Overall liking and sensory profiling of boiled *Amaranthus* leaves using the Check-all-that-apply question

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ABSTRACT
The study investigated consumers’ overall liking and sensory profiling of 13 boiled *Amaranthus* genotypes by using the Check-all-that-apply question. Fifty consumers ranked their preference on a nine-point hedonic scale to determine overall liking of boiled samples. Additionally, 100 consumers completed a CATA question, which contained 19 descriptive terms related to *Amaranthus* leaves. Significant differences were found in the frequency in which consumers used 11 out of the 19 terms. Correspondence analysis, explaining 68.1% variance, illustrated differences in sensory characteristics between genotypes. Hierarchical cluster analysis identified three consumer segments, indicating the heterogeneous acceptance of samples. External mapping of the samples’ configuration identified regions of maximum liking. Sensory characteristics of *Amaranthus* leaves varied between genotypes and species, with no relationship between specific species and their sensory properties. The information obtained can be recommended to farmers to be incorporated into breeding programmes.

1. Introduction

Traditional leafy vegetables (TLVs), neglected and underutilized food crops in many parts of the world (Ebert, 2014), can play a part in improving the food security status of poor households (Mavengahama, McLachlan, & De Clercq, 2013). Food insecurity is a major cause of micronutrient malnutrition, which is particularly evident in children, females and the elderly (Abdu-Raheem & Worth, 2011).

Over the past years, consumption of TLVs declined as a result of negligence, lack of cultivation practices and the negative connotation attached to it (Njume, Goduka, & George, 2014), as many believe that TLVs are weeds and only consumed by lower-income households (Jansen Van Rensburg et al., 2007). Urbanization also contributed to a decline in consumption of TLVs. Younger generations are not knowledgeable about traditional preparation and cooking methods and feel that these methods are tedious and time-consuming (Matenge, Van Der Merwe, De Beer, Bosman, & Kruger, 2012). Additionally, the consumption of modern crops, such as spinach and carrots, has increased (Naicker, Mathee, & Teare, 2015).

Even though there is presently an increased awareness of TLVs, research is needed to determine consumers’...
preferences to improve acceptability and consumption. Vegetable *Amaranthus* species is an excellent food crop that can contribute to the alleviation of micronutrient malnutrition, since it is rich in minerals, such as calcium, magnesium and vitamin C (Jiménez-Aguilar & Grusak, 2017). In addition, *Amaranthus* species are tolerant to adverse climatic conditions, including heat, drought, diseases and pests (Shukla, Bhargava, Chatterjee, Pandey, & Mishra, 2010).

Consumer liking is primarily influenced by sensory characteristics, such as appearance, aroma, texture and taste (Meilgaard, Civille, & Carr, 2006). These are the most important qualities that consumers take into account when making food choices (Dias et al., 2012). To understand how sensory characteristics are perceived by consumers, it is necessary to gather information on the product, using sensory techniques (Moskowitz, Beckley, & Resurreccion, 2012). Quantitative descriptive analysis is a traditional method, used to obtain complete and reliable results on the sensory qualities of products. However, it is time-consuming, and assessors may describe the product in ways, which are not relevant to the consumer (Carpenter, Lyon, & Hasdell, 2000).

Check-all-that-apply (CATA) is a less time-consuming information gathering technique that appears to be easy for consumers to complete. Check-all-that-apply questions determine which sensory attributes consumers perceive and consist of different terms or phrases, which are then selected by participants if they consider it appropriate to describe the product. For the compilation of the CATA question, terms are generated by a trained panel or by consumers not tasting the product. The degree of relevance for each term is then determined by calculating the frequency of terms used (Ares & Jaeger, 2015).

Many South African research institutions have researched indigenous and traditional vegetables over the past years (Shava & Nkopodi, 2016). Most of this research focuses on agronomic practices, selecting and gathering of baseline information. A newly released cultivar can have excellent yield and other characteristics, but without the overall liking of the consumers, it will not be taken up by farmers.

