QUANTITATIVE DESCRIPTIVE SENSORY ANALYSIS OF FIVE DIFFERENT CULTIVARS OF SWEET POTATO TO DETERMINE SENSORY AND TEXTURAL PROFILES

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ABSTRACT

A trained sensory panel was used to establish terminology for describing the sensory attributes of different cultivars orange-fleshed sweet potato (OFSP) and white-fleshed sweet potato (WFSP). Quantitative descriptive analysis was applied to evaluate the samples in terms of the aroma, texture, flavor and aftertaste attributes. Thirteen attributes were identified. Principal component analysis (PCA) was applied to identify any factors differentiating between the sweet potato cultivars. The findings indicated that the main differences were, in PC1, the flavor and density and adhesive textural characteristics, and, in PC2, the grainy and firm textural characteristics of the different cultivars. OFSP displayed a more dense and pasty texture, which was most intense in the Resisto cultivar. W119 had a more grainy texture when compared with the other cultivars tested. WFSP was more moist and fibrous. Therefore, OFSP differed in color, was sweeter and displayed flavor characteristics of yellow vegetables (such as butternut and pumpkin) when compared with WFSP.

PRACTICAL APPLICATIONS

Although standard sensory evaluation techniques were used in this project, the materials used were sweet potatoes, which are of interest. Sweet potato is a root vegetable, and in this project, a lexicon for the textural

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properties, as well as a flavor profile of sweet potato, was developed. Such information can be used for sensory evaluation of other root vegetables. The shear force of the sweet potatoes was measured, and the methodology to determine shear forces and its contribution to the overall evaluation of the texture of sweet potatoes is included in the article. Furthermore, white-fleshed sweet potatoes are commonly known, and the flavor of WFSP is compared with that of orange-fleshed sweet potatoes.

INTRODUCTION

Sweet potato is an important food crop in many parts of the world. Good yields are obtained when conditions such as rain, soil and climatic conditions are optimal. The storage roots contain large quantities of energy and substantial amounts of some vitamins and minerals (Laurie 2004 in Niederweiser). Currently, most South African cultivars have a white to light creamy-yellow flesh color, and the OFSP is relatively unknown. The Agricultural Research Council (ARC)-Roodeplaat Vegetable and Ornamental Plant Institute has a comprehensive sweet potato breeding program, which includes white-fleshed sweet potato (WFSP) and orange-fleshed sweet potato (OFSP). To date, at least 22 cultivars have been released by the program, and more cultivars will be released in the future. Beta-carotene rich OFSP is being introduced in South Africa and is becoming an important food crop in sub-Saharan Africa. It plays a significant role in resource-poor farming as a food security crop (Laurie and Niederwieser 2004 in Niederwieser), especially for its contribution to vitamin A intake. It is estimated that in sub-Saharan Africa, vitamin A deficiency contributes up to 25.1% to child mortality due to related diseases such as malaria, diarrheal diseases, acute respiratory infections, vaccine preventable diseases, as well as low weight-for-age (Black *et al.* 2003; Caulfield *et al.* 2004). OFSP has been successfully introduced into gardening projects in South Africa such as the Ndunakazi project in KwaZulu Natal, which showed success in improving vitamin A intake (Faber *et al.* 2002b), and, ultimately, the vitamin A status (Faber *et al.* 2002a) of children in population groups at risk of vitamin A deficiency.

However, little or no work has been done to determine the sensory acceptability of new cultivars that have shown potential for release to farmers and secondary nurseries in order for OFSP to be produced for the commercial market. Different cultivars OFSP are planted in various regions, and cultivar differences in flavor and texture may influence the taste acceptability. Quantitative descriptive analysis (QDA) can be used to measure significant differences between sensory descriptors/attributes for the flavor and textural components of WFSP and OFSP, as well as between different cultivars of OFSP.

Descriptive analysis has successfully been used to obtain detailed descriptions of the aroma, flavor and oral texture of foods and beverages. Samples are evaluated for a number of attributes by a trained panel (Lea *et al.* 1998). This provides an objective measure of the sensory quality of food products (Alvarez and Blanco 2000). The sensory profiles or pictures obtained can be used in product development and manufacturing, and is of particular use to nutritionists and food scientists who are interested in the development of food and beverage products (Woods 1998). These include activities such as the development of standards for quality control purposes, documenting product attributes before consumer testing to help select attributes for inclusion in the consumer questionnaire, helping explain results of consumer tests, as well as tracking sensory changes and reformulation of existing products due to ingredient changes (Meilgaard *et al.* 1991; Lawless and Heymann 1998).

Developing a lexicon for sensory testing of a product is a critical step in the research process. QDA is a time-consuming process. However, when applied to promising cultivars before release to nurseries or farmers, it can provide invaluable information regarding potential rejects and reasons for rejection by consumers (Van Oirschot *et al.* 2002). Obviously, many other factors also determine the success of a new cultivar in the market place, such as the dry matter content (texture), the yield (economic factor) or pest resistance. Product expectation generated by marketing messages through the media or packaging could further influence the success of a product in the market place (Wright *et al.* 2001).

