Non-structural Carbohydrate Profiles in Onion Bulbs Influence Taste Preference

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Abstract

The concentration of fructose, glucose, and sucrose was determined for onion (Allium cepa L.; cvs. SS1, Buffalo and Shakespeare) bulbs grown across two different growing sites. Sugar profiles were then compared to taste-panel data as a means of determining taste preference. Scores were given for likeability, sweetness and bitterness. Significant differences (P<0.001) in sugar profiles were found between each cultivar and corresponded to differences in taste preference. Fructose and then glucose were the most abundant carbohydrates found in cvs. SS1 and Buffalo. In contrast, sucrose was the most abundant sugar found in cv. Shakespeare. There was no correlation between sucrose and sweetness score.

INTRODUCTION

Onion (Allium cepa L) flavour research has principally been dominated by investigations into pungency associated with a number of volatile sulphur compounds produced when cells are disrupted during tissue maceration (Randle, 1997). Hydrolysis of odorless S-alk(en)yl-l-cysteine sulphoxides (ASCOs) flavour precursors by the vacuolar enzyme allinase (E.C. 4.4.1.4) leads to ammonia, pyruvate, thiopropanal S-oxide (lachrymatory factor) and various volatile sulphenic and thiosulphenic acids (Schwimmer and Weston, 1961; Uddin and MacTavish, 2003; Crowther et al., 2005). Pyruvate concentration (µmol g⁻¹ fresh weight (FW)) can be correlated to degree of pungency (Schwimmer and Weston, 1961; Wall and Corigan, 1992), but is occasionally confused with overall onion flavour (Crowther et al., 2005). Onion flavour and taste are complex and related to many compounds including probably sugars.

Fructose, glucose, sucrose and fructans (degrees of polymerisation 3-15) are the main non-structural carbohydrates found in onion bulb tissues (Shiomi, 1989; Kahane et al., 2001a; Benkeblia and Varoquaux, 2003) and can contribute up to 65% or more of dry
weight (Crowther et al., 2005). Fructans are fructose polysaccharides and are thought to be less important in determining sweetness than more simple carbohydrates. Research to date has tended to report on temporal changes in carbohydrate composition in onion bulbs during development or storage (Kahane et al., 2001b; Benkebla and Varoquaux, 2003). However, there is a dearth of information on the possible influence of simple non-structural carbohydrates on taste preference for different onion cultivars (Crowther et al., 2005). The aim of this preliminary study was to investigate further the role that fructose, glucose and sucrose may play in determining onion bulb taste preference.

MATERIALS AND METHODS

Onion bulbs

Onion cvs. SS1, Buffalo and Shakespeare bulbs were grown in 2004 using conventional horticultural practices in the UK at both Rustler Produce and Moulton Bulb Co. After harvest, onion bulbs (n=180) were randomly selected across cultivar and growing site and used in taste-panels (n=120) or for determining non-structural carbohydrate composition (n =60).

Sample preparation and extraction

Onion samples were prepared according to Kahane et al. (2001a) with slight modifications. All reagents were purchased from Sigma (Dorset, UK) unless otherwise stated. Individual 0.5 cm thick equatorial slices (dry scales removed) were taken from ten randomly selected onions bulbs for each cultivar and growing site, and immediately snap frozen in liquid nitrogen. Samples were stored briefly at -40°C before being freeze-dried and returned to the freezer until use. Dry samples (50 mg) were diluted in 80% (v/v) ethanol (50 ml) and refluxed for 1 h. The samples were passed through syringe filters (0.45 µm pore diameter) and re-adjusted to 50 ml with 70% (v/v) ethanol. Samples were then concentrated in a rotary evaporator under reduced pressure at <50ºC. Concentrated extracts were immediately diluted in 1 ml HPLC grade water and then stored at -20ºC until needed.

Soluble sugar analysis

Fructose, glucose and sucrose concentrations in onion bulb tissue (mg g⁻¹ DW) were determined by HPLC (Breeze System, Waters, UK). Filtered crude onion extracts (20 µl) were injected into a Novapak-NH₂ reverse-phase column of 250 mm x 4.6 mm diameter, 5 µm particle size and 80Å pore size (Waters, UK). The mobile phase was acetonitrile-water (80:20; v/v) at 2.0 ml min⁻¹ flow rate. Eluted carbohydrates were monitored by evaporative light scattering (ELSD 2420, Waters). ELSD was chosen as the preferred method of detection due to greater baseline stability and sensitivity as compared to conventional detection by refractive index. The presence and abundance of fructose, glucose, and sucrose were automatically calculated using external standards. Raffinose, which is not present in onion bulb tissue (Darbyshire and Henry, 1981), was used as an internal reference. Assays were performed in triplicate.