No sensory analysis studies have been performed on the different *Amaranthus* genotypes in South Africa (SA). It has become essential to obtain more information on the sensory characteristics of these genotypes, in order to develop a genotype best suited to feed a growing population. Thus, the objectives of this study were, firstly, to determine the consumers’ overall liking of *Amaranthus* genotypes. Secondly, sensory profiling was done on 13 genotypes, within seven species, by using the CATA question.

2. Materials and methods

2.1. Identification, selection and harvesting of leaves

Identification, selection and harvesting of *Amaranthus* leaves took place in collaboration with the Agricultural Research Council (ARC), SA, at Sorgvliet (S 29°29’30.5” E 25°31’12.1”), an agricultural farm outside Bloemfontein, Free State Province (FSP). Leaves from 13 *Amaranthus* genotypes were harvested early in the morning, to prevent shriveling and wilting (Gamage & Rahman, 1999). The harvested plant material was placed in woven polypropylene bags and transported to the sensory facility of the University of the Free State (UFS), where it was stored at 4°C.

The species that were harvested included: *Amaranthus caudatus* (AC16, TOT 2295, TOT 2273); *A. graecizans* (Thohoyandou); *A. tricolor* (AS); *A. cruentus* (Kobie, Potch, TL, PI477913 and Ames 22680); *A. dubius* (TOT 2266); *A. hypochondriacus* (TOT 4151); and *Amaranthus* sp (IP5). The latter genotype’s species is unknown (Gerrano et al., 2017).

2.2. Sample processing

Plant material was processed according to a standardized procedure, designed for the development of African indigenous vegetable products (Habwe & Walingo, 2008). Leaves were removed manually from the stem to prevent injury, and any material damaged by insects or pests and diseases was discarded. After rinsing with water and removing soil and other undesirable particles, leaves were blanched for 2 minutes (min) in boiling water at 95°C (Suganya & Sangamithra, 2016), followed by immersion in ice-water for an additional 2 min. This was done to prevent unpalatability and “off odours” from developing. Blanched leaves were left to cool, weighed and packed into individually marked 500g plastic bags. All samples were frozen at −18°C, to prevent any deterioration until sensory analysis was performed.

2.3. Sample preparation

Samples were prepared on the day of sensory analysis, by removing frozen plant material from the freezer and weighing off 250g samples. Textural changes, including decreased firmness and crispness, which ultimately leads to excessive softness, occur if leaves are allowed to thaw after freezing (Coggins & Chamul, 2008). Frozen leaves were pulsed in a Kenwood FP110 Food Processor for 10 seconds, to ensure that leaves were finely chopped, whereafter it was immersed in boiling water (0.005% NaCl) and boiled for 3 min. Leaves were then “shocked” in cold water to discontinue the cooking process (Brown, 2008). Portions (15g) were served in glass ramekins, covered with aluminium foil squares and marked with random three-digit codes. The samples were kept warm in a *bain Marie*, at 110°C, until they were served to the panel. Black male consumers in SA prefer cooked *Amaranthus* leaves to be bitter, being cooked without even the addition of salt (E. O. Amonsou, personal communication, March 7-8, 2017). It is even considered to give strength when it is prepared like that, while salt may not always be available, because of economic reasons. Furthermore, no carrier, like porridge, was used, because confusion may occur amongst consumers, who may concentrate more on the carrier than on the actual sample that needs to be evaluated (Choi, 2014).

2.4. Overall liking

Overall liking was determined using 50 participants, including staff members and students from the UFS, Bloemfontein (Table 1). Participants were selected based on their availability, willingness to participate and consumption of leafy green vegetables (at least once a week).

Sensory evaluation took place in individual booths under red lights to mask colour differences between samples. Red lights were used to prevent bias, since the purple colour of
TOT 4151 and Ames 22680 is not a widely accepted colour and thus could have affected overall liking.

Thirteen samples were evaluated: six samples in the first session, and seven samples in the second session. Samples were presented in a randomised order to participants. Fifteen grams of warm (40°C) boiled leaves were served in glass ramekins, codified with random three-digit numbers. Water was available for rinsing the palate before and between sampling. For each sample, participants had to evaluate their overall liking using a nine-point hedonic scale (1 = “dislike extremely,” 9 = “like extremely”).

