Determination of seasonal influences on sensory attributes of South African cactus pear cultivars

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Abstract

This paper reports on the effect of cultivar and season on sensory quality of cactus pear fruit. The sensory quality was evaluated by the Free Choice Profiling (FCP) method over the two agricultural seasons of 2007 and 2008. The five most frequently-used attributes used by the panel were sweet, sour, bitter, fruity and prickly pear, with the corresponding cultivars for season 2007 being Fresno, Robusta, Sharsheret, Malta and Amersfoort. For season 2008, the corresponding cultivars for the same attributes changed to Nudosa, Sharsheret, Robusta, Roly Poly and Ficus Indice, respectively. The FCP technique could successfully distinguish between the two seasons, but not between the majority of the cactus pear cultivars. The exception was Monterey and Robusta where FCP was able to differentiate them clearly from the rest of the cultivars. In an attempt to determine whether sensory quality of cactus pear fruit was influenced by the physico-chemical parameters, Pearson correlation analysis was performed between the physico-chemical and sensory data. Physico-chemical parameters like pulp glucose, pulp fructose and percentage pulp were correlated with sensory attributes like sweet, fruity and prickly pear. The descriptor “sweet” had a positive correlation (r = 0.2477) with pulp glucose and pulp fructose content (r = 0.2636) at a significance level of p < 0.05. A negative correlation at a significance level of p < 0.01 between the taste attributes “prickly pear” (r = 0.4259) and “sweet” (r = 0.3561) and % pulp was observed. “Prickly pear” had a positive correlation (r = 0.3547) with pulp pH at a significance level of p < 0.01.

Key words: cactus pear; correlation; fruit; season; sensory analysis.

Introduction

The cactus pear (Opuntia ficus-indica) is a plant that has the distinction of being a vegetable, fruit and flower all in one (Ntsane, 2008). The driving force behind its popularity is that each part of this plant functions as both food and medicine. Cactus pear fruit is known in various countries of the world where they are successfully cultivated. The content of proteins, carbohydrates, minerals, and vitamins in the fleshy cladodes as well as in the fruit are nutritionally significant (Gurrieri et al., 2000). It was demonstrated that the non-nutritive components of cactus pear is a source of potentially active antioxidant phytochemicals (Livrea and Tesoriere, 2006). Sugars and acids are the principle contributors to flavour in fruit. The ratio is often used as harvest- and quality indices in different fruit commodities. Cactus fruit has a mild, pleasant taste with subtle differences in the flavour of fruit from different species. The acid content is very low and the juice of cactus fruit with a lower acid content is favoured in sensory tests. Sensory preference testing, that has been done on cactus pear fruit, include mainly countries such as Italy (Gurrieri et al., 2000), Egypt (El-Samahy et al., 2007), Spain (Retamal et al., 2006), Argentina (Mestrallet et al., 2009), Mexico (Ruiz Pérez-Cacho et al., 2006), Chile (Sáenz and Sepulveda, 2001) and also recently in South Africa (Swart et al., 2009; Bothma et al., 2010). Recent sensory analysis done on cactus pear fruit was used to develop various products and applications such as: the possibility of long-term storage of cactus pears for their juice (Gurrieri et al., 2000); edible films and coatings to increase food quality and decrease disposable packaging (Del-Valle et al., 2005); sensory analysis of edible young cladodes, named nopalitos (Ruiz Pérez-Cacho et al., 2006); the possibility of producing a new value-added snack-type extrudate
based on cactus pear pulp concentrates (El-Samahy et al., 2007); canned cactus pear nectar to determine the heat resistance parameters of pectin methyl esterase (El-Samahy et al., 2008); powders obtained from spiny and spineless cladodes, showing a great technological potential in water binding capacity (WBC) and fat absorption capacity (FAC) (Ayadi et al., 2009) as well as ice-cream with cactus pear pulp (El-Samahy et al., 2009). The development of various products is due to consumer preference and taste. There is an increasing interest in the major markets for the fruit of the spineless cactus pear where it competes with some of the better known traditional fruits (Inglese et al., 1995). Research on cactus pear fruit is increasing in South Africa (Potgieter, 2000; Snyman, 2006; Swart et al., 2009; Bothma et al., 2010; De Wit et al., 2010; Rothman et al., 2012). An interesting study was done by Rothman et al. (2012) where chemical and physical attributes of cactus pear fruit in South Africa were evaluated for two agricultural seasons (2007 and 2008) where the influence of factors such as rainfall and temperature, for both seasons, was determined. However, the correlation between the chemical- and sensory attributes has not yet been determined to explain the specific tastes obtained from eating the pulp or fruit of the cactus pear.