The aims of this study were two pronged: first, to establish defined terminology for describing the sensory attributes (textural, aroma, flavor and aftertaste) of OFSP, and, second, to compare the sensory profiles of the different cultivars OFSP with each other, as well as with WFSP.

MATERIALS AND METHODS

Sample Selection

Five sweet potato cultivars were included in the project. Beauregard, Kano, W119 and Resisto cultivars OFSP and Blesbok cultivar WFSP were selected for the study at the request of the ARC-Roodeplaat. They required the analysis of various cultivars OFSP in terms of its sensory characteristics, as well as consumer acceptability, as compared with WFSP in order to be able to identify promising cultivars that are acceptable in taste to the South African consumer. Cultivars were selected as follow: Resisto cultivar OFSP was included in the study because it has the highest beta-carotene level of the cultivars introduced in South Africa. Resisto was previously used in a clinical trial by Van Jaarsveld *et al.* (2005), where it showed that beta-carotene rich OFSP contributed to the intake of vitamin A carotenoids by children, and has the potential to limit vitamin A deficiency in developing countries. Beauregard cultivar OFSP was included in the study, as it has been identified for commercialization in South Africa. Kano and W119 cultivars OFSP were included, as they have shown potential in terms of yield, taste and pest resistance. Blesbok cultivar WFSP has a cream flesh color and a purple skin (Laurie 2004), and is one of the most commonly consumed WFSP that is freely available on the market.

The sweet potatoes were harvested at the ARC-Roodeplaat and transported on the same day to the sensory laboratory of the ARC-Irene, where they were stored in a cool room. They were harvested at the end of the growing season (July 2006). As sweet potatoes vary in size and shape, samples that were similar in shape and weight were selected for the study. The average weight of the raw samples ranged between 250–350 g each, and each day, approximately 800 g of the different cultivars was cooked (three to four sweet potatoes). The training of panelists commenced 3 days after harvesting and the final sensory evaluation in the booths took place immediately after a 4-day training session. All the samples received the same treatment for storage and cooking throughout the project.

Selection of Trained Panel

Ten trained and experienced panel members were selected to participate in the development of sensory profiles for the five different cultivars of sweet potato. They were chosen based on their ability to provide similar responses to similar products on repeated occasions, smell acuity, interest in the project and availability for the duration of the study. In order to ensure that panelists were not influenced in any way, no information with regard to the nature of the samples was provided. Panelists were reminded not to use perfumed cosmetics and to avoid exposure to foods and/or fragrances at least 30 min before evaluation sessions.

Training Sessions

Panelists were exposed to 2-h training sessions on 4 consecutive days in order to develop a clear definition for each attribute identified for the different cultivars. Panelists each received a representative sample of the sweet potatoes and were trained to increase their sensitivity and ability to discriminate between the sensory attributes of the different cultivars. Descriptors and definitions (lexicon) of the characteristics of five different sweet potato cultivars were developed by the panelists. Reference books were used to guide the researcher to formulate suitable definitions for each attribute (Civille and Lyon 1996; Thybo and Martens 1998).

Scaling and Score Sheet

An 8-point category scale was used to measure the intensity of each sensory attribute (aroma, texture, flavor and aftertaste) for the different sweet potato cultivars. One (1) on the category scale denoted the least intense condition (e.g., no sweet potato aroma) and eight (8) denoted the most intense condition (e.g., extremely intense sweet potato aroma [refer to Table 1]).

Sample Preparation

The sweet potatoes were first washed and then scrubbed to remove any soil or dirt present and then placed into 2-L stainless steel saucepans, covered with 1–1.3 L boiling water and boiled in their skins. Sweet potatoes were boiled for approximately 45 min with a lid on the saucepan to prevent excessive moisture loss. The water was replenished when required to ensure that it covered the sweet potatoes. It was observed that the cooking time varied slightly between the different cultivars. The sweet potatoes were cooked until soft and a core temperature of 94C was reached, which was tested by inserting a hand-held digital stainless steel probe (Kane May C9003), equipped with a K-type thermocouple (Digi-Sense®, Cole Parmer, Vernon Hills, IL) to record the internal temperature at the geometrical center of the sweet potato. Sweet potatoes were removed from the saucepan and allowed to cool slightly before being used for sensory evaluation.

Serving Procedure

Figure 1 is a graphical representation of the sweet potato sample as served to the panel. A portion of the sweet potato in the skin was served to the panel members for evaluation. Sweet potatoes were sliced into 20-mm slices and halved to form small half-circle portions weighing approximately 40 g each. Each portion was wrapped in aluminum foil with the shiny side in, and coded with a random three-digit code. Samples were placed in heated glass containers and kept warm at 60C in calibrated Miele ovens for 2–3 min before serving to the panel. The serving temperature was 40C. One cultivar was served at a time.

When served to the panel, a coded sample was placed on a heated side plate and served on a white plastic tray. Care was taken to ensure uniformity of each sample (volume served and serving temperature) and of each replication of the different samples. Samples were randomized to exclude any bias due to the position effect. A score sheet for the evaluation accompanied the sample. Panel members were provided with water at room temperature, which served as palate cleansers in between evaluation sessions.

