Hedonic evaluation and check-all-that-apply (CATA) question for sensory characterisation of stewed vegetable *Amaranthus*

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Revised: 27 August 2019 / Accepted: 29 August 2019 / Published online: 4 September 2019
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Abstract Hedonic assessment and sensory characteristics of 13 *Amaranthus* genotypes, stewed with onions, tomatoes and potatoes, were evaluated. 50 consumers ranked their preference on a nine-point hedonic scale to determine overall acceptability of the stewed samples. In addition, 100 consumers were asked to select sensory characteristics that described the genotypes best, using the Check-all-that-apply question. Hedonic responses indicated significant differences ($p < 0.001$) between stewed samples. Significant differences were also found in the frequency with which consumers used 15 of the 23 terms generated to characterise the sensory profile of stewed *Amaranthus* leaves. Correspondence analysis illustrated differences in sensory characteristics between genotypes, describing 72.4% variance. Agglomerative

hierarchical clustering indicated three consumer preference clusters, while external preference mapping showed the regions of maximum liking. There was no correlation between hedonic evaluation and sensory characteristics. In addition, no strong association between specific species, genotypes and sensory attributes was observed.

Keywords *Amaranthus* leaves · Sensory analysis · Check-all-that-apply · Preference mapping · Correspondence analysis

Introduction

Although enough food is produced to feed the earth's entire population, 10.7% still suffer from malnutrition, mostly in developing countries (FAO et al. 2017). Food shortages and poverty, which eventually lead to micronutrient malnutrition (MNM), are two of the main reasons for food insecurity (Ihuoma 2015). While various fortification and supplementation strategies have been put in place to address MNM, people are advised to include a variety of foods in their diet (Faber and Wenhold 2007). Govender et al. (2017) recommend traditional leafy vegetables (TLVs) to serve as an inexpensive alternative food source for a nutritious and balanced diet, which will contribute to food security.

Over the past few decades, there has been more interest in improving the nutritional quality of plant-based foods (Sands et al. 2009), since research has shown that TLVs can greatly improve an individual's vitamin A and iron (Fe) intake. According to Labadarios et al. (2008), a portion of cooked leafy vegetables can make a significant contribution to a person's daily iron, vitamin C and beta-carotene intake. Regardless of the nutritional traits of TLVs, consumers

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ultimately determine the success of a product (Stone 2018). According to Venter et al. (2007), there is a need to conduct sensory tests on TLVs to provide valid and reliable information about their sensory characteristics.

Trained panels are used for laboratory evaluation of products (in terms of differences or similarities) and for the identification and quantification of sensory characteristics. On the other hand, affective or consumer sensory testing can identify consumer needs that are not currently met by the available food products (Stone 2018).

Amaranthus, an underutilised TLV, is cultivated and consumed in many parts of the world (Amornrit and Santiyanont 2016), including South Africa (SA), where it is known by various vernacular names (Jansen Van Rensburg et al. 2007). It has recently gained importance as a promising food crop, since it adapts to various climatic conditions, it is highly resistant to stresses (heat, drought) and it has high nutritional value (Alemayehu et al. 2015). Rural populations in developing countries mostly consume *Amaranthus* because it is an inexpensive food source rich in proteins, vitamins, fibre and minerals (Shukla et al. 2003, 2006). In SA, beet spinach (*Beta vulgaris* var. *cicla* L.) is the foremost leafy vegetable consumed and *Amaranthus* is often added as an extender to dishes prepared with spinach (Jansen Van Rensburg et al. 2007).

Recent evidence (Hiscock et al. 2018) reveals that consumers find certain *Amaranthus* genotypes less acceptable due to undesirable taste attributes, such as a bitter taste and aftertaste. The bitter taste, derived from glucosinolates and isoflavones (Drewnowski and Gomez-Carneros 2000), is widely appreciated by older generations with a rural decent, but rarely by young Western consumers (Owuor and Olaimier-anyara 2007).

Thus, it was proposed to incorporate *Amaranthus* leaves into a stewed dish that is widely and habitually consumed by rural consumers in SA. This study aimed to evaluate consumers' hedonic responses towards the overall acceptability of 13 stewed *Amaranthus* genotypes, as well as to determine their sensory profiles through the application of the Check-all-that-apply (CATA) question, in order to gain insight in differences and similarities.

Materials and methods

Study area, experimental design and plant materials

The study was conducted at Sorgvliet (S29°29'30.5" E25°31'12.1"), an agricultural farm located 90 km south-west of Bloemfontein, Free State Province, SA, during the 2015/2016 season. A randomised complete block design with three replications was used, where each plot was 3 metres (m) in length, with 0.75 m spacing between rows and 0.3 m within row spacing.