### 2.5. Check-all-that-apply (CATA) question

Hundred consumers were recruited from the UFS, including members from the overall liking test, staff and students. The demographics of the CATA panel were similar to the overall liking test. It was mainly female participants, as men are usually not fond of green leafy vegetables. The results of the overall liking test dictated the number of panel members for the CATA question. The smaller the differences between the samples in the overall liking test, the more panel members are needed for the CATA question (Ares & Jaeger, 2015; Ares, Tárrega, Izquierdo, & Jaeger, 2014), thus, also ensuring reliable results (Symoneaux, 2017).

The CATA question consisted of 19 attributes that were generated by a panel (Ares & Jaeger, 2015) of 10 assessors, (eight females and two males) with 40 s (h) experience in the evaluation of leafy vegetables. During a single 4-h round-table discussion, assessors were presented one sample at a time, in no specific order, and were asked to generate individual descriptors for each sample. Through discussion with the panel leader, assessors agreed on easy-to-understand attributes that described the samples best.

Red lights were not used for the CATA question, since the sensory profile of the genotypes were determined. Participants were asked to check all the attributes from a fixed-order list that they considered appropriate to describe each of the samples. Attributes were presented in a random order on the sheet and not according to the sensory modality (appearance, taste and texture) order. Each consumer evaluated six samples on the first day and seven samples on the second day; participants retuned on day two, but not necessarily on corresponding scheduled times. Samples were presented in a randomised order. Fifteen grams warm (40°C) boiled leaves were served in glass ramekins covered with foil and codified with random three-digit numbers. Water was provided for rinsing the palette before and between sampling.

### 2.6. Statistical analysis

Analysis of variance (ANOVA) was done on the overall liking data to establish significant differences (p ≤ 0.05) between genotypes. If the main effect was significant, the Tukey Kramer multiple comparison test (p ≤ 0.05) was used to determine the direction of the differences between mean values (Number Cruncher Statistical Systems (NCSS), 2011).

For the analysis of the CATA question, the frequency of use for each term was determined by counting the total number of times that each participant selected a term to describe a sample. Cochran’s Q test identified significant differences (p ≤ 0.05) among samples for each of the terms from the CATA question (XLSTAT, 2018). The Marascuilo procedure (p ≤ 0.05) determined the direction of the used terms between samples. Correspondence analysis (CA) graphically displayed rows and columns of a contingency table, containing responses to the CATA question. Thus, it was performed (XLSTAT, 2018) on responses to the CATA question, to identify relationships between the terms and the samples, and to provide a two-dimensional sensory map of the similarities and differences between samples, as well as sensory attributes that described them (Ares & Jaeger, 2015).

To understand consumers’ responses further, hedonic ratings were also analysed using agglomerative hierarchical clustering (AHC). The dendrogram obtained from the AHC was used to identify distinct clusters and grouped samples together, based on their different sensory characteristics (Hasted, 2018). The automatic truncation option was selected to display the clusters and to decide when aggregating observations should be stopped, also considering Euclidean distances and Ward’s aggregation criterion (XLSTAT, 2018). Finally, external preference mapping (EPM) linked consumer overall liking scores and responses to the CATA question. Class centroids, from AHC, principal coordinates from the CA and a vector model, were used to create a preference map and contour plot. The preference map was superimposed on the contour plot (XLSTAT, 2018).

### 2.7. Ethical consideration

Ethical approval for the study was obtained from the Ethics Committee of the Faculty of Natural and Agricultural Sciences, UFS, Bloemfontein. The ethics clearance number is UFS-HSD2017/0264.

### 3. Results and discussion

#### 3.1. Overall liking of boiled leaves

Table 2 shows the results of the consumer acceptance test carried out on the boiled leaves. There was a significant difference (p = 0.004) in the overall liking among the different genotypes.