All samples were evaluated by the trained panel according to the methods described in the Annual Book of the American Society for Testing and

TABLE 1.
LEXICON FOR DESCRIPTIVE SENSORY ANALYSIS OF FIVE DIFFERENT SWEET POTATO CULTIVARS

Attribute	Description
Aroma	
Earthy	Aromatic notes associated with damp soil, wet foliage or slightly undercooked potatoes.
Sweet potato	Aromatic associated with cooked sweet potato, typical of WFSP.
Burn	An aromatic associated with vegetables that were burnt while cooking.
Texture – initial impression: squeeze sweet potato lightly between fingers, holding it on the skin side	
Moistness	Hold sample between forefingers and evaluate the amount of wetness/juiciness released by the sample, which is visible when squeezing sample *lightly*.
Firm	Degree to which the sample retains its shape after lightly squeezing it.
First bite	
Denseness	The solidness/compactness of the sample.
Moistness	The amount of moistness/wetness of the sample in the mouth.
Mastication	
Fiber	Using a fork, gently break piece off sweet potato to observe fibers and then evaluate the amount of stringy fibers perceived in the mouth.
Adhesive (Stickiness/pasty)	The amount to which the sample sticks to any of the mouth surfaces such as teeth, gums or palate and is perceived as pasty.
Grainy	Use the tongue to press the sweet potato on to the palate. Degree to which surface is uneven, amount of graininess or roughness of particles on chewing.
Flavor	
Vegetable sweet	Taste characteristics of sweet vegetable varieties, such as sweet corn, sweet potato, butternut or sweet carrots.
Sweet potato	Flavor notes associated with the taste of cooked WFSP.
Yellow vegetables (Butternut, carrots, pumpkin)	Taste associated with yellow starchy vegetables such as butternut, pumpkin, carrots, and, to a lesser degree, squash.
Aftertaste	
Sweet	An aftertaste that leaves a sweetness on the tongue and in the mouth that is pleasant.

WFSP, white-fleshed sweet potato.

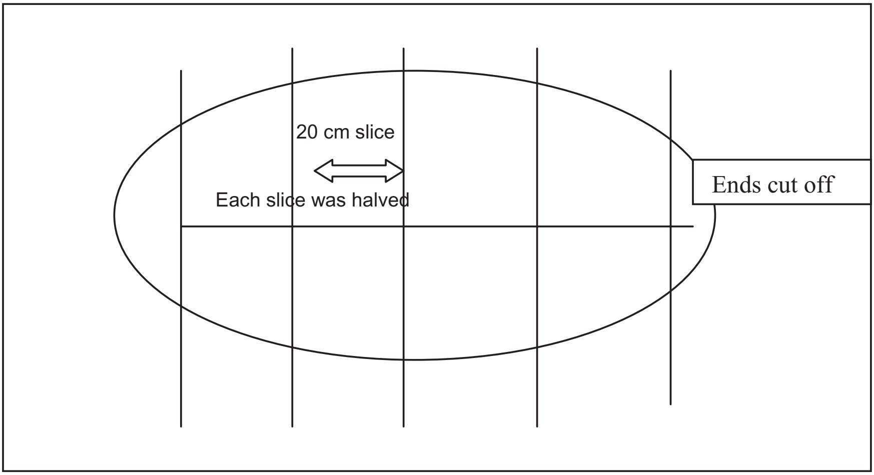

FIG. 1. GRAPHICAL PRESENTATION OF THE SERVING PROCEDURE OF THE SWEET POTATO

Materials Standards (ASTM 1989). The sensory analysis facilities were constructed according to ASTM design guidelines for sensory facilities, with all the elements necessary for an efficient sensory program. Samples were evaluated daily for 4 consecutive days under red light conditions in order to mask any differences in the color of the different sweet potato cultivars.

Shear Values

The remaining sweet potato samples were cooled in an air conditioned sensory laboratory to an internal temperature of 17–18C and then cored. Sweet potatoes were sliced in half and eight cylindrical cores with a diameter of 12.7 mm were removed from the sweet potatoes – four from the left half of the sweet potato and four from the right half of the sweet potato. One shear value for each core was obtained using an Instron Universal Testing Machine (Model 4301) (Instron Corporation 1990), with a Warner Bratzler shear device mounted on a Universal Instron apparatus. The reported value in kilograms represented the average peak force measurement.

Statistical Analysis: Testing for Differences between Means

A randomized complete block design with four replications was used to determine the descriptive attributes ($P \leq 0.05$) for the different sweet potato cultivars (aroma, flavor, aftertaste and textural). Four repetitions were applied, which ensured further reliability of the results (Stone and Sidel 1993). The significance of all the sensory attributes measured for each sweet potato sample was tested by means of factorial analysis of variance (ANOVA), which tested the main effect of the sample, panelists, as well as the sample-by-panelist interactions at a 5% level of significance. If the sample main effect was significant, Fisher's protected *t*-test least significant difference was applied to separate the sample means.

