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

Rothman, M.; de Wit, M.; Bothma, C.; and Hugo, A.

Department of Microbial, Biochemical and Food Biotechnology
University of the Free State, PO Box 339, Bloemfontein, 9300, South Africa

*Corresponding author, e-mail: dewitm@ufs.ac.za

Received 5th June, 2012; Accepted 23th November, 2012

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-Samahay *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, Muscatel, 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 ºC 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 Generalyzed 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; Oreskovich *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 manupilate data (Gower, 1975; Schlich, 1989; Oreskovich *et al.*, 1991). 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 ($p \leq 0.0001$), rotation ($p \leq 0.0001$) and translation ($p \leq 0.0001$) 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.

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

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

Attribute	Cultivar 2007	Cultivar 2008
Sweet	Fresno	Nudosa
Sour	Robusta	Sharsheret
Bitter	Robusta	Robusta
Fruity	Sharsheret	Roly Poly
Prickly pear	Malta and Amersfoot	Ficus Indice

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 $\geq$ 0.5). No descriptors had values $\geq$ 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.

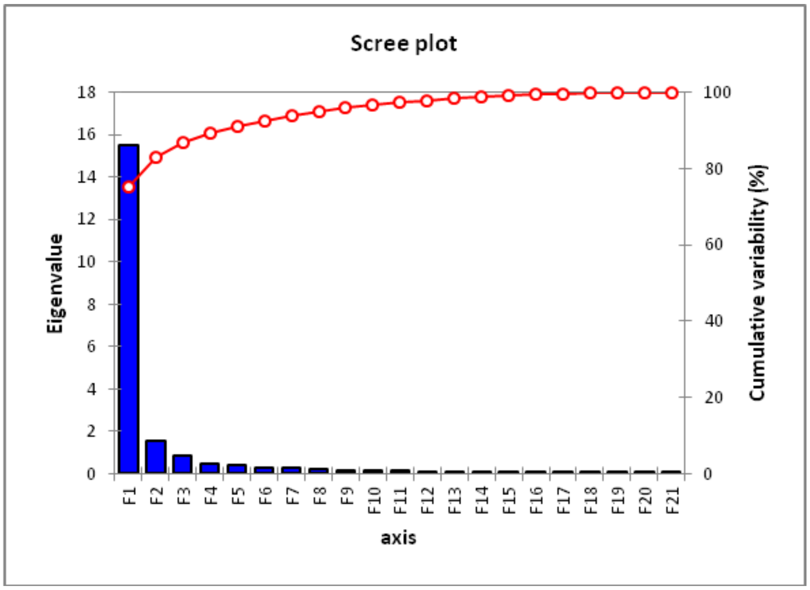

Figure 1. Scree plot of eigen values of FCP for the taste attribute done on 34 cultivars of cactus pears for season 2007 and 2008.

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.

Dimension	Correlation	Descriptors with values ≥ 0.5
1	+ 2007	Cucumber
	- 2008	Sweet, bitter, fruity, astringent, watermelon, prickly pear, melon, watery, pear
2	+ 34 cultivars	
	- Robusta and Monterey	Bitter, pungent, raw potato, beetroot, vegetable

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).

