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Modification of perceived beer bitterness intensity, character and temporal profile by hop aroma extract

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ABSTRACT

The effect of hop aroma on perceived bitterness intensity, character and temporal profile of beer was investigated. A hop aroma extract was added at 3 levels (0, 245, 490 mg/L) to beers at low, medium and high bitterness. Beers were evaluated for perceived bitterness intensity, harshness, roundedness and linger by a trained panel using a rank-rating technique at each bitterness level, with and without nose clips. The use of nose clips enabled the olfactory aspect to be decoupled from taste and mouthfeel aspects of bitterness perception. Results showed significant modification of perceived bitterness in beer by hop aroma depending on the inherent level of bitterness. These modifications were mainly driven by olfaction – in an example of taste-aroma interactions, as well as certain tactile sensations elicited by the hop aroma extract in the oral cavity. At low bitterness, beers with hop aroma added were perceived as more bitter, and of 'rounded' bitterness character relative to those without hop aroma. When judges used nose clips, this effect was completely eliminated but the sample was perceived to have a 'harsh' bitterness character. Conversely, at high bitterness, even when nose clips were used, judges still perceived beers containing hop aroma to be more bitter. These increases in bitterness perception with nose clips indicates the stimulating of other receptors, e.g. trigeminal receptors by hop aroma extract, which in tandem with the high bitterness, cause perceptual interactions enhancing bitterness intensity and also affecting bitterness character. Bitterness character attributes such as 'round' and 'harsh' were found to significantly depend on bitterness and aroma levels, with the second level of aroma addition (245 mg/L) giving a 'rounded' bitterness in low bitterness beers but 'harsh' bitterness in high bitterness beers. The impact of aroma on temporal bitterness was also confirmed with time-intensity measurements, and found to be mostly significant at the highest level of hop aroma addition (490 mg/L) in low bitterness beers. These findings represent a significant step forward in terms of understanding bitterness flavour perception and the wider impact of hop compounds on sensory perception.

1. Introduction

The flavour of food and beverages is multifaceted - involving taste, smell, texture, visual appearance, sound and trigeminal sensations; all of which are key for consumer satisfaction (Sørensen, Møller, Flint, Martens, & Raben, 2003). Of the four main brewing ingredients (water, malted barley, yeast and hops) hops (*Humulus lupulus* L.) remain an essential flavour ingredient in beer (Schönberger & Kostelecky, 2011). Hop resins and essential oils, located within the lupulin glands of the female hop flowers are the sources of bitterness and aroma characters in beer, respectively (De Keukeleire, 2000; Van Opstaele, Goiris, De Rouck, Aerts, & De Cooman, 2012b). For bitterness, hop α-acids found within hop resins are thermally isomerised to bitter tasting iso-α-acids during the boiling stage of the brewing process (De Keukeleire, 2000). Bitterness units (BUs) are used as an analytical estimate of bitterness intensity by brewers, with 1 mg/L of iso-α-acids approximately equalling 1 BU (Oliver & Colicchio, 2011). Generally the higher the level of iso-α-acids the higher the perceived bitterness intensity. Lager beers today are reported to typically range from 6–30 BU although much more bitter beers (>35 BU) are also widely available commercially (Schönberger & Kostelecky, 2011).

Hop essential oils contain several volatile aroma compounds which are the source of desirable 'hoppy' character, often sensorially characterised using descriptors such as 'floral', 'fruity', 'spicy', 'herbal' or 'woody' in beer (Eyres, Marriott, & Dufour, 2007; Eyres, Marriott, Leus, & Lysaght, 2015). These oils are complex in nature, with numerous odour-active compounds which significantly contribute to their aroma profile yet to be identified (Eyres et al., 2007). The total essential oil constituent of hops is typically isolated by a combination of CO_2 extraction

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and distillation processes, with fractions of individual odour characters such as 'floral', 'citrus' and 'spicy' obtained from the total hop essential oil by chromatography and further distillation (Van Opstaele, Goiris, De Rouck, Aerts, & De Cooman, 2012a; Van Opstaele et al., 2012b). The 'spicy' fraction of hop essential oils is currently the subject of intense research to identify the compounds responsible for this particular hop character in beer (Van Opstaele, Praet, Aerts, & De Cooman, 2013). Significantly, the use of the descriptive term 'spicy' to describe certain hop flavour impressions in beer may indicate the activation of trigeminal receptors in the oral and nasal cavities by aroma compounds present within this fraction of hop essential oil.