Correlation matrices of the sensory and quality data were performed in order to identify correlations between sensory parameters and quality. The descriptive data was further analyzed using PCA to identify any factors differentiating the sweet potato cultivars. All statistical analyses were done using GenStat for Windows (Payne 2003) statistical computer program.

RESULTS

Weight Gain of Samples during Cooking

The sweet potatoes were weighed before and after cooking. It was found that sweet potatoes increased in weight during cooking, although no significant differences were found for the amount of weight gained between the different cultivars (Table 2). The increase in weight could be due to the fact that a moist heat cooking method was applied, and that the sweet potatoes absorbed moisture (being starch based) during the cooking period. Starch granules in the raw state are hard, closely packed, microscopic agglomerations of starch molecules, which give a chalky mouth-feeling when chewed out of the cells. During cooking, the starch granules start to soften at about 66C (it varies from plant to plant), and moisture is absorbed, which disrupts their compact structure and the granules swell up to many times their original weight (McGee 2004).

Lexicon Development

The final list of descriptive attributes, as developed by the trained panel, encompassed the aroma, texture on appearance and in the mouth, flavor and aftertaste attributes. Reference books and food samples were used as reference

TABLE 2.
WEIGHT GAIN OF SWEET POTATOES DURING COOKING

	Unit	Beauregard	Kano	W119	Resisto	Blesbok
Weight gained during cooking	%	6.8	3.1	6.1	6.1	4.9

guides to develop the lexicon. For each of these attributes, a clear definition was developed as presented in Table 1.

Descriptive Analysis

The descriptive attribute intensity means ($n = 40$) for the five different sweet potato cultivars are listed in Table 3. OFSP differed from WFSP in that it had an earthy aroma and a less intense sweet potato aroma. The earthy aroma was associated with aroma notes of damp soil and slightly undercooked potatoes. The sweet potato aroma and flavor of Blesbok WFSP was typical of

TABLE 3.
LEAST SQUARE MEAN VALUES FOR THE SENSORY ANALYSIS OF FIVE SWEET POTATO CULTIVARS AND THE SHEAR FORCE MEASURE ($n = 40$)

Sensory attribute	*P* value	SEM	Orange-fleshed sweet potato cultivars				
			Beauregard	Kano	W119	Resisto	Blesbok
Aroma							
Earthy	0.005	0.209	3.6^{a}	3.8^{a}	3.8^{a}	3.9^{a}	2.8^{b}
Sweet potato	<0.001	0.243	4.8^{b}	4.7^{bc}	3.9^{d}	4.1^{cd}	5.9^{a}
Burnt	<0.001	0.188	1.8^{b}	1.8^{b}	2.9^{a}	2.0^{b}	1.1^{c}
Texture							
Moistness (visible on surface)	<0.001	0.2	4.9^{b}	5.0^{b}	3.4^{c}	3.5^{c}	6.1^{a}
Firm (retain shape)	0.008	0.184	5.1^{ab}	4.5^{c}	5.4^{a}	4.7^{bc}	4.6^{bc}
First bite							
Denseness	<0.001	0.197	4.6^{a}	4.3^{bc}	5.2^{a}	5.2^{a}	3.8^{c}
Moistness	<0.001	0.165	4.7^{b}	4.5^{b}	3.2^{c}	3.3^{c}	5.5^{a}
Mastication							
Fibers (with fork)	0.010	0.225	4.6^{b}	4.2^{b}	4.6^{b}	4.1^{b}	5.2^{a}
Adhesive (pasty)	<0.001	0.188	3.7^{b}	4.1^{b}	4.2^{b}	5.3^{a}	2.9^{c}
Grainy (tongue on palate)	<0.001	0.189	3.7^{bc}	3.5^{bc}	4.6^{a}	3.3^{c}	3.9^{b}
Flavor							
Vegetable sweet	<0.001	0.180	4.6	4.8^{b}	4.7^{b}	5.4^{a}	3.9^{c}
Sweet potato	0.002	0.240	4.7^{b}	4.7^{b}	4.1^{b}	4.7^{b}	5.6^{a}
Yellow vegetables (butternut/pumpkin/carrot)	<0.001	0.208	3.8^{a}	4.1^{a}	3.9^{a}	4.3^{a}	1.6^{b}
Aftertaste							
Vegetable sweet	<0.001	0.208	4.8^{b}	4.9^{b}	4.9^{b}	5.5^{a}	4.0^{c}
Shear force measurement (kg)	0.449	NA	0.4	0.4	0.4	0.4	0.3

Means in row with different superscript (a, b and c) represent significant difference ($P \leq 0.05$). Means in same row followed by the same letter are not significantly different at $P \leq 0.05$ (Fisher's protected *t*-test LSD). Means in same row not followed by a letter = no significant difference $P \leq 0.05$. Intensities measured on an 8-point scale with 1 = least intense and 8 = extremely intense.
LSD, least significant difference; NA, not applicable; SEM, standard error of the mean.

sweet potatoes commonly consumed in South Africa. OFSP was found to be sweeter, with flavor characteristics of yellow vegetables such as butternut, pumpkin and carrots when compared with WFSP. Resisto cultivar OFSP had the most intense yellow vegetable flavor, vegetables sweet flavor and sweet aftertaste. W119 had a slight burnt aroma, which was associated with vegetables that were burned while cooking (this particular aroma was almost undetectable in the other four cultivars tested).