**Aim**

The aim of this study was to determine the sensory fruit quality of cactus pear fruit cultivated in South Africa. Sensory analysis was used to distinguish among the available 34 cultivars, not only for their taste, but also to establish the cultivar most stable to varying environmental conditions. The study determined whether sensory quality of cactus pear fruit was influenced by the chemical parameters by attempting to correlate the chemical data with the sensory data. This paper will focus on the correlation between the chemical composition and the sensory analysis of cactus pear fruit.

**Materials and methods**

**Collection of cactus pear fruit**

The Waterkloof germplasm collection is located in the Bloemfontein district in the Free State, South Africa (29°10’53” S 25°58’38” E). This semi-arid area is located 1348 meter above sea level (m.a.s.l.) and receives on average 556 mm annual rainfall. The orchard is eight years old. Climatic data was captured via an automatic weather station (Mike Cotton Systems), installed 50 m from the site. Mean daily values for temperature (°C) and rainfall (mm) were summarized as monthly values. Cultivars included in the study are from two species, namely *Opuntia ficus-indica* and *Opuntia robusta*. Thirty-two cultivars, suitable for human consumption, are from *Opuntia ficus-indica* sp., with two cultivars from *Opuntia robusta*, namely Robusta and Monterey, which are mainly used as fodder. Robusta and Monterey has been included in this study as control parameters and served as an additional *Opuntia* specie. Fruit was harvested and evaluated over two agricultural seasons: 2007 and 2008. The fruit was picked at 50 % colour break stage. All of the fruit was therefore at the same stage of ripeness (Avenant and Fouche, 2008).

Thirty-two *Opuntia ficus-indica* spp. analyzed included: R1251, R1259, R1260, Algerian, American Giant, Amersfoort, Blue Motto, Corfu, Cross X, Direkteur, Fresno, Gymno Carpo, Malta, Messina, Meyers, Morado, Muscated, Nudosa, Ofer, Postmasburg, Robusta X Castillo, Roedtan, Roly Poly, Rossa, Santa Rossa, Schagen, Sicilian Indian Fig, Tormentosa, Turpin, Van As, Vryheid and Zastron.

**Free Choice profiling**

**Cactus pear juice samples**

The fresh cactus pear fruit was refrigerated at 4 °C before peeling. The juice was extracted by a manual piston press. The juice was poured into 250 ml plastic juice bottles (Freepak, Bloemfontein), sealed and frozen at-18 °C (not longer than one month), until the sensory test was conducted.
Panel training
A group of ten naive consumer panellists, whom had tasted cactus pear fruit before, were selected to participate in the Free Choice Profiling (FCP) study. No vocabulary development was carried out; each panelist used his/her own descriptive words for the taste attributes.

An unstructured line scale, with appropriate anchors, ranging from zero (0) denoting not, (e.g. not sweet) to fifteen (15) denoting extreme (e.g. extremely sweet) was constructed and used to evaluate the different samples. In order to ensure that panelists were not influenced in any way, no information with regard to the nature of the samples was provided. Three evaluation sessions were conducted.

Sample preparation, serving and evaluation procedures
Applicable juice samples were removed from the freezer 24 hours before tasting and thawed at 4 °C. All samples were served and evaluated according to the sensory principles and methods described in the ASTM Manual on Descriptive Analysis Testing for Sensory Evaluation (ASTM Manual Series: MNL 13, 1992).