Taste panel protocol

Taste-panels were conducted according to Crowther et al. (2005) with slight modifications. Four taste-panel sessions were assembled from among the directors and staff of four major onion supply companies in the UK. The panels, usually seven
members, were, therefore, composed entirely of people of working age and were approximately balanced for gender. Panellists attended a one-day training session before participation.

Samples for each taste-panel session were prepared out of sight so that the external appearance of the onions could not bias expectations of flavour. Taste-panels were arranged so that participants had no prior knowledge of the samples being evaluated. The person preparing and presenting the onion samples was from an independent organisation and not involved in tasting. Onions were cut across the equator and a 1 cm thick slice from the centre used. The skin and one outer ring was discarded plus the centre ring. Slices from five raw onions of each cultivar and growing site were roughly chopped and mixed together not more than 15 min before tasting. The rather severe flavour of onions prohibited more samples being assessed at any one taste-panel session (Crowther et al., 2005).

Panellists were asked to assess sweetness, bitterness and likeability of each sample, scored on a hedonic 1-7 scale, with 1 being the least strong response in each case; whereby 1 = bland, 7 = very sweet (sweetness scale); 1 = no bitterness or aftertaste, 7 = high level of bitterness overriding sweetness (bitterness scale). Likeability was adjudged as the overall acceptability of eating fresh / uncooked onion, where 1 = poor acceptability, 7 = very acceptable (likeability scale). Panellists were provided with written descriptors for guidance in their assessment and a reference onion which had been previously classified between 6-7 on the likeability scale.

Statistical analyses

Data were subjected to analysis of variance using Statistica version 7 (StatSoft Inc., USA). Mean values for sugar and taste-panel data were used to calculate the Pearson r correlation coefficients.

RESULTS

The concentration of fructose, glucose and sucrose varied significantly \( (P<0.001) \) across cultivar (Table 1) and corresponded to distinct differences in taste preference (Table 2). There was no significant difference between growing sites. Fructose, and then glucose were the most abundant carbohydrates found in cvs. SS1 and Buffalo (Table 1; Fig. 1), whereas sucrose was the predominant sugar found in cv. Shakespeare (Table 1; Fig. 1). Fructose and glucose were positively correlated with likeability \( (r = 0.75; 0.78) \) and sweetness \( (r = 0.77; 0.78) \) score, but there was no correlation with sucrose. There was no significant difference between taste-panel sessions assessing both perceived sweetness or likeability, respectively. Fructose and glucose were negatively correlated with bitterness \( (r = -0.86, -0.91) \), despite there being a significant difference \( (P<0.004) \) between taste-panel sessions. Glucose concentration in cv. SS1 \( (ca. 240 \text{ mg g}^{-1} \text{ DW}; P<0.05) \) was 1.38- and 3.7-fold higher as compared to cvs. Buffalo and Shakespeare, respectively (Table 1). Accordingly, onion cv. SS1 bulbs, which also had peak fructose at \( ca. 250 \text{ mg g}^{-1} \text{ DW} \) (Table 1), were preferred over cvs. Buffalo and Shakespeare, respectively (Table 2).

DISCUSSION

Sweetness in many vegetables is a desirable attribute that is often governed, in part, by tissue sugar concentration. Indeed, there is an increasing market in the UK for sweet, low pungency onions (D.O’Connor, pers. commun., 2005). It is generally
recognised that the measurement of pyruvate in onion bulbs is equivalent to pungency and even onion flavour (Schwimmer and Westin, 1961; Randle, 1992). Crowther et al. (2005) suggested that pungency masked the perception of sweetness once pyruvate exceeded ca. 4.0 µmol g⁻¹ FW. The cultivars assessed in the present study all had pyruvate levels (measured using same assay) above 5 µmol g⁻¹ FW (data not shown). Besides pyruvate, there are very few published studies which have reported the possible relationship between other biochemicals and onion flavour or sweetness.

Previous work by Crowther et al. (2005) found no relationship between perceived sweetness and individual sugar concentrations in onion tissue for <100 onion bulb samples. Despite onions containing sufficient sugar (sucrose equivalents) to be perceived as being sweet, Crowther et al. (2005) suggested that other factors were thought to be responsible for the perception of sweetness. In the present study, however, the presence and abundance of sugars in onion bulb tissue has for the first time been shown to have profound effects on onion taste preference. Onion bulbs with the highest concentrations of fructose and glucose were preferred. Sucrose was shown to have no significant influence over onion bulb taste preference.