Textural differences were found among the different sweet potato cultivars. W119 had a firm texture on appearance and was dense and slightly pasty on mastication. It had the most intense grainy texture of the five cultivars tested and was not very moist. The OFSP cultivars had a less moist texture on appearance and first bite, whereas WFSP had the most moist and fibrous texture of the five cultivars tested. OFSP was characterized by a denser and more adhesive texture than that of WFSP. Resisto cultivar had the most adhesive or pasty texture, which referred to the amount the sweet potato flesh stuck to any surface of the mouth. A grainy texture was identified in W119, which referred to the amount of graininess or roughness of particles on chewing. Although the orange color of the different cultivars was not measured, color differences were observed with Resisto cultivar that had the darkest orange color, which is an indication of high beta-carotene content.

Shear Force

No significant differences were found for the shear force measurement of the different sweet potato cultivars. The average measure was 0.35 kg.

CORRELATION ANALYSIS

The sensory aroma, texture, flavor and aftertaste parameters of the sweet potato cultivars have significant correlation coefficients among themselves, as shown in Table 4. Only attributes with correlation coefficient $r > 0.8$ are reported. Generally, a coefficient of about ±0.7 or more is regarded as indicating fairly strong correlation, and in the region of ±0.9, it indicates very strong correlation. In the region of ±0.5 the correlation is moderate, and in the range −0.3 to +0.3, it is weak (Rayner 1969). For example, if $r = 0.5$, even if statistically significant, the $R^2 = 25\%$. This indicates that 25% of the variation between the observations is accounted for by the relationship between the two variates, but 75% variation remains unexplained (personal consultation with statistician, July 2007).

The earthy aroma correlated positively with the vegetable sweet and yellow vegetable flavor attributes. This agreed with the results obtained from

TABLE 4.
CORRELATION COEFFICIENTS AMONG SENSORY ATTRIBUTES

	Earthy Ar	SP Ar	Burn Ar	Moist Ap	Firm Ap	Dense FB	Moist FB	Fibre Mas	Adhes Mas	Grainy Mas	Vegsweet Fl	SPato Fl	Yellow veg Fl	Instron
Correlation matrix														
Earthy Ar	1													
SP Ar	–0.945	1												
Burn Ar	–	–0.891	1											
Moist Ap	–	0.974	–0.883	1										
Firm Ap	–		–	–	1									
Dense FB	–	–0.955	–	–0.989	–	1								
Moist FB	–	0.971	–0.882	0.994	–	–0.967	1							
Fibre Mas	–0.93	–	–		–	–	–	1						
Adhes Mas	0.886	–	–	–0.849	–	0.836	–	–0.892	1					
Grainy Mas	–	–	–	–	–	–	–	–	–	1				
Vegsweet Fl	0.904	–	–	–	–	–	–	–0.948	0.986	–	1			
SP Fl	–0.885	0.938	–0.952	0.878	–	–0.864	–	–	–	–	–	1		
Yellow veg Fl	0.991	–0.896	–	–	–	–	–	–0.949	0.851	–	0.89	–	1	
Veg-sweet At	0.943	–0.892	–	–0.85	–	0.843	–	–0.937	0.987	–	0.991	–	0.922	1
Instron			0.826	–	–	–	–	–	–	–	–	–	–	–

Correlation coefficients >0.878 are significant at $P \leq 0.05$; coefficients of >0.959 are significant at $P \leq 0.01$; coefficients >0.991 are significant at $P \leq 0.001$.
SP, sweet potato; Veg, vegetable; Adhes, adhesive; Ar, aroma; Ap, appearance; FB, first bite; Mas, mastication; Fl, flavor; At, aftertaste; –, not significant.

the ANOVA, as OFSP scored higher values for the earthy, yellow vegetable and vegetable sweet attributes, as well as having a stronger earthy aroma than WFSP. With regard to the texture of sweet potatoes, the moist texture attributes correlated negatively with the dense texture attributes, as well as with the shear force measurement of the sweet potatoes. Blesbok cultivar WFSP scored higher values for the moistness attribute in appearance and on first bite, whereas OFSP scored lower values for moistness, but higher values for denseness. Resisto and W119 cultivars OFSP had the highest value for denseness.

Principal Component Analysis (PCA)

PCA was performed to illustrate graphically (Figs. 2 and 3) the correlation ratings given to the different descriptors. In PCA, all attributes were taken, and it was applied on the mean values of each individual attribute per sweet potato cultivar as obtained from sensory analysis (aroma, texture, flavor and aftertaste). Figure 2 graphically represents the position of the different sweet potato cultivars relative to the attributes that were rated the most intense in each cultivar. Figure 3 graphically represents the PCA loadings of the attributes and is an indication of the correlation structure of the sensory attributes.