Harvesting of 13 *Amaranthus* genotypes took place in February 2016, 10 weeks after planting seedlings provided by Agricultural Research Council-Vegetable and Ornamental Plants (ARC-VOP). In order to simulate poor farm practices, plant material was cut back to 0.4 m above ground during manual harvesting and left to grow again for a next harvest event. After harvesting, the 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. Leaves were manually removed from the stem to prevent injury and any material damaged by insects was discarded.

The species that were harvested included *Amaranthus caudatus* (AC16, TOT 2295, TOT 2275); *A. graecizans* (Thohoyandou); *A. tricolor* (A5); *A. cruentus* (Kobie, Potch, TL, PI477913 and Ames 22680); *A. dubius* (TOT 2266); *A. hypochondriacus* (TOT 4151); and *Amaranthus* sp. (IP5), the species of which is unknown (Gerrano et al. 2017).

Sample preparation for sensory analysis

Samples were prepared on the day of sensory analysis under the supervision and assistance of a professional sensory analyst. Blanched samples (200 g) were defrosted and prepared according to a method used by Matenge et al. (2012). This preparation method was selected, because it represented a dish that was generally accepted and prepared by rural communities (Faber et al. 2010), in the event that money was available to purchase additional ingredients.

Uncooked *Amaranthus* leaves (37.7%), onions (18.8%) and tomatoes (18.8%) were separately pulsed in a food processor (Kenwood FP110) for 10 s, to ensure that the samples were homogeneous in appearance. Potatoes (15.2%) were pre-cooked in an electric pressure cooker and mashed to a smooth consistency. Subsequently, onions were sautéed in oil (0.9%), after which leaves, additional vegetables and water (5.6%), were added together with flavourings, including sugar (0.9%) and salt (0.2%).

Samples (40 g) were presented in glass ramekins, covered with foil, codified with random three-digit numbers and randomly served at 40 °C to the panel, for both the hedonic evaluation and CATA sensory technique. Panel-lists attended two evaluation sessions over 2 days (six samples on day one and seven samples on day two) for each sensory technique. Mineral water was available as neutraliser between samples to avoid any carryover effects.

Hedonic evaluation

50 untrained consumers (Table 1), including students and staff members from the UFS, were recruited to participate in the study. Participants who declared themselves regular

consumers of LGVs were asked to evaluate the overall liking of the samples on a nine-point hedonic scale (1 = “dislike extremely”, 9 = “like extremely”).

Check-all-that-apply (CATA) question

100 consumers, recruited from the UFS, completed a CATA question. According to Ares and Jaeger (2015), the smaller the differences between samples from the results obtained from the hedonic evaluation test, the more consumers are required to perform the CATA question.

The selection of attributes for the CATA question was based on a list of attributes that were generated by a panel of 10 assessors (eight women and two men) and a panel leader with experience in LGVs evaluation. A list of 23 attributes characterising the stewed samples best was compiled from their discussions. Panellists were asked to check all the attributes that they considered appropriate to characterise each of the samples on a ballot sheet. The CATA ballot sheet was presented to panellists in a fixed order and attributes were listed in a randomised order, not according to sensory modalities.

Statistical analysis

An analysis of variance (ANOVA), followed by a Tukey–Kramer multiple-comparison test ($p \leq 0.05$), was carried out on the hedonic evaluation data to determine significant differences between genotypes (NCCS 11 Statistical Software 2016).

For the CATA question, the frequency of use for each attribute was determined by counting the number of

participants that used the attribute to evaluate the stewed sample and a contingency table was created with these results. Cochran’s Q test was done to determine significant differences ($p \leq 0.05$) between samples for each attribute. The Marascuilo procedure ($p \leq 0.05$) determined the direction of use between samples. Correspondence analysis (CA) was conducted on the contingency table and was plotted to obtain sample and attribute configurations (XLSTAT 2018).

Agglomerative Hierarchical Cluster Analysis (AHC) was carried out using the Euclidean distances and Ward’s aggregation method. The dendrogram obtained from the AHC was used to identify clusters and grouped samples, based on their sensory characteristics (XLSTAT 2018; Hasted 2018). To conclude, external preference mapping (EPM) linked consumer overall liking scores and responses to the CATA question. A preference map and contour plot were created from class centroids, from the AHC, principal coordinates of the CA and a vector model. The preference map was superimposed on the contour plot (XLSTAT 2018).

Ethical consideration

The Ethics Committee of the Faculty of Natural and Agricultural Sciences, UFS, Bloemfontein approved this study. The ethical clearance number is UFS-HSD2017/0264.