Panellists received 30 ml samples per product and 11 cultivars were tested each day. The cactus pear fruit juice was diluted with Dairy Belle’s Real Juice apple (100 % apple juice) (Tiger Food Brands limited, Bryanston) in a ratio of 250:100 ml, because of limited juice sample volumes. This specific brand was chosen for its bland taste, as not to influence the distinctive aroma of each cultivar. Samples were prepared on the day before analysis, stored at a temperature between 2-6 °C, and left at room temperature (± 22 °C) for 30 minutes before assessment.

The samples were served, one at a time, in a 40 ml clear plastic cup (Plastform Consol Ltd., Johannesburg), on a white polystyrene tray, at 22 °C under red fluorescent light and in individual sensory booths. All samples were served blinded, coded (3-digit codes) and the serving order randomized to exclude any bias due to the position effect. Clover’s Aquartz mineral (Clover Danone Beverages Ltd, Roodepoort) water was provided as palate cleansers before the start of evaluation and between samples.

Four evaluation sessions per day were scheduled, with a total of eight cultivars for three of the four sessions and nine cultivars for the last session. The whole range of 34 cultivars was tasted per day. The whole process was repeated two days later. Two replications were considered the absolute minimum to ensure reliability and validity of results.

Test methodology
With reference to the objective of the study, Free Choice Profiling was used in order to determine whether differences exist between the cactus pear fruit juice samples for the agricultural seasons: 2007 and 2008. FCP (Williams and Langron, 1984) differs from conventional descriptive testing, in that the members of a taste panel describe perceived qualities of a product in an individual manner, using their own list of terms to describe the sensory characteristics of that product.

One of the unique features of FCP is the statistical treatment of the scores from the panellists. Samples were scored on unstructured line scales, using the assessors’ own vocabularies, anchored at the ends by the terms “not present/none” and “extremely/very high”. Data were recorded on paper ballots and entered into worksheets for analysis.

Statistical analysis
Recorded data was entered into a Microsoft Excel 2003 worksheet and analyzed by Generalized Procrustes Analysis (GPA), using Xlstats (Version 7.5.2). GPA (Gower, 1975), was used to provide information on the inter-relationships between samples and assessors (Arnold and Williams, 1986; Oreskovitch et al., 1991). The main objectives were to obtain an insight into the basic cognitive factors that the consumers used to distinguish between products, as well as the relationships between products in these factors (Hauser and Koppleman, 1979). GPA is a statistical technique used to mathematically manipulate data (Gower, 1975; Schlich, 1989; Oreskovitch...
The GPA usually provides a consensus picture of the data from each individual panelist in two- or three-dimensional space (Lawless and Heymann, 1998). The relationship among samples and assessors (including the consensus and individual configurations) are provided by GPA (Rubico and McDaniel, 1992). The GPA consisted of three logically distinct steps: to eliminate the effect of use of different parts of the scales, the centroids of each assessor’s data matrix were matched; isotropic scale changes removed differences in the scoring range used by different assessors; and by rotation and reflection of the axes, configurations were matched as closely as possible (Arnold and Williams, 1986). A perceptual space was produced for each assessor, which was matched as closely as possible with other assessors. A consensus configuration was then calculated as the average of individual configurations and simplified to a reduced dimensional plot by Principal Component Analysis (PCA).

The interpretation of descriptive sensory evaluation was simplified with the assistance of the multivariate statistical procedure, PCA. The smallest number of latent variables, called principle components, was identified by using PCA. These principle components explained the greatest amount of observed variability. Residual errors, or the distances between the assessors’ individual configurations and the consensus, were then used to calculate co-ordinates for plotting the assessors, to identify outliers or groups (Jack, 1994).