In a bid to achieve desirable 'hoppy' characters and enhanced flavours in beer, brewers now regularly add hops at numerous stages of the brewing process, including the latter stages during fermentation or maturation in a process known as 'dry-hopping'. Alternatively, hop essential oils from selected varieties are available commercially as hop aroma extracts and can be added to beer post-fermentation for flavour intensification and product differentiation (Eyres & Dufour, 2009). The addition of hop aroma extracts to unhopped beer has been reported to contribute to an improved mouthfeel, fullness and increased bitterness perception (Goiris et al., 2002; Van Opstaele et al., 2012a, 2012b,2013). What remains unclear is the mechanism behind the latter observation, since hop aroma extracts are a complex mixture of volatile compounds assumed to lack any taste qualities. In this regard, the phenomenon of taste-aroma and taste-trigeminal interactions should be considered since many reports in the literature have shown a strong relationship between the human sense of taste and olfaction (Pfeiffer, Hollowood, Hort, & Taylor, 2005; Small & Prescott, 2005; Stevenson, Prescott, & Boakes, 1999). The perception of flavour during food consumption usually involves the concurrent stimulation of the olfactory epithelium (OE) in the nasal cavity by volatile compounds/odours via sniffing (orthonasal); and during oral processing/swallowing, which forces volatiles into the OE via the back of the throat (retronansal) (Hummel, 2008; Visschers et al., 2006). Some examples of this phenomenon include the common attribution of perceived taste qualities to odours e.g. the description of vanilla as having a 'sweet' smell, and the perceptual increase in intensity ratings of samples containing congruent odours and tastants (Dalton, Doolittle, Nagata, & Breslin, 2000; Murphy, Cain, & Bartoshuk, 1977; Pfeiffer et al., 2005). Other examples, based on detection threshold experiments (controlled for physiochemical interactions) between taste and odour compound pairs have revealed that subthreshold concentrations of odour compounds are more easily detected orthonasally when presented together with a subthreshold concentration of a taste compound, than when it is presented alone (Dalton et al., 2000). The role of congruency on the observed level of taste-aroma interactions is inconsistent; some researchers only observed additivity in congruent taste-aroma pairs (Dalton et al., 2000; Labbe, Damevin, Vaccher, Morgenegg, & Martin, 2006), while others have reported additivity in taste-aroma pair irrespective of congruency (Delwiche & Heffelfinger, 2005).

Although both taste and trigeminal sensations are sensed by distinct sensory systems, interactions exist between them which can also affect the perception of flavour in foods (Hewson, Hollowood, Chandra, & Hort, 2009). Trigeminal sensations involve the perception of texture, pungency and temperature within the oral cavity, nasal cavity or on the tongue (Cullen & Leopold, 1999). Oral irritation can reduce perceived intensity of taste and odour (Prescott, Allen, & Stephens, 1993), Lawless, Rozin, and Shenker (1985) also demonstrated the masking of both olfactory and gustatory sensations by oral capsaicin (Lawless et al., 1985).

The aim of this study was to investigate the impact of hop aroma compounds on the perceived intensity, character and temporal profile of bitterness in beer. A pure aroma extract of the Hersbrucker Spät hop variety was selected for this purpose. This hop variety has been reported to impart a 'hoppy', 'green'/'herbal' aroma as well as a 'spicy' mouthfeel to beer (Van Opstaele et al., 2012a). Analytically, it contains relatively higher levels of oxygenated sesquiterpenes, the compounds thought to be responsible for the 'spicy' character of hoppy aroma in beer (Peacock, Deinzer, Likens, Nickerson, & McGill, 1981; Tressl, Engel, Kossa, & Koeppler, 1983; Van Opstaele et al., 2012b).

2. Materials and methods

To investigate the impact of hop aroma compounds on bitterness perception, an unhopped base lager beer was brewed, to which pre-isomerised iso-α-acid and hop aroma extracts were added, to produce a two factorial design of samples at different BU levels and hop aroma concentrations. Various aspects of perceived sample bitterness were then assessed by a trained sensory panel using a combination of descriptive, discrimination and time-intensity techniques. Notably, to enable the effects of olfactory components of perception to be decoupled from oral (taste and mouthfeel) components, sensory tests were performed with and without nose clips.

2.1. Base beer production

The unhopped lager base beer used for this study was prepared at the 10 hL SABMiller research brewery at the Sutton Bonington campus of the University of Nottingham. The standard brew (5% ABV) was prepared from a grist composition of 70% pilsner malt and 30% dextrose adjunct. Mash-in temperature was 48 °C with addition of $CaCl_2$ at a rate of 100 mg/L. This was followed by wort boiling for 60 min (5% evaporation) and a 15 min trub stand time. The wort was cooled and fermented with a standard SABMiller lager yeast for 10 days, and maturation followed for 4 days. The beers were packaged in 330 mL brown bottles and stored at 3 °C until their preparation for sensory appraisal. The original gravity and pH of the beer were 1.044 and 4.23, respectively.

2.2. Pre-isomerised iso-α-acid extract (Isohop)

Different BU levels (Low 13 BU, Medium 25 BU, High 42 BU) were achieved by the addition of a commercially available food grade standardised solution of iso-α-acids (30% w/w, density = 1.075 g/mL), kindly provided by Botanix Ltd. (Kent, UK).

2.3. Hop aroma extract product

A commercial pure hop aroma extract of the Hersbrucker hop variety (60% w/w, density = 1.020 g/mL) was used to add and vary the level of hop aroma compounds in the base beer, by addition at the following levels – L0, L1 and L2, corresponding to 0, 245, 490 mg/L of beer respectively. The hop aroma extract was supplied as a food grade solution, and was kindly provided by Botanix Ltd. (Kent, UK). These commercial products contain hop aroma compounds blended into propylene glycol for easy dissolution into beer. They are acquired by a combination of CO_2 extraction and distillation, and do not contain hop acids or other bitter-tasting congeners known to contribute to beer bitterness.

2.4. Sample preparation

Beer samples were prepared from the base beer 48 h in advance of sensory evaluation. Preparation involved uncapping the bottled base beer, followed by the addition of the respective level of Isohop (for bitterness) and hop aroma extract (for aroma). For 13, 25 and 42 BU levels, Isohop was added at 13, 26 and 43 μL per 330 mL of beer. For the three hop aroma levels (L0, L1 and L2) hop aroma extract was added at 0, 132 and 264 μL per 330 mL of beer, respectively. Both solutions were accurately added to the beer using Rainin pipettes fitted with sterilised graduated pipette tips (Mettler Toledo, US). After addition, the bottles were recapped with sterilised bottle caps and gently mixed by inverting the bottle at a rate of one inversion per second for 10 s. The beers were immediately transferred to cold storage (3 °C) until sensory testing.