The concentration of fructose, glucose and sucrose (mg g⁻¹ DW) found in cvs. SS1 and Buffalo tissue was similar to that reported for cv. Jaune d’Espagne (Benkeblia et al., 2004). In contrast, fructose concentration was double that reported for cv. Sentinel (Salama et al., 1990). Onion cvs. SS1 and Buffalo contained negligible concentrations of fructans (data not shown; cf. Fig. 1) as compared to cv. Shakespeare or that reported for cv. Jaune d’Espagne (Benkeblia et al., 2004). Onion cv. Shakespeare bulbs contained similar concentrations of sucrose to cv. Sentinel (Salama et al., 1990). Differences in sugar profiles between cultivars were accentuated if presented as a proportion of fresh weight (data not shown) as cv. Shakespeare had a higher dry matter content than cvs. Buffalo and SS1, respectively.

Taste-panels are valuable for establishing taste preference across different onion cultivars and can be correlated with simple sugar concentration; specifically fructose and glucose. Ongoing work aims to verify the role that these sugars may play in taste preference and identify additional candidate markers of onion flavour and sweetness to enable superior diagnostics to be developed for enhanced onion flavour standardisation (Abayomi et al., 2004).

ACKNOWLEDGEMENTS

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Literature Cited


TABLES

Table 1. Mean concentration of simple non-structural carbohydrates (mg g\(^{-1}\) dry weight) in onion cvs. SS1, Buffalo and Shakespeare bulbs averaged over two different growing sites\(^a\). Data are main factor × (±S.E.); n=60.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Fructose (±S.E.)</th>
<th>Glucose (±S.E.)</th>
<th>Sucrose (±S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS1</td>
<td>256.82 (±4.89)</td>
<td>241.54 (±9.25)</td>
<td>67.64 (±3.70)</td>
</tr>
<tr>
<td>Buffalo</td>
<td>260.15 (±10.65)</td>
<td>175.30 (±9.03)</td>
<td>57.71 (±3.23)</td>
</tr>
<tr>
<td>Shakespeare</td>
<td>46.27 (±2.95)</td>
<td>65.21 (±5.13)</td>
<td>126.85 (±5.67)</td>
</tr>
</tbody>
</table>

\(^a\)No significant difference between growing sites

Table 2. Mean taste scores (sweetness, bitterness and likeability; 1-7, with 1 being the least strong response in each case) for onion cvs. SS1, Buffalo and Shakespeare bulbs averaged over four taste-panel sessions and two different growing sites\(^a\). Data are main factor × (±S.E.).

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Sweetness (±S.E.)</th>
<th>Bitterness (±S.E.)</th>
<th>Likeability (±S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS1</td>
<td>3.78 (±0.18)</td>
<td>3.12 (±0.22)</td>
<td>4.06 (±0.20)</td>
</tr>
<tr>
<td>Buffalo</td>
<td>3.14 (±0.18)</td>
<td>3.59 (±0.22)</td>
<td>3.31 (±0.22)</td>
</tr>
<tr>
<td>Shakespeare</td>
<td>2.65 (±0.18)</td>
<td>4.16 (±0.23)</td>
<td>2.67 (±0.22)</td>
</tr>
</tbody>
</table>

\(^a\)No significant difference between growing sites
Profil des glucides non structuraux des bulbes d’oignon influencent la préférence de goût

Mots-clés : Allium cepa L., amertume, acceptabilité, douceur, panel de gustation

Résumé
Les concentrations en fructose, glucose et saccharose étaient mesurées sur des bulbes d’oignon (Allium cepa L. cvs. SS1, Buffalo et Shakespeare) cultivés sur deux terrains différents. Les profils des sucres étaient ensuite comparés avec les données du panel de gustation afin de déterminer les préférences de goûts. L’acceptabilité, la douceur et l’amertume étaient notées. Des différences significatives (P < 0,001) de profils des sucres étaient trouvées entre chaque cultivar, correspondant aux différentes préférences de goût. Le fructose et ensuite le glucose étaient les glucides les plus abondants trouvés dans les cvs SS1 et Buffalo. Par comparaison, le saccharose était le sucre le plus abondant trouvé dans cv Shakespeare. Il n’y avait aucune corrélation entre le saccharose et les notes de douceur. Le glucose était négativement corrélé avec l’amertume. Il y avait une corrélation positive entre la concentration en fructose et en glucose, avec les notes de douceur et d’acceptabilité. La concentration en glucose dans cv SS1 (env. 240 mg g-l matière sèche (MS)) était 1,38 et 3,7 fois plus important comparé à les cvs Buffalo et Shakespeare respectivement. En conséquence, les bulbes de cv SS1, qui aussi avaient une concentration maximum de fructose d’environ 250 mg g-l MS, étaient préférées sur les cvs Buffalo et Shakespeare.