Results and discussion

Free Choice Profiling
Amongst the ten panelists, Free Choice Profiling (FCP) generated 21 descriptors for the attribute taste (Table 1). The four basic tastes namely sweet, sour, bitter and salty were included, as well as various vegetable and fruit flavours. Examination of the descriptors indicated that consumers used words such as “prickly pear” or “typical prickly pear aroma” to describe the same attribute perception. A possible reason for this is that the cactus pear juice was unusual for the participants, making it difficult to describe the product. Furthermore, no guarantee exists that all the assessors used the descriptors in the same way or attached the same importance to them in the discrimination amongst the samples. The lack of panel training was also reflected by the use of elementary words to describe the assessors’ perception of the juice. According to Deliza (2004), training of assessors would improve reproducibility of results and lead to the use of more specific sensory terms. Precisely defined vocabularies are, however, not needed for describing of products in order to reveal relationships and differences between samples (Deliza, 2004). Descriptors like “nutty”, “beetroot”, “metallic”, “raw potato”, “pungent”, “melon” and “vegetable” were used by only one assessor, making them hard to interpret. Most of the assessors used descriptors like “sweet”, “prickly pear”, “pear” and “fruity”.

Table 2 indicated which cultivar had the most frequently-used attribute for seasons 2007 and 2008. The results were determined by the score for each attribute given, by using the hedonic scale by each panelist for each cultivar tasted. Table 2 shows the descriptor which was most commonly used with a specific cultivar, according to the panelists. The five most frequently-used attributes were sweet, sour, bitter, fruity and prickly pear, with the corresponding cultivars for 2007 being Fresno, Robusta, Sharsheret, Malta and Amersfoort. For season 2008, the corresponding cultivars changed to Nudosa, Sharsheret, Robusta, Roly Poly and Ficus Indice, respectively.

Scaling (p ≤ 0.0001), rotation (p ≤ 0.0001) and translation (p ≤ 0.0001) transformations used by the GPA analysis were all significant. These transformations, performed by the GPA, corrected the differences between the individual assessor’s judgements (Arnold and Williams, 1986) as follows: the rotation step corrected the differences in terms used (the interpretation effect); the translation step corrected the level effect; and the isotropic scaling step corrected the range effect.

According to the eigen values (% by which variation is explained in a plot), 75.34 % of the variation was explained by dimension 1, and 7.44 % of the variation by dimension 2 (Figure 1). The first two factors allowed a representation of 82.78 % of the initial variability of the data. This figure also shows the importance of every factor on its own, as well as the accumulating values. Although 82.78 % is a fair result, the plots which follow
should be interpreted with care, as some information might be hidden in the next factors. For the purpose of this publication, only dimensions 1 and 2 will be discussed.

Table 1. List of the idiosyncratic descriptors developed by ten semi-naïve panelists to describe the taste attribute of 34 cactus pear cultivars, as well as their frequency of use for seasons 2007 and 2008.

<table>
<thead>
<tr>
<th>Descriptor</th>
<th>Frequency of use for season 2007</th>
<th>Frequency of use for season 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Sweet</td>
<td>390</td>
<td>390</td>
</tr>
<tr>
<td>2.Sour</td>
<td>209</td>
<td>202</td>
</tr>
<tr>
<td>3.Bitter</td>
<td>188</td>
<td>202</td>
</tr>
<tr>
<td>4.Fruity</td>
<td>142</td>
<td>248</td>
</tr>
<tr>
<td>5.Cucumber</td>
<td>114</td>
<td>79</td>
</tr>
<tr>
<td>6.Prickly pear</td>
<td>97</td>
<td>171</td>
</tr>
<tr>
<td>7.Salty</td>
<td>63</td>
<td>71</td>
</tr>
<tr>
<td>8.Banana</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>9.Grassy</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>10.Waterly</td>
<td>43</td>
<td>57</td>
</tr>
<tr>
<td>11.Watermelon</td>
<td>25</td>
<td>85</td>
</tr>
<tr>
<td>12.Pear</td>
<td>19</td>
<td>83</td>
</tr>
<tr>
<td>13.Rubber/plastic</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>14.Astringent</td>
<td>15</td>
<td>92</td>
</tr>
<tr>
<td>15.Vegetable</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>16.Melon</td>
<td>9</td>
<td>47</td>
</tr>
<tr>
<td>17.Pungent</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>18.Raw potato</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>19.Metallic</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>20.Beetroot</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>21.Kiwi fruit</td>
<td>4</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 2. Attributes that was most commonly used with specific cultivars.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Cultivar 2007</th>
<th>Cultivar 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet</td>
<td>Fresno</td>
<td>Nudosa</td>
</tr>
<tr>
<td>Sour</td>
<td>Robusta</td>
<td>Sharsheret</td>
</tr>
<tr>
<td>Bitter</td>
<td>Robusta</td>
<td>Robusta</td>
</tr>
<tr>
<td>Fruity</td>
<td>Sharsheret</td>
<td>Roly Poly</td>
</tr>
<tr>
<td>Prickly pear</td>
<td>Malta and Amersfoot</td>
<td>Ficus Indice</td>
</tr>
</tbody>
</table>