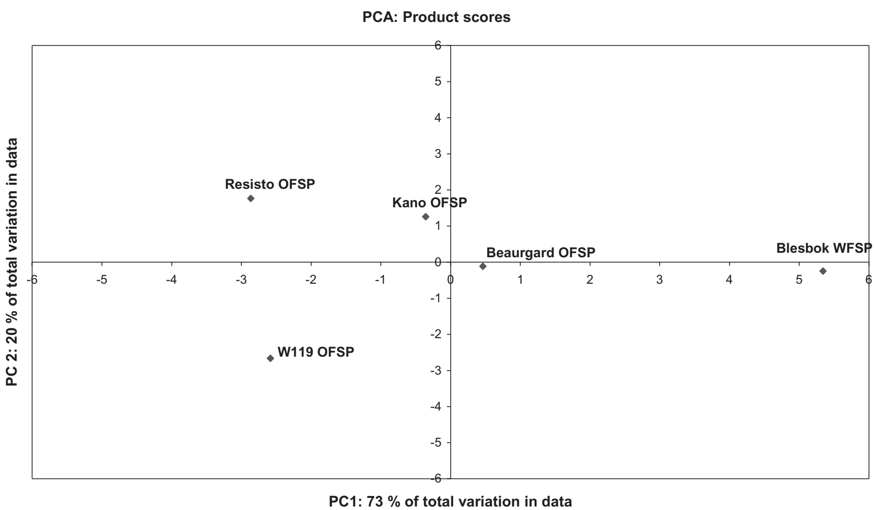

FIG. 2. GRAPHICAL REPRESENTATION OF THE POSITION OF EACH SWEET POTATO CULTIVAR IN RELATION TO THE PC SCORES OF EACH CULTIVAR
PCA, principal component analysis; OFSP, orange-fleshed sweet potato; WFSP, white-fleshed sweet potato.

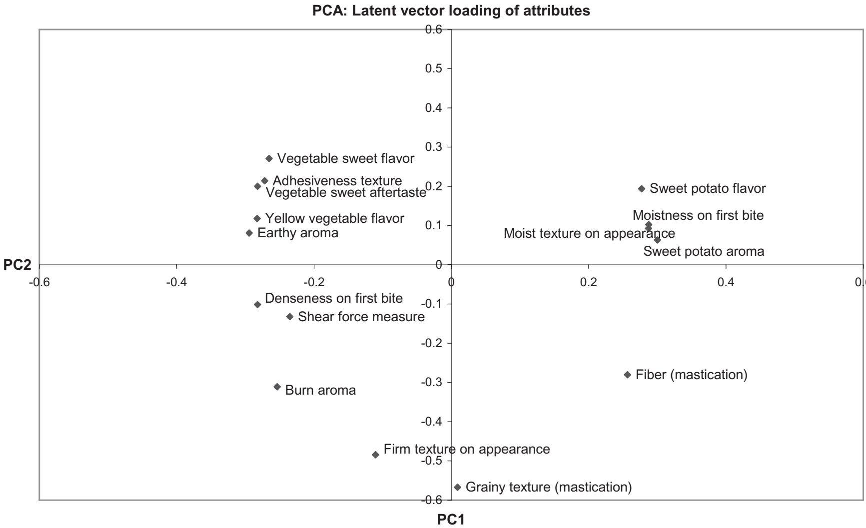

FIG. 3. GRAPHICAL PRESENTATION OF THE MAIN ATTRIBUTES IDENTIFIED IN THE PCA THAT DISCRIMINATED BETWEEN THE SWEET POTATO CULTIVARS
PCA, principal component analysis.

The first two principal components explained 94.9% of the total variance. The first principal component (PC 1) accounted for 72.9% of the total variation in the data. It was characterized by the sweet potato aroma, sweet potato flavor, moist texture on appearance and moist texture on first bite with positive loadings, while the earthy aroma, yellow vegetable flavor, vegetable sweet aftertaste, dense and adhesive texture attributes displayed a negative loading. In Fig. 1, the PCI (*x*-axis) shows that Resisto and W119 cultivars OFSP (left of graph) contrasted with the Blesbok cultivar WFSP (right of graph), the strongest with the regard to the attributes identified in PC1.

For the second principal component (PC 2), the grainy texture on chewing and the firm texture on appearance showed a negative loading. PC2 (*y*-axis) showed that W119 cultivar OFSP contrasted with Resisto and Kano cultivars.

To summarize – reading Figs. 2 and 3 adjacent to each other clearly shows that in PC1 Resisto cultivar OFSP was mainly associated with the vegetable sweet and yellow vegetable flavor attributes and textural attributes such as intense adhesiveness/pasty texture and low moisture texture attributes, whereas Blesbok cultivar WFSP was mainly associated with the sweet potato flavor attributes, as well as with the moist texture attributes. In PC 2, W119 cultivar OFSP was mainly associated with the firm and grainy texture attributes, which scored lower values in Resisto cultivar OFSP.

