLC analysis has confirmed that 1 ppm (i.e. 1mg/l) of pure iso-alpha acid has a BU of approximately 0.7.

However, in the normal range of bitterness using whole hops, BU and ppm of iso-alpha acid are assumed to be roughly equivalent because of the other contributing materials to the analytical BU. So, in spite of the relatively non-specific nature of the analytical procedure, in the range 10-40 BU, approximate equivalence between BU and ppm iso-alpha acid is achieved with iso-alpha contributing to the analytical BU at 0.7 per ppm and other hop derived materials contributing the remainder. An understanding of this situation is of particular importance in correlating perceived bitterness to analytical BU, when using “purer” hop preparations.

Generally speaking, pre-isomerized products contribute less non-iso-alpha acid material (which absorbs at 275nm) and, consequently, the analytical BU method will underestimate the organoleptic bitterness potential (to varying degrees) unless some compensatory factors are applied.

HPLC analysis of pre-isomerized hop products and of beers produced from them has enabled the correct compensatory factors to be established in order to modify the conventional BU determination method, so as to achieve comparable estimation of the relative bitterness potentials of the different hop products.

As stated before, HPLC analysis of pure iso-alpha acid has confirmed that the BU equivalent of 1 ppm is 0.7 or, by inversion, the multiplication factor to correlate BU to ppm (and perceived bitterness) is 70 rather than 50.

Similar analysis of beers produced using 100% pre-isomerized hop pellets has identified that, for beers brewed in our brewery, the correct multiplication factor is 58 due to some degree of ‘purification’ of iso-alpha acid, relative to conventional hopping, but not to the same extent as for the more highly refined ‘pure’ iso-alpha preparations. This has been confirmed consistently by flavor analysis, so that a BU specification, expressed using factor 58, matches satisfactorily the required perceived bitterness specification.

In order to simplify analytical procedures and setting of product specifications, our routine Quality Assurance Laboratory can confidently carry out BU determination on beers prepared with different hop products, without the necessity for HPLC analysis, and still be able to correlate with standard perceived bitterness targets, by adopting targets based on BU, with the appropriate factor identified as a suffix.
Consequently, BU specifications for 100% conventionally hopped beers are expressed as:

- \( \text{BU}(50) \)

For beers with 100% pre-isomerized hop pellets:

- \( \text{BU}(58) \)

For comparison, beers with 100% pure iso-alpha acid addition:

- \( \text{BU}(70) \)

In this way, perceived bitterness specifications can be adequately correlated with analytical BU, without the need for more sophisticated analysis on a routine basis.

A full correlation of these analytical considerations with perceived bitterness targets is presented in Table 1, which summarizes how the relationship between ppm (mg/l), analytical BU (with the appropriate multiplication factor) and taste equivalents can be compensated to establish working bitterness specifications for beers brewed with pre-isomerized hop pellets.

### 3. Use of Pre-Isomerized Hop Pellets

At Ushers, we have several years’ experience of the use of pre-isomerized hop pellets, principally for bittering using, predominantly, English-grown “Wye Target” hops (at approximately 10% iso-alpha acid).11

#### TABLE 1A

Analytically determined bitterness relative to a standard taste perceived bitterness of 20 BU.

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>PERCEIVED BITTERNESS UNIT</th>
<th>ANALYTICAL ppm</th>
<th>( \text{BU}(50) )</th>
<th>( \text{BU}(70) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD HOPS</td>
<td>20</td>
<td>’20’</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>PRE-ISOMERIZED PELLETS</td>
<td>20</td>
<td>’20’</td>
<td>17</td>
<td>20 @ ( \text{BU}(58) )</td>
</tr>
<tr>
<td>PURE ISO-( \alpha )-ACID</td>
<td>20</td>
<td>20</td>
<td>14</td>
<td>20 @ ( \text{BU}(70) )</td>
</tr>
</tbody>
</table>

#### TABLE 1B

Analytically determined bitterness and taste perceived bitterness, relative to bitterness measured at \( \text{BU}(50) \).

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>ANALYTICAL ( \text{BU}(50) )</th>
<th>( \text{BU}(70) )</th>
<th>ppm</th>
<th>PERCEIVED BITTERNESS UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD HOPS</td>
<td>20</td>
<td></td>
<td>’20’</td>
<td>20</td>
</tr>
<tr>
<td>PRE-ISOMERIZED PELLETS</td>
<td>20</td>
<td>23 @ ( \text{BU}(58) )</td>
<td>’23’</td>
<td>23</td>
</tr>
<tr>
<td>PURE ISO-( \alpha )-ACID</td>
<td>20</td>
<td>28 @ ( \text{BU}(70) )</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

#### FIGURE 2

Comparison of key hop hop flavors.