Table 3 lists the descriptors which had significant correlations with the two dimensions of average space generated by GPA. The first principal component was positively correlated (2007) with “cucumber”, the only descriptor to coincide with a value higher than 0.5. The descriptors “sweet”, “bitter”, “fruity”, “astringent”, “watermelon”, “prickly pear”, “melon”, “watery” and “pear” were negatively correlated (2008) to the first component (values ≥ 0.5). No descriptors had values ≥ 0.5 and were positively correlated with the second dimension (34 cultivars). “Bitter”, “pungent”, “raw potato”, “beetroot” and “vegetable” were negatively correlated with the second dimension (Robusta and Monterey).

Figure 2 is the GPA biplot of the FCP of 34 cultivars for the taste attribute, of 2007 (A) and 2008 (B). From this biplot, it was clear that the assessors could clearly distinguish between the two seasons 2007 and 2008 (75.34 %). The 34 cultivars from season 2007 were all situated to the right side of the figure, with season 2008 to the left side. The two cultivars used mainly for animal feed, Robusta and Monterey, were placed at the bottom right side and were characterized by descriptors “sour”, “pungent”, “vegetable”, “bitter”, “beetroot” and “raw potato”. Only 7.44 % of the variation was explained by dimension 2, referring to the descriptors used to describe “Robusta” and “Monterey”. The assessors were not successful in distinguishing between the other cultivars.
Figure 1. Scree plot of eigen values of FCP for the taste attribute done on 34 cultivars of cactus pears for season 2007 and 2008.

Table 3. Descriptors having significant correlations with the two dimensions of average space generated by GPA, for the taste attribute of 34 cultivars of cactus pears for season 2007 and 2008.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Correlation</th>
<th>Descriptors with values ≥ 0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+ 2007</td>
<td>Cucumber</td>
</tr>
<tr>
<td></td>
<td>- 2008</td>
<td>Sweet, bitter, fruity, astringent, watermelon, prickly pear, melon, watery, pear</td>
</tr>
<tr>
<td>2</td>
<td>+ 34 cultivars</td>
<td>Bitter, pungent, raw potato, beetroot, vegetable</td>
</tr>
<tr>
<td></td>
<td>- Robusta and Monterey</td>
<td></td>
</tr>
</tbody>
</table>

**Pearson correlation coefficients and significance levels**

Since part of the aim of the study was to investigate if a relationship existed between the physico-chemical quality and sensory quality, an attempt was made to correlate the physico-chemical parameters with that of the sensory attributes obtained by FCP. Pearson significance levels, as well as correlation coefficients were determined. The correlation coefficients between the physico-chemical parameters and the taste attributes are indicated in Table 4. The first column of each attribute explains the type of correlation, i.e. positive or negative, as well as the % of correlation.

A positive correlation means that when the levels of one parameter increases, the level of the other parameter (or attribute) will increase as well, while a negative correlation implies that when the level of one attribute increases, the level of the other parameter will decrease.