Genotype Potch obtained the highest overall acceptability, followed by TOT 2266, with no significant difference between the two. Thohoyandou obtained the lowest mean score and was significantly different from Potch and
Table 2. Analysis of variance (ANOVA) for consumers’ overall liking of boiled Amaranthus samples.

| Species and genotype         | Ranking |
|-----------------------------|---------|
| Amaranthus caudatus AC16     | 4.50± 2.68 |
| TOT 2295                    | 4.38± 2.51 |
| TOT 2275                    | 5.04± 2.30 |
| A. cruentus Kobie            | 4.76± 2.10 |
| Potch                       | 5.72± 2.27 |
| TL                          | 4.60± 2.11 |
| P1477913                    | 4.36± 2.74 |
| Ames 22680                  | 4.30± 2.41 |
| Amaranthus species IPS       | 5.16± 2.49 |
| A. graecians Thohoyandou     | 3.70± 2.29 |
| A. hypochondriacus TOT 4151 | 4.62± 2.25 |
| A. dubius TOT 2266          | 5.40± 2.42 |
| A. tricolor AS              | 4.52± 2.47 |

**Significance level**

Means with different superscripts in the same column differed significantly.

TOT 2266. Although these genotypes are derived from different species, there was no significant difference between genotypes belonging to the same species. For instance, Potch (A. cruentus) differed significantly from Thohoyandou (A.graecizans), but there were no difference between Potch and other genotypes of the same specie. The only exceptions of species that differed significantly from one another were Thohoyandou (A. Graecizans) and TOT 2266 (A. dubius).

3.2. Check-all-that-apply (CATA) question

Table 3 shows the frequency at which each of the terms of the CATA questions was used to describe boiled Amaranthus leaves. The most frequently used terms were “leafy,” “spinach,” “soft,” “tasteless,” “grassy,” “sandy” and “bitter aftertaste”. The least used terms were “sweet”, “sweet aftertaste” and “sour”. Significant differences were found in the frequencies for 11 of the 19 terms in the CATA question used to describe samples. No significant differences were found for “leafy”, “fibrous” and “spinach”, as well as “sweet”, “sour”, “salty”, “salty aftertaste” and “metallic aftertaste” (Table 3).

As shown in Table 3, genotype Potch, which obtained the highest overall acceptability (Table 2), were described as “tasteless” and “soft”, with a less “sandy” texture and “bitter aftertaste”. Genotypes TOT 4151, TOT 2295 and TL were also described by very similar attributes but were significantly more “sandy” than Potch. The “sandy” texture noted in the Amaranthus leaves may be attributable to calcium oxalate crystals. These crystals could be a result of the interaction of calcium and oxalic acid in leafy vegetables. *Amaranthus* leaves have been reported to have a high oxalic content (Saveage & Radek, 2008) that ranges from 85 to 129mg per 100g and varies among different *Amaranthus* genotypes and species (Awasthi, Kumar, Singh, & Thakur, 2011). The leaves of AS were significantly more “sandy” (Table 3) and could indicate that this genotype might have a higher concentration oxalates than the other samples.

Genotype TOT 2266, which obtained the second highest rank (Table 2) for overall liking, was described by attributes similar to Potch, along with a “grassy” aroma. Additionally, genotypes TOT 2295 and Kobie were aromatically perceived as more “grassy” and differed significantly from TOT 4151. Research shows that a “grassy” aroma is present in all leafy green vegetables, but the intensity varies (Talavera, Chambers, & Chambers, 2009). Volatile aldehydes (trans−2-hexenal), alcohols (cis−3-hexenol), and C6 compounds are mainly responsible for the characteristic green odour, reminiscent to leaves and freshly cut grass (Jelen & Gracka, 2016).

Genotypes Ames 22680, P1477913 and Thohoyandou were significantly more “bitter” than Potch, TOT 4151, TOT 2295 and TL. Thohoyandou, which obtained the lowest mean score (Table 2), and P1477913 were frequently described using terms like “bitter” and “bitter aftertaste” while being significantly less “tasteless” than other genotypes.

From the results in Table 3, it was noticeable that there was a difference in bitterness observed between genotypes. According to research, alkaloids and phenolic compounds (glucosinolates) are responsible for the bitterness of leafy vegetables (Forney & Song, 2017). The occurrence and concentrations of alkaloids and glucosinolates vary according to species and cultivars as well as tissue type, physiological age and nutrition (Holst & Fenwick, 2003). A study by Tordoff and Sandell (2009) suggests that increased levels of calcium can also be responsible for the bitterness of vegetables. Although *Amaranthus* is a good source of calcium, no current study was conducted, indicating that the bitter taste of the leaves was related to the calcium content.