It can be seen that the major flavor characters (on an Intensity Scale of 0 to 4.0) for aroma (A), palate (P) and after palate (AP) are essentially identical, indicating a good flavor match.

Other relevant analytical data are presented in Table 2, showing that no adverse effects on haze stability have been experienced, with a modest improvement in head retention (as indicated by the Nibem value) noted; these data refer to the means of 3 separate brewing trials.

#### TABLE 1C

Analytically determined bitterness and taste perceived bitterness, relative to a standard iso-\( \alpha \)-acid value.

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>ANALYTICAL ppm</th>
<th>( \text{BU}(50) )</th>
<th>( \text{BU}(70) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDARD HOPS</td>
<td>’20’</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>PRE-ISOMERIZED PELLETS</td>
<td>’20’</td>
<td>17</td>
<td>20 @ ( \text{BU}(58) )</td>
</tr>
<tr>
<td>PURE ISO-( \alpha )-ACID</td>
<td>20</td>
<td>14</td>
<td>20 @ ( \text{BU}(70) )</td>
</tr>
</tbody>
</table>

Figure 2 presents a typical comparison of key hop flavor characteristics for the same brand of ale brewed with:

(a) conventionally, ‘Type 90’ “Target” hop pellets (CONTROL) and

(b) 100% pre-isomerized “Target” hop pellets (TRIAL), to achieve the same BU specification of 28 (confirmed by HPLC).
TABLE 2
Comparative beer analyses
Standard vs Pre-Isomerized Pellets.

<table>
<thead>
<tr>
<th>HEAD RETENTION</th>
<th>STABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Rudin (secs)</td>
<td>Nibem (secs)</td>
</tr>
<tr>
<td>CONTROL</td>
<td>93</td>
</tr>
<tr>
<td>TRIAL</td>
<td>94</td>
</tr>
</tbody>
</table>

4. Analyses of Pre-Isomerized “Target” Hop Pellets

A typical analysis for “Target” pre-isomerized pellets is presented in Table 3, showing in this case, a conversion of alpha acids to iso-alpha acids of 99%.

TABLE 3
Typical analysis of “Target” Iso-Pellets.

- ISO - α - ACIDS : 9.8%
- α - ACIDS : 0.1%
- β - ACIDS : 2.8%
- % CONVERSION : 99%
- TOTAL OIL : 0.6 ml/100g (1.0)
  - MYRCENE : 9.2% (47.0)
  - β-CARYOPHYLLENE : 10.3% (7.9)
  - FARNESENE : 0.1% (0.1)
  - α-HUMULENE : 24.9% (18.1)

The values in parentheses for the oil components refer to the equivalent analyses for the corresponding hops, prior to isomerisation. This shows that although the total oil content is reduced during pelleting and processing, it is predominantly the lighter fraction - mostly Myrcene - that is reduced (and which is almost totally removed during kettle boiling). Hence, there is effectively a concentration of the true “Hoppy” characters associated with the levels of β-Caryophyllene and α-Humulene. However, it should be pointed out that our interest at this stage was only in the bittering ability of the “Target” pre-isomerized pellets, not their hop oil potential.

The quality in terms of purity of iso-alpha acids of the pre-isomerized pellets is displayed in Figure 3 which is a chromatogram of the “Target” iso-pellets showing clean peaks for the iso-alpha acids and only trace quantities of the corresponding alpha acids, indicating very good conversion (at least 99%); the beta acids remain virtually intact and there is little evidence of any deterioration of the resins (such as oxidized alpha acids) as indicated by the very low levels at the front of the HPLC trace.

The corresponding HPLC analysis for the beer produced (at 28 BU(68)) using these “Target” iso-pellets is presented in Figure 4. This chromatogram again shows clean peaks for iso-alpha acids, with little trace of any oxidized resins.

5. Utilization of Pre-Isomerized Hop Pellets

A very significant feature arising from the use of pre-isomerized hop pellets is enhanced hop utilization.

Hop utilizations with pre-isomerized pellets, at the Ushers Brewery, have been consistently demonstrated to be increased significantly with average figures of 80% into wort collected prior to fermentation and, as indicated in Table 4, up to 65% into beer at end of fermentation.

FIGURE 3
Chromatogram of “Target” Iso Pellets.

FIGURE 4
Chromatogram of “Target” Iso Pellets in beer.
TABLE 4
Comparison of % Utilization
Standard vs Pre-Isomerized Hop Pellets.

<table>
<thead>
<tr>
<th></th>
<th>HPLC/HPLC</th>
<th>HPLC/BU_{50}</th>
<th>HPLC/BU_{58}</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td>37</td>
<td>38</td>
<td>-</td>
</tr>
<tr>
<td>TRIAL</td>
<td>65</td>
<td>55</td>
<td>64</td>
</tr>
</tbody>
</table>

For comparison, results for standard pellets are 55% into wort and never greater than 40% into beer. These figures have been confirmed by HPLC analysis but use of BU determination using the modified factor (58) gives comparable results.