According to Table 4, the correlations that were significant at p < 0.05, were: the correlation between the taste attribute “bitter” and the physico-chemical parameter fruit mass (positive correlation); “fruity” and pulp pH (positive correlation); “sour” and % pulp TA (positive correlation); “sweet” and pulp glucose (positive correlation); and “sweet” and pulp fructose (positive correlation).
Figure 2. Generalized Procrustes Analysis biplot of FCP for descriptors of the taste attribute of 34 cultivars for seasons 2007 and 2008.

Table 4. Pearson correlation coefficients and statistical significance levels between taste attributes and physical/chemical parameters

<table>
<thead>
<tr>
<th>Physico-Chemical parameters</th>
<th>Sweet</th>
<th>Bitter</th>
<th>Sour</th>
<th>Peppy</th>
<th>Prickly pear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit mass (g)</td>
<td>0.1390</td>
<td>NS</td>
<td>0.2656</td>
<td>*</td>
<td>-0.0991</td>
</tr>
<tr>
<td>% pulp</td>
<td>-0.3561</td>
<td>**</td>
<td>-0.5728</td>
<td>***</td>
<td>0.2080</td>
</tr>
<tr>
<td>°Brix</td>
<td>0.2059</td>
<td>NS</td>
<td>-0.0905</td>
<td>NS</td>
<td>-0.3465</td>
</tr>
<tr>
<td>Pulp pH</td>
<td>0.3227</td>
<td>**</td>
<td>0.1969</td>
<td>NS</td>
<td>-0.2453</td>
</tr>
<tr>
<td>% pulp TA</td>
<td>-0.2167</td>
<td>NS</td>
<td>0.1083</td>
<td>NS</td>
<td>0.2592</td>
</tr>
<tr>
<td>Pulp glucose g/100 g</td>
<td>0.2477</td>
<td>*</td>
<td>0.0784</td>
<td>NS</td>
<td>-0.0688</td>
</tr>
<tr>
<td>Pulp fructose g/100 g</td>
<td>0.2636</td>
<td>*</td>
<td>-0.1329</td>
<td>NS</td>
<td>-0.1153</td>
</tr>
</tbody>
</table>

Keys: NS= Not Significant; *= significant at p < 0.05; **= significant at p < 0.01; ***= significant at p < 0.001; TA=Titratable Acid.
The correlations that were significant at $p < 0.01$, were: the correlation between the taste attribute “sweet” and the physico-chemical parameter % pulp (negative correlation); “prickly pear” and % pulp (negative correlation); “sour” and °Brix (negative correlation); “prickly pear” and pulp pH (positive correlation); and “sweet” and pulp pH (positive correlation) (Table 4).

The correlations that were significant at $p < 0.001$, were: the correlation between the taste attribute “fruity” and the physico-chemical parameter % pulp (negative correlation); and “bitter” and % pulp (negative correlation) (Table 4).

There was a positive correlation between the taste attribute “bitter” and the physico-chemical parameter of fruit mass (Table 4) at $p < 0.05$. According to Rothman et al. (2012), Robusta had the highest fruit mass value for both seasons 2007 and 2008, with a value of 186.04 g. The taste attribute “bitter” was more likely given to Robusta by the taste panel (Table 2). “Bitter” is defined as the taste associated with caffeine (Heymann, 1995).

There was a positive correlation at $p < 0.05$ for the taste descriptor “fruity” and pulp pH. “Fruity” was frequently used by the panel during both seasons (Table 1). Because a FCP panel was used and no definition for the term “fruity” was available, it was decided to use a general definition. According to the Cambridge Advanced Learners Dictionary (2008), “fruity” refers to a smell or taste of fruit. Fruits are usually associated with sweet and sour tastes and smells, therefore, acidity and sugars will play major roles (Beaulieu and Baldwin, 2002). Sharsheret was characterized by the panel during season 2007 as being fruity and Roly Poly during season 2008 (Table 2). Pulp pH for Roly Poly was 5.46 (Rothman et al., 2012). The average pH of a cactus pear fruit should be 5.3-7.1 at the time of harvest (Saenz and Sepulveda, 2001). According to Rothman et al. (2012), percentage TA for Roly Poly 2008 was 3.36 %, which was relatively low and corresponded with the high pH. Pulp fructose (29 mg/g), pulp glucose (26.33 mg/g) and °Brix (11.93) were in the range reported for production potential (Gregory et al., 1993). However, Roly Poly is not one of the top nine cultivars consumed in South Africa (Fouche, 2009), showing that the descriptor “fruity” is not an indication of consumer acceptability.