Results and discussion

Hedonic evaluation of stewed leaves

The hedonic evaluation results are summarised in Table 2, revealing that there were highly significant differences ($p < 0.001$) between the overall hedonic acceptability of stewed samples.

Genotype Potch (*A. cruentus*) and TOT 2266 (*A. dubius*) obtained the highest overall hedonic acceptability, with moderate preference. However, the differences in acceptability for both genotypes were the best. Although these genotypes originated from two different species, they were both “liked moderately” by panellists. On the other hand, AC 16 (*A. caudatus*) and A5 (*A. tricolor*), which obtained the lowest mean scores and were “neither liked nor disliked”, differed significantly from Potch and TOT 2266. Similar results were also reported by Hiscock et al. (2018) on boiled *Amaranthus* genotypes. In the present investigation, no meaningful association could be made between genotypes of the same species.

Table 1 Demographic profile and cluster analysis of 50-member consumer panel for stewed *Amaranthus* samples

	Percentage (%)	Cluster 1	Cluster 2	Cluster 3
Gender				
Male	21	21	20	21
Female	79	79	80	79
Race				
African	75	75	80	72
White	23	25	15	24
Coloured	2	0	5	4
Age (years)				
20–29	21	20	17	25
30–39	30	33	28	23
40–49	32	27	49	37
50–59	15	17	6	15
> 60	2	3	0	0

Table 2 Mean scores for overall hedonic acceptability of stewed *Amaranthus* samples

Specie	Score
<i>Amaranthus caudatus</i>	
AC 16	5.30 ^a ± 2.72
TOT 2295	5.84 ^{ab} ± 2.33
TOT 2275	6.42 ^{ab} ± 2.00
<i>A. cruentus</i>	
Kobie	6.00 ^{ab} ± 2.16
Potch	7.12 ^b ± 1.97
TL	6.02 ^{ab} ± 1.97
P1477913	5.92 ^{ab} ± 2.30
Ames 22680	5.72 ^{ab} ± 2.54
<i>A. specie</i>	
IP5	6.64 ^{ab} ± 2.15
<i>A. graecizans</i>	
Thohoyandou	5.92 ^{ab} ± 2.01
<i>A. hypochondriacus</i>	
TOT 4151	6.00 ^{ab} ± 2.12
<i>A. dubius</i>	
TOT 2266	6.96 ^b ± 1.59
<i>A. tricolor</i>	
A5	5.26 ^a ± 2.35
Significance level	$p < 0.001$

Check-all-that-apply (CATA) question

A summary of the sensory characteristics of stewed *Amaranthus*, as well as the frequency of use and the significant differences between genotypes can be found in Table 3. Most frequently selected terms were “leafy”, “spinach”, “onion”, “sandy”, “onion aftertaste” and “bitter aftertaste”, while the least selected terms were “sour”, “metallic aftertaste”, “peppery” and “tasteless”. Significant differences were found in the frequencies for 15 of the 23 terms in the CATA question.

Textural attributes, including “soft”, “coarse” and “firm”, differed significantly among genotypes. Genotypes Potch and TOT 4151 had a significantly higher frequency of use ($p \leq 0.001$) for the term “soft” than Ames 22680 and A5. In contrast, Ames 22680 and TOT 2275 differed significantly ($p \leq 0.01$) from TOT 4151 and Thohoyandou for the attributes “coarse” and “firm”, respectively. Texture is a major determinant of consumer preference. However, during freezing, ice crystals are formed that damage the rigid cellular structure and lead to changes in the flavours and pigments of the plant material (Fellows 2000). Furthermore, during cooking, structural carbohydrates soften due to the cellular wall structure that becomes

permeable during heating. This leads to water loss and, consequently, loss of the cell walls’ turgor and rigidity. Thus, during heating, the plant material softens and eases chewing (Srilakshmi 2003). According to Weinberger and Msuya (2004), the leaves of *Amaranthus* spp. are generally regarded as soft, although some species are coarser and more fibrous.

The frequency of use for the term “stalky” differed significantly ($p \leq 0.001$) between TOT 2266, and A5 and Ames 22680. According to Akaneme and Ani (2013), *Amaranthus* species can be distinguished from one another by means of their petiole length. Vorster et al. (2002) mention that young and soft petioles are preferred over old and hard petioles, and that it is often removed during the preparation of vegetable dishes.