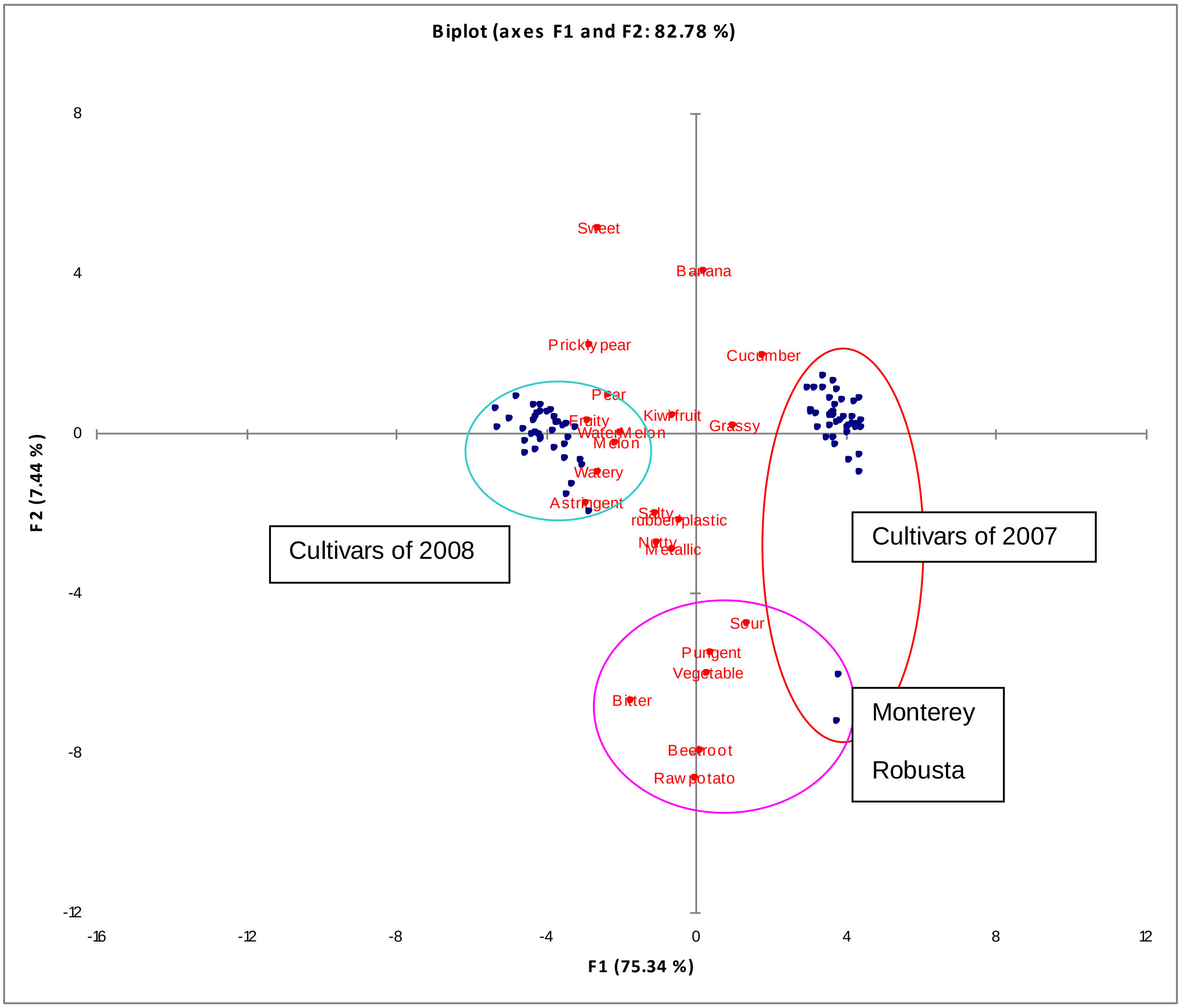

Figure 2. Generalized Procrustes Analysis biplot of FCP for descriptors of the taste attribute of 34 cultivars for seasons 2007 and 2008.

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

Physico-Chemical parameters	Sensority attributes									
	Sweet		Bitter		Sour		Fruty		Prickly pear	
Fruit mass (g)	0.1390	NS	0.2656	*	-0.0991	NS	0.2117	NS	0.1647	NS
% pulp	-0.3561	**	**-0.5728**	***	0.2080	NS	**-0.5213**	***	-0.4259	**
°Brix	0.2059	NS	-0.0905	NS	-0.3465	**	0.1689	NS	0.2142	NS
Pulp pH	0.3227	**	0.1969	NS	-0.2453	NS	0.2921	*	0.3547	**
% pulp TA	-0.2167	NS	0.1083	NS	0.2592	*	-0.1904	NS	-0.1575	NS
Pulp glucose g/ 100 g	0.2477	*	0.0784	NS	-0.0688	NS	0.2386	NS	0.2431	NS
Pulp fructose g/100 g	0.2636	*	-0.1329	NS	-0.1153	NS	0.1624	NS	0.1740	NS

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). Sensory analysis on the juice of *Opuntia robusta* was carried out with untrained panelists by Gurrieri *et al*. (2000). The results showed that 65.9 % of the panelists found the juice unacceptable for its insipid taste and the presence of vegetable aroma. It must also be kept in mind that Robusta, from the genus *Opuntia robusta*, is mainly cultivated for animal fodder production (Snyman, 2006).