Percentage pulp TA had a positive correlation with the taste descriptor “sour” (Table 4). Sour is defined as the taste associated with tartaric acid (Heymann, 1995). As mentioned in the previous discussion, sourness is a fundamental taste characteristic of many fruits. In the 2007 season, the panel associated the term “sour” with Robusta, with a % pulp TA of 14.68, and a very low pH of 4.3 (Rothman et al., 2012). The following season (2008), Robusta again was the cultivar associated with sourness (Table 2). However, % pulp TA for this season was 2.69 and the pH was 6.29 (Rothman et al., 2012), which was in contrast to the physico-chemical finding of the previous season and the panel. This can be explained by the fact that for season 2008, the °Brix value was very low (8.43) compared to the values of the rest of the cultivars of season 2008 (Rothman et al., 2012), which could be due to the high rainfall in this season, resulting in the dilution of sugars and acids (De la Barrera and Nobel, 2004).

The descriptor “sweet” had a positive correlation with pulp glucose at $p < 0.05$ (Table 4). A definition for “sweet” is the taste of sucrose in water (Heymann, 1995). Like mentioned earlier, “sweet” is characteristic and often most important for fruit quality (Inglese et al., 1995). During the 2007 season, Fresno was most frequently associated with this descriptor by the panel and had a °Brix of 13.8 (Rothman et al., 2012). Pulp glucose was very high at 44.68 mg/g (Rothman et al., 2012). Nudosa was the panel’s most frequently associated cultivar for 2008 for this descriptor (Table 2) and had a °Brix and pulp glucose content of respectively 9.63 °Brix and 53.00 mg/g (Rothman et al., 2012).

“Sweet” also had a positive correlation with pulp fructose at $p < 0.05$ (Table 4). The same cultivars as in the previous discussion were involved. For Fresno (2007), the pulp fructose was 29.67 mg/g and for Nudosa (2008),
it was 44.33 mg/g (Rothman et al., 2012). The reported pulp fructose values for cactus pears should be 5.4-6 % (54-60 mg/g) (Gurrieri et al., 2000). Along with the pulp glucose and °Brix, the total effect was achieved of a very sweet taste.

At p < 0.01, a negative correlation between “sweet” and % pulp was observed (Table 4). Fresno (2007) had a very low % pulp at 49.25, while Nudosa (2008) had a pulp content of 43 % (Rothman et al., 2012). Degrees Brix for Fresno was 13.8 and 9.63 for Nudosa, the latter, being very low. In 2007 there was less rainfall, resulting in sweeter fruit (Rothman et al., 2012).

A negative correlation existed between the descriptor “prickly pear” and % pulp at p < 0.01 (Table 4). The descriptor is not easy to define and it can just be said that it is a flavor associated with cactus pear which is melon-like (Saenz, 2000). Like in the case of “fruity”, sourness and sweetness would play an important role. The correlation between “sweet” and % pulp has already been discussed in the previous paragraph and it was decided that sourness in this case was not applicable.

The taste descriptor “sour” and °Brix had a negative correlation at p < 0.01 (Table 4). In the discussion on the positive correlation of “sour” with % pulp TA, it was already mentioned that Robusta (2007) had a very low °Brix of 10.6 and a very high % TA of 14.68 % (Rothman et al., 2012), resulting in extreme sourness.

“Prickly pear” had a positive correlation with pulp pH at p < 0.01 (Table 4). As suggested earlier, this descriptor is strongly associated with the descriptor “sweet”. Fresno (2007) had a pulp pH of 5.34, while Nudosa (2008) had a pulp pH of 6.79, which was relatively high (Rothman et al., 2012). Fresno had a high °Brix (13.8), while the glucose was 44.67 mg/g, which also was very high. On the other hand, Nudosa’s °Brix was relatively low, but the glucose was very high (53.00 mg/g) (Rothman et al., 2012).