DISCUSSION

Cooked sweet potatoes are not a uniform product. OFSP and WFSP exhibited a great deal of diversity with regard to flavor and texture attributes. A study conducted by Van Oirschot *et al.* (2002) evaluated the sensory characteristics of different cultivars OFSP when stored under tropical conditions. They found that the main characteristics that discriminated between the different cultivars were primarily related to the different textural components.

Prior to this study, very little research had been done to determine the flavour profile of sweet potatoes (Woolfe 1992; Woolfe 1992; Van Oirschot *et al.* 2002) reported on information regarding the flavour profile of sweet potatoes in that the sweetness of sweet potatoes was largely due to the presence of different carbohydrates, i.e., maltose, glucose, sucrose and fructose. This causes the sweetness to vary among different cultivars due to the combination of the different carbohydrate fractions to the total sugar (Woolfe 1992). In this study, OFSP was found to have a more intense vegetable-sweet flavor when compared with WFSP, and Resisto OFSP was found to be most intense in this attribute.

Texture plays an important role in the overall acceptance and eating quality of sweet potatoes. The correlation of dry matter content with texture attributes has been studied before, and it was found that the dry matter could be correlated to some degree with the texture of potatoes, although this fact is not very clear (Van Marle *et al.* 1997). The dry matter content of OFSP ($\pm$20%) was somewhat higher than that of WFSP (18.2% [Kruger *et al.* 1998]) (cultivar unspecified). The higher dry matter content of OFSP could have contributed to its being less moist on appearance, more dense and pasty (adhesive) than the WFSP. The slightly lower dry matter content of WFSP could explain the higher watery appearance (moisture content) of the cooked WFSP when evaluated in the foil by the trained panel. WFSP had a more moist appearance and a moist texture on first bite and appeared less firm than OFSP. The method of cooking used in the preparation of sweet potatoes could influence the dry matter content, as it was found that water evaporation during steaming increased the dry matter content of cooked samples over a range of cultivars tested by Truong *et al.* (1997).

Blesbok cultivar WFSP had a higher fiber content than OFSP cultivars. The dietary fiber content in sweet potato roots varies between different cultivars. In some cultivars, the fiber content can be so high that the sweet potato is unusable directly as human food and is directed toward industrial processing. However, the dietary fiber in sweet potato is similar to some other roots and tubers, although is much higher than food such as cooked rice (Woolfe 1992).

Although textural differences were found by the trained sensory panel, the results of the shear force resistance for cooked sweet potatoes showed no significant difference between the different cultivars tested. However, PCA found negative correlations between the moistness texture attributes, such as moistness on appearance and moistness on first bite with the shear force measurement (refer to Fig. 3). This agrees with the results obtained from the ANOVA in that Blesbok cultivar WFSP had the lowest value for the shear force measurement (refer to Table 2, although not significant) and the highest value for the moistness on appearance, as well as moistness on first bite. These findings are different to the results obtained by Truong *et al.* (1997), who found significantly different values for compressive strain and stress at failure between cultivars. A reduction in both shear strain and stress values was observed in all steamed cultivars compared with the values for raw sweet potatoes. This could be explained by the magnitude in which starch and cell wall substances degrade during cooking, which impacts on different textural properties among sweet potato cultivars. Therefore, compression or shear force measurement on raw samples may not be an accurate prediction of the textural characteristics of sweet potatoes (Truong *et al.* 1997).

CONCLUSION

OFSP can be regarded as a nutritious food product that could be easy to grow, is pest resistant, and, in some cultivars, deliver adequate yields in selected regions. The data on the nutrient content of OFSP can provide a valuable guideline for nutritionists who are involved in community health to calculate adequate nutrient intakes (Leighton 2007). The sensory profiles of OFSP and WFSP indicated differences in sweetness and texture. As the texture of different cultivars plays an important role in the taste acceptability of root vegetables, such as potatoes and sweet potatoes, new emerging cultivars can be profiled using the lexicon that was developed in this study to identify textural and taste differences among different cultivars. In addition, these findings have important implications for overall consumer acceptability of the different cultivars and can be used in future studies to profile new emerging cultivars.

As a follow-up study, it is recommended that the sensory profiles of different OFSP breeding crops should be determined at different stages of storage. The benefits of improved disease resistance and superior yields may not override unacceptable sensory qualities. Such a study would identify off flavors that may develop during storage and which may result in consumers rejecting such a cultivar once it has been introduced into the market place. Consumer studies could be conducted to determine the acceptability of different cultivars OFSP and other yellow vegetables, such as butternut and pumpkin. Specific gravity and dry matter should be determined and correlated as it impacts on the moisture and density properties of the cultivar.

REFERENCES

ALVAREZ, P. and BLANCO, M. 2000. Reliability of the sensory analysis data of a panel of tasters. J. Sci. Food Agric. *80*, 409–418.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM). 1989. Standard definitions of terms relating to sensory evaluation of materials and products. In *Annual Book of ASTM Standards*, (J.T. Kuznicki, A.F. Rutkiewic and R.A. Johnson, eds.) pp. 5–15, ASTM American Society for Testing and Materials, Philadelphia, PA.