6. Rate of Solution of Iso Alpha Acids

A further key benefit from the use of pre-isomerized hop pellets arises from the rapid solution of the iso-alpha acids, as seen in Figure 5, which plots the rate at which the iso-alpha acids dissolve into wort during boiling.

![FIGURE 5](image1)

Rate of solution of iso-\(\alpha\) in boiling wort.

It is apparent that no more than 10 minutes boiling time is required to achieve maximum potential. This rapid dissolution rate is of particular significance for late kettle hopping, since it has already been established that the quality of the hop oil is well preserved during the pelletization and isomerization process. We have confirmed that pre-isomerized hop pellets added 10 minutes before the end of boil achieve similar utilizations to those added at the start.

7. Use of Pre-Isomerized Aroma Hop Pellets

At Ushers all bittering had been achieved using “Target” pre-isomerized pellets. However, several beers, especially cask-conditioned ales, were being brewed using a mixture of pre-isomerized “Target” pellets for bittering and standard ‘Type 90’ aroma hop pellets for late kettle addition, the principal variety used being “Styrian Goldings.”

The “Styrian Goldings” pellets were added as 25% of the total weight of the hop grist at 10 minutes before the end of boil. The main bittering potential, derived from “Target” pre-isomerized pellets was, of course, added separately and much earlier in the boiling sequence.

TABLE 5
Typical analysis of “Styrian Goldings” Iso-Pellets.

- ISO - \(\alpha\) - ACIDS : 3.8%
- \(\alpha\) - ACIDS : 0.1%
- \(\beta\) - ACIDS : 2.2%
- % CONVERSION : 97.5%
- TOTAL OIL : 0.8 ml/100g
  - MYRCENE : 16.0%
  - \(\beta\)-CARYOPHYLLEN : 11.5%
  - FARNESENE : 5.0%
  - \(\alpha\)-HUMULENE : 37.7%

The consequence of this hop formulation was that often variable perceived bitterness was obtained due to an unpredictable contribution from the aroma hop alpha acid content (approx. 3.8%), plus the fact that any delay in kettle emptying allowed further increase in utilization of the aroma hop alpha acids. These factors also led to a complication of BU determination since, with variable contribution to the total iso-alpha acid from the aroma hops, it proved impossible to determine the precise BU multiplication factor (between 50 and 58).

The solution to these complications was to evaluate the use of pre-isomerized pellets produced from “Styrian Goldings” hops.

8. Analyses of Pre-Isomerized “Styrian Goldings” Hop Pellets

A typical analysis for the “Styrian Goldings” pre-isomerized pellets is included in Table 5 and shows a conversion of alpha to iso-alpha acids of over 97%.

![FIGURE 6](image2)

Chromatogram of “Styrian Goldings” Iso-Pellets.
Analysis of the oil content shows the expected low level of Myrcene, combined with a high level of $\alpha$-Humulene and a high ratio of $\alpha$-Humulene to $\beta$-Caryophyllene. The measurable content of Farnesene (at 5%) is typical of this variety.\(^{16}\)

A typical HPLC trace for the "Styrian Goldings" iso-pellets is presented in Figure 6, which again shows very clean iso-alpha acid peaks, only trace quantities of alpha acids and very low levels of oxidized resins.

The corresponding GC trace of the oil content of these "Styrian Goldings" iso-pellets is presented in Figure 7. This chromatogram indicates the presence of a significant (and normal) content of the late running (post-humulene) oxidized compounds (mostly derived from $\beta$-Caryophyllene and $\alpha$-Humulene) that are generally held to be responsible for "late hop" character in beer.

![FIGURE 7](image)

**Figure 7**
Chromatogram of oil content of "Styrian Goldings" Iso Pellets.

9. Use of Pre-Isomerized "Styrian Goldings" Hop Pellets

The trials to evaluate the use of "Styrian Goldings" iso-pellets were completely successful in terms of obtaining a satisfactory flavor match to control beer using standard late kettle hopping.

The pre-isomerized aroma hop pellets provided precisely the same late kettle hop character by addition 10 minutes before the end of the boil, with the correct balanced "Hoppy" profile in terms of: "FLORAL," "CITRUS," "SPICY," "GRASSY" characters on aroma and palate.

To achieve the same overall intensity of total hop character, it proved to be necessary to increase the proportion of aroma hop pellets in the total grist by 15% (i.e. from 25% of the total weight of hop pellets to 30%). However, this was primari-ly a seasonal factor related to the lower hop oil content in the pre-isomerized "Styrian Goldings," which were not of the same crop year as the standard "Styrian Goldings" used in the earlier control brews (total oil content approximately 1.5 ml/100 gms).