Bitterness in vegetables is seen as a negative characteristic (Hayes & Keast, 2011) in Westernised countries but can easily be masked by the addition of fat, sugar or salt (Drewnowski, 1996). According to Vorster, Jansen Van Rensburg, Van Zijl, and Van Den Heever (2002), *Amaranthus* leaves are sweet and preferred among consumers, even though Onyango, Shibairo, Imungi, and Harbinson (2008) reported that consumers found *Amaranthus* leaves less acceptable due to the bitter taste. Research has shown that the overwhelming bitterness of plant foods seems to suppress the sweet taste of leaves (Dinehart, Hayes, Bartoshuk, Lanier, & Duffy, 2006). As mentioned, salt masks bitterness and acts as a flavour enhancer that increases the palatability of food (Liem, Miremadi, & Keast, 2011). However, when used in low concentrations, food can easily be described as “tasteless” or “bland” (Piquaras-Fiszman, 2014). Thus, results from the present study suggested that *Amaranthus* samples, which were described as ‘bitter’ with a “bitter aftertaste”, were not considered ‘sweet’, with a “sweet aftertaste”, nor “tasteless”, and vice versa.

Furthermore, Thohoyandou was characterised by a “soft” texture, similar to Potch and TOT 4151. The attribute “soft” can, thus, not be considered a driver for overall acceptability, since Potch and Thohoyandou, which differed significantly from each other (Table 2), had the attribute “soft” in common. The “soft” texture could have been due to a combination of freeze damage during freezing, leading to softening of tissues (Oey et al., 2017), and morphological characteristics, that vary among *Amaranthus* species. In general, the texture of *Amaranthus* leaves are considered soft; for example, *A. dubius* has an obovate leaf shape and are described as tender with a neutral flavour (Grubben, 2004). However, Weinberger and Musya (2004) found that broader and larger *Amaranthus* leaves are characterised by a coarse texture (species unknown).
| Specie           | A. caudatus | A. cruentus | A. specie | A. gynecizans | A. hypochondriacus | A. dubius | A. tricolor |
|-----------------|-------------|-------------|-----------|---------------|-------------------|-----------|------------|
|                 | AC 16       | TOT 2295    | TOT 2275  | Kabie         | Poth             | TL        | Ames 22680 | P1477913   | IP 5        | Thohoyandou | TOT 4151  | TOT 2266 | A5         |
| Sour            | 4           | 1           | 2         | 0             | 1                | 2         | 1           | 4           | 2           | 3           | 1         | 3          | 5          |
| Sweet           | 5           | 6           | 1         | 1             | 4                | 4         | 2           | 0           | 6           | 0           | 6         | 3          | 1          |
| Salty           | 18          | 15          | 18        | 12            | 24               | 27        | 15          | 19          | 16          | 14          | 26        | 20         | 19         |
| Fibrous         | 24          | 26          | 30        | 24            | 24               | 33        | 28          | 23          | 31          | 18          | 26        | 21         | 20         |
| Leafy           | 67          | 69          | 76        | 70            | 68               | 72        | 76          | 66          | 71          | 75          | 71        | 69         | 67         |
| Spinach         | 54          | 48          | 50        | 47            | 48               | 40        | 35          | 47          | 44          | 42          | 54        | 53         | 47         |
| Salty aftertaste | 9           | 9           | 9         | 11            | 12               | 16        | 5           | 10          | 7           | 4           | 14        | 8          | 11         |
| Metallic aftertaste | 11       | 12          | 10        | 9             | 14               | 11        | 14          | 19          | 7           | 22          | 13        | 13         | 9          |
| Peppery         | 0           | 5           | 6         | 6             | 6                | 6         | 5           | 6           | 11          | 5           | 8         | 6          | 2          |
| Sweet aftertaste | 1           | 4           | 5         | 0             | 4                | 5         | 1           | 1           | 7           | 1           | 4         | 2          | 1          |
| Grassy          | 34          | 46          | 43        | 42            | 28               | 38        | 38          | 38          | 30          | 37          | 25        | 31         | 43         |
| Firm            | 26          | 12          | 26        | 17            | 16               | 13        | 29          | 11          | 15          | 13          | 13        | 11         | 18         |
| Coarse          | 12          | 13          | 16        | 2            | 14               | 14        | 23          | 11          | 8           | 10          | 12        | 7          | 21         |
| Stalky          | 31          | 21          | 26        | 23            | 14               | 28        | 13          | 13          | 28          | 15          | 12        | 14         | 18         |
| Soft            | 40          | 48          | 55        | 40            | 52               | 43        | 24          | 43          | 52          | 54          | 49        | 49         | 29         |
| Sandy           | 30          | 43          | 42        | 43            | 18               | 45        | 40          | 40          | 31          | 36          | 34        | 27         | 61         |
| Bitter          | 38          | 15          | 23        | 36            | 18               | 13        | 40          | 42          | 37          | 69          | 17        | 25         | 31         |
| Bitter aftertaste | 33         | 19          | 22        | 29            | 21               | 18        | 37          | 56          | 40          | 68          | 23        | 20         | 27         |
| Tasteless       | 35          | 50          | 33        | 41            | 51               | 50        | 39          | 24          | 25          | 27          | 52        | 32         | 38         |