BLACK, R.E., MORRIS, S.S. and BRYCE, J. 2003. Where and why are 10 million children dying every year? Lancet *361*, 2226–2234.

CAULFIELD, L.E., DE ONIS, M., BLÖSSNER, M. and BLACK, R.E. 2004. Under-nutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria and measles. Am. J. Clin. Nutr. *80*, 193–198.

CIVILLE, G.V. and LYON, B.G. 1996. *Aroma and Favour Lexicon for Sensory Evaluation.* ASTM Data Series publication DS 66. ASTM, West Conshohocken, PA.

FABER, M., PHUNGULA, M.A.S., VENTER, S.L., DHANSAY, M.A. and BENADÉ, A.J.S. 2002a. Home gardens focussing on the production of yellow and dark-green leafy vegetables increase the serum retinol concentration of 2–5-year-old children in South Africa. Am. J. Clin. Nutr. *76*, 1049–1054.

FABER, M., VENTER, S.L. and BENADE, A.J.S. 2002b. Increased vitamin A in children aged 2–5 years through targeted home-gardens in a rural South African community. Public Health Nutr. *5*, 11–16.

INSTRON CORPORATION. 1990. *Series IX Automated Materials Testing System: Operating Instruction Manual*, Issue B: November, Instron Corporation, High Wycombe Bucks, U.K.

KRUGER, M., SAYED, M., LANGENHOVEN, M. and HOLING, F. 1998. *Composition of South African Foods: Vegetables and Fruit*, p. 36, UDMS, Cape Town, South Africa.

LAURIE, S.M. 2004. Sweet potato in perspective. In *A Guide to Sweet Potato Production in South Africa*, CDP Printers, (J.G. NIEDERWIESER, ed.) pp. 1–6, ARC-Roodeplaat Vegetable and Ornamental Plant Institute, Pretoria, South Africa.

LAURIE, S.M. and NIEDERWIESER, J.G. 2004. The sweet potato plant. In *A Guide to Sweet Potato Production in South Africa*, CDP Printers, (J.G. Niederwieser, ed.) pp. 7–14, ARC-Roodeplaat Vegetable and Ornamental Plant Institute, Pretoria, South Africa.

LAWLESS, H.T. and HEYMANN, H. 1998. *Sensory Evaluation of Food: Principles and Practices*, p. 351, Aspen, Gaithersburg, MD.

LEA, P., NÆS, T. and RØDBOTTEN, M. 1998. *Analysis of Variance for Sensory Data*, p. 4. John Wiley and Sons, Chichester, U.K.

LEIGHTON, C.S. 2007. *Nutrient and sensory quality of orange-fleshed sweet potatoes*. Master's thesis, University of Pretoria.

MEILGAARD, M., CIVILLE, G.V. and CARR, B.T. 1991. *Sensory Evaluation Techniques*, 2nd Ed., p. 188, CRC Press, New York.

MCGEE, H. 2004. *McGee on Food and Cooking. An Encyclopaedia of Kitchen Science, History and Culture*, p. 283, Hodger and Stoughton, London, U.K.

PAYNE, R.W. 2003. *The Guide to Genstats® Release 8*. Lawes Agricultural Trust. VSN International, Oxford, U.K.

RAYNER, A.A. 1969. *A First Course in Biometry for Agriculture Students*. University of Natal Press, Pietermaritzburg, South Africa.

STONE, S. and SIDEL, J.L. 1993. *Sensory Evaluation of Food*, 2nd Ed., p. 111, Academic Press, Redwood City, CA.

THYBO, A.K. and MARTENS, M. 1998. Development of a sensory texture profile of cooked potatoes by Multivariate data analysis. J. Sensory Studies *29*, 453–468.

TRUONG, V.D., WALTER, W.M. and HAMANN, D.D. 1997. Relationship between instrumental and sensory parameters of cooked sweet potato textures. J. Texture Studies *28*, 163–185.

VAN JAARSVELD, P.J., FABER, W.M., TANUMIHARDJO, S.A., NESTEL, P., LOMBARD, C.J. and BENADE, A.J.S. 2005. Beta-carotene rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. Am. J. Clin. Nutr. *81*, 1080–1087.

VAN MARLE, J.T., VAN DER VUURST DE VRIES, R., WILKINSON, E.C. and YUKSEL, D. 1997. Sensory evaluation of the texture of steam-cooked table potatoes. Potato Res. *40*, 79–90.

VAN OIRSCHOT, Q.E.A., REES, D. and AKED, J. 2002. Sensory characteristics of five sweet potato cultivars during storage under tropical conditions. Food Qual. Pref. *14*, 673–680.

WOODS, M.P. 1998. Taste and flavour perception. Proc. Nutr. Soc. *57*, 603–607.

WOOLFE, J.A. 1992. *Sweet Potato: An Untapped Food Resource*, pp. 57, 142–143, 605, Cambridge University Press, Cambridge.

WRIGHT, T.L., NANCARROW, C. and KWOK, P.M.H. 2001. Food taste preferences and cultural influences on consumption. Br. Food J. *103*, 348–357.