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 Nudosa 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.

Acknowledgements

The authors would like to thank Dr. Herman Fouche and the ARC for providing the cactus pear fruit, as well as the NRF and UFS Strategic Research Cluster 4 for funding.

References

Arnold, G.M., Williams, A.A. 1986. The use of Generalized Procrustes technique insensory analysis. In: J.R. Piggott, Statistical Procedures in Food Research. London: Elsevier Applied Science, p. 233-255.

Avenant, P., Fouche, H.J. 2008. Agricultural Research Council (ARC) of South Africa. Personal Communication.

Ayadi M.A., W. Abdelkaksoud, M. Ennouri, and H. Attia. 2009. Cladodes from *Opuntia ficus-indica* as a source of dietary fiber: Effect on dough characteristics and cake making. Industrial Crops and Products, p. 40-47.

Bealieu, J.C., Baldwin, E.A. 2002. Flavor and aroma of fresh-cut fruits and vegetables. In: Lamikanra O. (ed.), *Fresh-Cut Fruits and Vegetables. Science, Technology and Market*. Boca Raton, FL: CRC Press, p. 391-425.

Bothma, C., Frey, R., De Wit, M., HUGO, A. 2010. Evaluation of the suitability of cactus pear fruit for jelly making. Combined Congress of South African Society of Crop Production, Soil Science Society of South Africa, Southern African Society for Horticultural Sciences and Southern African Weed Science Society. Bloemfontein, South Africa, January 19-21.

Cambridge Advanced Learner's Dictionary. 2008. 3rd ed. Cambridge University Press.

De La Barerra, E., Nobel, P.S. 2004. Carbon and water relations for developing fruits of *Opuntia ficus-indica (*L.) Miller, including effects of drought and gibberellic acid. The Journal of Experimental Botany 55: 719-729.

Deliza, R. 2004. The consumer sensory perception of passion-fruit juice using free-choice profiling. Journal of Sensory Studies 20: 17-27.

Del-Valle, V., Hernández-MuŇoz, P., Guarda, A., Galotto, M.J. 2005. Development of a cactus-mucilage edible coating (*Opuntia ficus-indica*) and its application to extend strawberry (*Fragaria ananassa*) shelf-life. Journal of Food Chemistry 91(4): 751-756.

De Wit. M., Nel, P., Osthoff, G., Labuschagne, M.T. 2010. The effect of variety and location on cactus pear (*Opuntia ficus-indica*) fruit quality. Plant Foods for Human Nutrition 65(2): 136-145.

El-Samahy, S.K, Abd El-Hady, E.A., Habiba, R.A., Moussa-Ayoub, T.E. 2007. Some Functional, Chemical, and Sensory Characteristics of Cactus Pear Rice-Based Extrudates. Department of Food Technology, Faculty of Agriculture, Suez Canal University, 41522, Ismailia, Egypt, p. 136-147.

El-Samahy, S.K, El-Mansy, H.A, Bahlol, H.E, El-Desouky, A.I., Ahmed, A.E. 2008. Thermal Process Time and Sensory Evaluation for Canned Cactus Pear Nectar. Food Technology Department Faculty of Agriculture Suez Canal University, Egypt, p. 85-96.

El-Samahy, S.K., Youssef, K.M., Moussa-Ayoub, T.E. 2009. Producing ice cream with concentrated cactus pear pulp: A preliminary study. Department of Food Technology, Faculty of Agriculture, Suez Canal University, 41522, Ismailia, Egypt, p. 1-8.

Fouche, H. 2009. President of the South African Cactus Network. Personal communication.

Gower, J.C. 1975. Generalized Procrustes analysis. *Psychometrika*, 40, p. 33-50.

Gregory, R.A., Kuti, J.O., Felker, P. 1993. A comparison of *Opuntia*fruit quality and winter hardiness for use in Texas. Journal of Arid Environments 24: 37-46.

Gurrieri, S., Miceli, L., Lanza, C.M., Tomaselli, F., Bonomo, R.P., Rizzarelli, E. 2000. Chemical characterization of Sicilian Prickly Pear (*Opuntia ficus-indica*) and Perspectives for the Storage of Its Juice. Journal of Agricultural and Food Chemistry 48: 5424-5431.