Of greater significance was the necessary reduction in the addition rate of the pre-isomerized bittering hops used ("Target") of 20%. This change was directly due to realization of the full bittering potential of the aroma hop iso-alpha acids. Considerable cost savings in terms of total hop pellet additions have thereby been achieved, with the added quality benefit of obtaining a predictable contribution of all added iso-$\alpha$-acids, thus ensuring consistent and more meaningful determination of BU values in the beer.

10. New Product Opportunities from Pre-Isomerized Aroma Hops

Because of the rapid solution rate of iso-alpha acids, it is normal to realize all the achievable bittering potential of pre-isomerized pellets by late kettle addition (e.g. 10 minutes before end of boil). In this way, if desired, it is possible to obtain (without economic penalty) some contribution to hop oil character from hops predominantly added for their bittering potential (e.g. "Target"). More importantly, by pre-isomerization of the alpha acids, it is possible to enhance the late kettle hop character by a cost effective increase in the proportion of aroma hops in the hop grist.

To this end, for the last two years, Ushers has been producing two cask-conditioned ales that have been brewed to 30 BU with 100% pre-isomerized "Styrian Goldings" hop pellets, all added as late kettle addition. This somewhat unconventional hopping procedure has achieved a fresh, crisp hop character, which has proven to be an excellent complement to the light, refreshing flavor achieved in these cask ales, brewed with malted oats and malted wheat (the production of which was presented to the 1997 MBAA Convention in Baltimore\(^{17}\)).
An HPLC chromatogram of hop resin acids extracted from a beer brewed with 100% “Styrian Goldings” pre-isomerized pellets is presented in Figure 8, again showing very little content of deterioration products.

Undoubtedly, to have brewed these beers with 100% aroma hops as conventional pellets would have proven to be prohibitively expensive.

CONCLUSIONS

The variety of hop products now available provide the brewer with a wide selection of opportunities to increase the cost effectiveness of hop usage. Further, selective use of the many different, often highly processed products, allows a number of valuable beer quality and flavor attributes to be readily exploited in a better controlled manner than before. However, one of the most versatile categories of modern hop products is produced by a relatively simple technology, namely, pre-isomerized hop pellets and the straightforward processing is reflected in the very significant cost and quality benefits that can be realized.

Of course, the use of pre-isomerized hops requires careful consideration since certain aspects of their use can only be determined by trial and error, having regard to specific beer products and the brewing plant pertinent to individual breweries and their operating procedures.

The practical guidelines suggested in this paper indicate that the use of pre-isomerized hop pellets can be readily monitored without the need for highly sophisticated analytical methods and that the existing methods of bitterness determination can still be used for routine analyses, provided that an appropriate factor is applied to enable correlation with perceived bitterness expectations.

Regarding the cost benefits associated with pre-isomerized hop pellets, there are two conflicting factors, namely:

- improved utilization
- increased processing costs

However, the additional cost of the pre-isomerization process over the standard cost of pelletization is only some £16/zentner (i.e. approximately $25/zentner). Depending on the hop varieties involved, this may be as little as 5% of the total cost, unlikely to be more than 10%. Since one can quite reliably anticipate at least a 50% increase in hop utilization from the use of pre-isomerized pellets (e.g. 65% versus no better than 40% for conventional hopping), clearly substantial cost savings will be realized as a consequence of a corresponding reduction in the hop bill. In addition, since the original rationale for the pre-isomerization of hop pellets was to stabilize the alpha acid content \(^{13}\), further savings may also accrue from this increased stability.

Also, because the use of aroma hops in the form of pre-isomerized pellets is more than acceptable, an even greater cost benefit is available. Consequently, it will always be cost advantageous to use pre-isomerized pellets, whether for high alpha acid content bitter hops or for aroma hops added late to the boil.

There are no conflicts at all when considering the quality benefits of using pre-isomerized hop pellets. It is very easy to demonstrate:

- increased consistency of bittering potential,
- ease of BU determination and correlation with perceived bitterness, especially if the total hop grist is in the form of pre-isomerized pellets,
- that the use of pre-isomerized aroma pellets can enhance significantly the perceived “Hoppy” character and can provide interesting and exciting new product and novel flavor profile opportunities.

DEDICATION

This paper is dedicated to the memory of the late Peter M. Humphrey, Director of Ushers of Trowbridge plc and President-Elect of The Institute of Brewing, 1999.

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The authors wish to express their appreciation to the Directors of Ushers of Trowbridge Ltd., of S.S. Steiner Inc., of Steiner Hops Ltd. and of HHV m.b.H. for their permission to publish this paper.

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