“Fruity”, or “sweet” and “sour”, as previously explained, was negatively correlated with % pulp at p < 0.01 (Table 4). The correlation between “fruity”/“sweet” has already been discussed. Robusta can be used as an example to explain this finding. Robusta (2007) had a % pulp of 45, a pH of 4.3 and a % pulp TA of 14.68 (Rothman et al., 2012). The overall average values for these parameters for 2007 were 52.66 for % pulp, 5.92 for pulp pH and 6.08 for % TA. These values indicated that Robusta (2007) had a lower than average % pulp and pH, and a higher than average % TA value (Rothman et al., 2012).

A negative correlation existed between the descriptor “bitter” and % pulp (Table 4). “Bitter” is defined as the taste associated with caffeine (Heymann, 1995). Robusta 2007 and 2008 had a pulp % of 45.27 and 45.84, respectively. The low °Brix of 10.6 (2007) and 8.43 (2008), along with the low glucose (36.67 / 23.33 mg/g) and fructose values (16.67 / 26.00 mg/g) (Rothman et al., 2012), explain the high values of bitterness indicated by the panel.

Nudosa (2008) was most frequently correlated with the descriptor “sweet” by the panel (Table 2) and also had the higher pulp glucose (53 mg/ml) and pulp fructose (44.33 mg/g) (Rothman et al., 2012). Van As had the lowest pulp TA of 1.82 % in 2008. The others, Meyers, Morado, Malta, Algerian and Gymno Carpo had rather mediocre average values for the two seasons for pulp glucose and pulp fructose: 34.8 / 36.13 mg/g pulp glucose (2007/2008) and 25.2/28.47 mg/g pulp fructose (2007/2008) (Rothman et al., 2012).

**Conclusions**

Sensory analysis data on cactus pear fruit and cladodes is limited, but product development carried out on cactus pear fruit has become more popular and food scientists are more interested in this nutritious fruit. In this study, sensory analysis was used to distinguish among agricultural seasons 2007 and 2008. The five most frequently used attributes were sweet, sour, bitter, fruity and prickly pear, with the corresponding cultivars for 2007 being Fresno, Robusta, Sharsheret, Malta and Amersfoort. For season 2008, the corresponding cultivars changed to Nudosa, Sharsheret, Robusta, Roly Poly and Ficus Indice, respectively. The sensory data were supported by
chemical composition and findings were that a positive correlation at p < 0.05 for the taste descriptor “fruity” and pulp pH was observed. Fruits are usually associated with sweet and sour tastes and smells, therefore, acidity and sugars will play major roles which influence the pH (Beaulieu and Baldwin, 2002).

*Opuntia robusta* had a significant influence when attempting the correlation of the chemical data with the sensory analysis and influenced the following findings: a positive correlation between the taste attribute “bitter” and the chemical parameter fruit mass at p < 0.05; percentage pulp TA had a positive correlation with the taste descriptor “sour” (p < 0.05); the taste descriptor “sour” and °Brix had a negative correlation at p < 0.01; a negative correlation existed between the descriptor “bitter” and % pulp (p < 0.001).

Fresno and Nudos had significant influence when attempting the correlation between the chemical data - pulp glucose, pulp fructose, % pulp and the sensory attributes sweet, fruity and prickly pear in the following findings: the descriptor “sweet” had a positive correlation with pulp glucose and fructose at p < 0.05; a negative correlation at p < 0.01 between the taste attributes “prickly pear” and “sweet” and % pulp was observed; “prickly pear” had a positive correlation with pulp pH at p < 0.01.

This study indicated that there were sensory quality differences between the cultivars. Season had a definite influence on sensory fruit quality parameters: Prominent interactions between seasons and cultivars, namely cultivar X season interactions were observed.

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**References**