Hauser J.R., Koppleman, F.S. 1979. Alternative perceptual mapping techniques: Relative accuracy and usefulness. Journal of Marketing Research, 16: 495-506.

Heymann, H. 1995. 3-day Advanced Sensory Analysis Workshop, April. ANPI. Irene. South Africa, p. 19-21.

Inglese, P., Barbera, G., La Mantia, T., 1995. Research strategies and improvement of cactus pear (*Opuntia ficus-indica*) fruit quality and production. Journal of Arid Environments 29: 455-468.

Jack, F.R. 1994. Perception of Texture in Cheddar Cheese. Unpublished Ph.D. Thesis, University of Strathclude, United Kingdom.

Lawless, H.T.. Heymann, H. 1998. Free-choice profiling. In: *Sensory Evaluation of Food, Principles and Practices*. New York: Chapman & Hall. p.368-373.

Livrea, M.A., Tesoriere, L. 2006. Health Benefits and Bioactive Components of the fruits from *Opuntia ficus-indica* [L.] Mill. Journal of the Professional Association of Cactus Development 8: 73-90.

Mestrallet, M.G., Nepote, V, Quiroga, P.R., Grosso, N.R. 2009. Effect of prickly Pear (*Opuntia ficus-indica*) and algarrobo (*Prosopis spp*.) pod syrup coatings on the sensory and chemical stability in roasted peanut products. Journal of Food Quality 32: 334-351.

Ntsane, S.M. 2008. Fruit yield and quality of cactus pear (Opuntia spp.) cultivars in Central Free State. Department of Soil, Crop and Climate Sciences. Faculty of Natural and Agricultural Sciences. University of the Free State, p. 1,6.

Oreskovich, D.C., Kiein, P.B., Sutherland, J.W. 1991. Procrustes analysis and its application to free-choice and other sensory profiling. In: *Sensory Science Theory and Applications in Foods.* (H.T. Lawless and B.P. Klein (Eds.), Marcel Dekker, Inc., New York. p. 353-393.

Potgieter, J.P. 2000. Riglyne vir die verbouing van doringlose turksvye vir vrugteproduksie. 4 de hersiene uitgawe. Groep 7 Drukkers en Uitgewers BK. Sinoville. 15 pp.

Retamal, N., Duran, J.M., Fernandez, J. 2006. Ethanol production by fermentation of fruits and cladodes of prickly pear cactus [*Opuntia ficus-indica* (L.) Miller]. Journal of the Science of Food and Agriculture 40(3): 213-218.

Rothman, M., De Wit, M., Hugo, A., Fouche, H.J. 2012. The influence of variety and season on cactus pear (*Opuntia ficus-indica*) fruit quality. Acta Horticulturae, accepted.

Rubico, S.M., Mcdaniel, M.R. 1992. Sensory evaluation of acids by free-choice profiling. Chemical senses 17(3): 273-289.

Ruiz-Perez-Cacho, Galan-Soldevilla, H., Corrales García, J., Hernandez Montes, A. 2006. Sensory Characterization of Nopalitos (*Opuntia* spp.). Food Research International 39: 285-293.

Saenz C., and Sepulveda E. 2001. Cactus-Pear Juices. Journal of the Professional Association of Cactus Development 4: 3-10.

Saenz, C. 2000. Processing technologies: an alternative for cactus pear (*Opuntia* spp.) fruits and cladodes. Journal of arid environments 46: 209-225.

Schlich, P. 1989. A SAS/IML program for generalized Procrustes analysis. SEUGI’ 89. Proceedings for the SAS European Users Group International Conference, Cologne, Germany, May 9-12, 1989

Snyman, H.A. 2006. Root distribution with changes in distance and depth of two-year-old cactus pears *Opuntia ficus-indica* and *O. robusta* plants. South African Journal of Botany 72(3): 434-441.

Swart, P.Z., De Wit, M., Bothma, C., Hugo, A. 2009. The influence of different heat treatments on the sensory aspects of juices from eight cactus pear cultivars. 4th Africa Congress of the International Federation of Home Economics. Swaziland. September, 22-25.

Williams, A., Langron, S. 1984. The use of free-choice profiling for the evaluation of commercial ports. Journal of Food and Agriculture 35: 558-568.

XLSTAT Version 2007. 2. Addinsoft SARL 40, rve Damrémut, 75018. Paris, France.