Frequencies with different superscripts in the same row differed significantly.

*** Indicates significant differences among samples according to Cochran's Q test at p ≤ 0.001
** Indicates significant differences among samples according to Cochran's Q test at p ≤ 0.01
* Indicates significant differences among samples according to Cochran's Q test at p ≤ 0.05
a Indicates no significant difference among samples according to Cochran's Q test at p > 0.05

Las frecuencias con diferentes superíndices en la misma fila son significativamente diferentes.

*** Indica diferencias significativas entre las muestras según la prueba Cochran's Q a p ≤ 0.001.
** Indica diferencias significativas entre las muestras según la prueba Cochran's Q a p ≤ 0.01.
* Indica diferencias significativas entre las muestras según la prueba Cochran's Q a p ≤ 0.05.
a Indica que no hay diferencias significativas entre las muestras según la prueba Cochran's Q a p > 0.05.
In contrast, genotype Ames 22680, which obtained the second lowest mean score (Table 2), was characterised by a “stalky” appearance with “firm” and “coarse” texture, which differed significantly from TOT 2295 and TOT 2266. These textural descriptors could be attributed to cellulose, hemicellulose, lignin and pectin substances present in the leaves, which contribute to texture and firmness (Sivasankar, 2002). The “stalky” appearance of Ames 22680 and AC16 could also be

![Symmetric plot](image)

**Figure 1.** Sample and term representations in the first and second coordinates of the CA performed on the frequency of use of the terms of the CATA questions, for the evaluation of 13 boiled Amaranthus samples.

**Figura 1.** Representaciones de muestras y términos utilizados en la primera y segunda coordenadas del análisis de clúster (CA) aplicado a la frecuencia de uso de los términos del cuestionario CATA, para la evaluación de 13 muestras hervidas de Amaranthus.

![Dendrogram](image)

**Figure 2.** Dendrogram of the three major consumer clusters identified for 13 boiled Amaranthus samples.

**Figura 2.** Dendrograma de los tres principales clústeres de consumidores identificados para las 13 muestras hervidas de Amaranthus.
attributed to the presence of longer petioles. Literature confirms that *A. caudatus* can have petiole lengths of 8 cm (Brink & Belay, 2006), which validates the use of the term “stalky”.

### 3.3. Correspondence analysis (CA)

Figure 1 illustrates the results of the CA carried out for the CATA question. The first dimension of the CA explained 44.8% of the variance and the second dimension a further 23.3%, giving a total of 68.1%.

Genotypes Potch and TOT 4151 were situated in the positive side of the first dimension and were described by the terms “soft”, “tasteless” and “sweet aftertaste”. Genotype Thohoyandou, positioned far from the rest of the samples, as well as P1477913, were situated in the negative side of the first dimension and described by terms “bitter” and “bitter aftertaste”. Genotype Ames 22680, situated in the negative side of the second dimension, was strongly associated with terms related to texture, including “firm”, “coarse” and “stalky”.

Lastly, situated in the positive side of the second dimension, genotype TL was described by terms “tasteless” and “salty aftertaste”. Genotype A5 was strongly associated with terms “sandy” and “stalky”. The latter term was not frequently selected to describe A5 (Table 3) and does not fit in the sensory profile of this genotype. It should be noted that this figure only illustrates relative values based on the contingency table of the CATA question (Table 3) (Greenacre, 2010).

Genotypes and attributes located close to origin are not discussed, as there is little or no robust association between genotypes and attributes.

### 3.4. Agglomerative hierarchical clustering (AHC) and external preference mapping (EPM)

Agglomerative hierarchical cluster (AHC) analysis with Ward’s method was carried out on the consumer data for overall liking (Figure 2) and showed that the consumer population consisted of three clusters. The dotted line on the dendrogram represents the automatic truncation at level 40, leading to three clusters.

Cluster 1 consisted mostly of black females aged between 20 and 49 years (Table 4). This cluster had the largest percentage of white respondents, in comparison to the other clusters. Genotype IP5 was liked, similarly to Potch and TOT 4151 (Figure 3). Respondents also preferred TOT 2266 and TL. Genotype TOT 2295 was not much preferred, although it was more preferred than AC16. Cluster 2 was made up of black females aged between 30 and 49 years (Table 4). This cluster had the lowest percentage of male respondents, with no coloured respondents. Genotypes in this cluster were least preferred and included TOT 2275, Ames 22680, P1477913 and Thohoyandou. Cluster 3, also consisting mainly of black females, between the ages of 30–49 years (Table 4), preferred genotypes A5 and Kobie.

As shown in the contour plot (Figure 3), genotypes Potch, TOT 4151, TOT 2266, TL and IP5 were located in the region...

### Table 4. Demographic profile (%) between clusters for boiled *Amaranthus* samples.

| Race      | Cluster 1 | Cluster 2 | Cluster 3 |
|-----------|-----------|-----------|-----------|
| Black     | 63        | 82        | 74        |
| Colored   | 1         | 0         | 1         |
| White     | 36        | 18        | 25        |
| Gender:   |           |           |           |
| Female    | 80        | 92        | 85        |
| Male      | 20        | 8         | 15        |
| Age:      |           |           |           |
| 20–29     | 26        | 16        | 22        |
| 30–39     | 25        | 36        | 30        |
| 40–49     | 30        | 33        | 28        |
| > 50      | 16        | 15        | 17        |

Fig. 3. External preference map of identified consumer clusters and 13 boiled *Amaranthus* samples.

Figura 3. Mapa externo de preferencias de los clústeres de consumidores identificados y las 13 muestras hervidas de *Amaranthus*. 
that included overall acceptance values between the values for 60–80% of preference. In contrast, AC16, TOT 2295, TOT 2275, Ames 22680, P1477913, Thohoyandou, Kobie and A5 were located in the region with 20–40% of preference.

4. Conclusions

Traditional leafy vegetables, especially *Amaranthus*, are receiving more attention amongst modern-day plant breeders and farmers because of its high nutritional value and the potential for human consumption. The results of the present study indicated similar overall liking of the *Amaranthus* leaves, although differences in the sensory characteristics did occur, which varied significantly between genotypes and species. However, there was no robust connection between specific species and their sensory properties, as genotypes in the same species had shown both similar and contradictory sensory properties (e.g. Potch and P1477913). The sensory properties of these genotypes have now been identified and can be recommended to farmers to be incorporated into breeding programmes. In conclusion, cooking method and the lack of knowledge should be addressed to increase the overall liking for *Amaranthus*. From literature, it is evident that the taste of the leaves can be improved by adding additional ingredients, for example, tomatoes, onions and potatoes. This will not only increase the liking of the leaves but also mask certain attributes and improve the nutritional value of the meal.

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