The use of the attribute “sandy” was most noticeable in genotypes Kobie, Ames 22680, A5 and TL, and differed significantly ($p \leq 0.01$) from P1477913. The “sandy” texture detected may be ascribed to the occurrence of calcium oxalate crystals in *Amaranthus* leaves. This confirms the results of Onyeoziri et al. (2018), who detected a sandy texture in *Amaranthus cruentus* and *Cleome gynandra* leaves and suspected that it may be due to an interaction between calcium and oxalic acid present in the vegetables. The oxalic content of *Amaranthus* leaves can vary between genotypes and species, and can be reduced by boiling (Chai and Liebman 2005).

There were significant differences between the frequency of use for attributes related to taste and aftertaste. The attributes “bitter” and “bitter aftertaste” were frequently selected to describe genotypes P1477913 and Ames 22680, and differed significantly ($p \leq 0.001$) from TOT 2295, TL and TOT 4151. Thohoyandou was by far the “bitterest” of all the genotypes. These results correlate with the studies of Hiscock et al. (2018), who found that Thohoyandou and P1477913 were most frequently described as “bitter”, which suggests that there may be a difference in the concentration of bitter-inducing compounds between genotypes. Research indicates that components, such as glucosinolates (Drewnowski and Gomez-Carneros 2000), the calcium content of vegetables (Tordoff and Sandell 2009), and the presence of alkaloids in TLVs (Essack et al. 2017) are responsible for the bitter taste, which is the reason why consumption is often avoided (Slavin and Lloyd 2012).

In addition to unacceptable taste attributes, the frequency of use for the attribute “metallic aftertaste” differed significantly ($p \leq 0.001$) between Thohoyandou and TOT 2295, TOT 2275, IP5, TOT 4151, TOT 2266 and A5. Lawless et al. (2005) state that the attribute “metallic aftertaste” is often used to describe the taste of salt compounds, including calcium (bitter) and magnesium (bitter). The results obtained from the current study are consistent

Table 3 The frequency of use of attributes associated with stewed *Amaranthus* samples

Species	<i>A. caudatus</i>				<i>A. cruentus</i>				<i>A. sp</i>				<i>A. graecizans</i>	<i>A. hypochondriacus</i>	<i>A. dubius</i>	<i>A. tricolor</i>
	AC 16	TOT	TOT 2295	TOT 2275	Kobie	Potch	TL	P	1477913	Ames	22680	IP 5	Thohoyandou	TOT 4151	TOT 2266	A5
Leafy ^{NS}	68	72		68	75	65	58	61	69			66	65	66	63	74
Spinach ^{NS}	57	54		49	54	45	45	55	47			47	41	51	55	51
Fibrous ^{NS}	28	27		29	26	30	22	27	33			33	27	25	26	33
Salty ^{NS}	21	31		28	25	27	23	24	32			30	17	18	26	25
Salty Aftertaste ^{NS}	17	14		14	11	9	16	12	16			21	8	9	8	16
Peppery ^{NS}	7	9		7	2	6	12	13	12			10	17	9	10	8
Tasteless ^{NS}	12	13		13	9	9	14	5	7			8	3	13	10	7
Sour ^{NS}	7	6		3	4	6	6	11	4			10	6	5	7	8
Grassy*	28 ^{ab}	25 ^{ab}		23 ^{ab}	20 ^{ab}	11 ^a	22 ^{ab}	24 ^{ab}	36 ^b			27 ^{ab}	23 ^{ab}	19 ^{ab}	22 ^{ab}	27 ^{ab}
Sandy**	37 ^{ab}	39 ^{ab}		36 ^{ab}	48 ^b	35 ^{ab}	43 ^b	20 ^a	44 ^b			28 ^{ab}	32 ^{ab}	39 ^{ab}	33 ^{ab}	44 ^b
Firm**	20 ^{ab}	33 ^{ab}		36 ^b	20 ^{ab}	23 ^{ab}	20 ^{ab}	18 ^{ab}	28 ^{ab}			30 ^{ab}	16 ^a	16 ^a	31 ^{ab}	29 ^{ab}
Coarse**	13 ^a	21 ^{ab}		25 ^{ab}	18 ^{ab}	10 ^a	17 ^{ab}	19 ^{ab}	34 ^b			21 ^{ab}	15 ^a	14 ^a	20 ^{ab}	26 ^{ab}
Sweet Aftertaste**	14 ^{ab}	17 ^{ab}		14 ^{ab}	9 ^{ab}	14 ^{ab}	13 ^{ab}	5 ^a	3 ^a			8 ^{ab}	4 ^a	21 ^b	10 ^{ab}	6 ^a
Onion Aftertaste**	28 ^{ab}	37 ^{ab}		36 ^{ab}	35 ^{ab}	36 ^{ab}	24 ^{ab}	22 ^{ab}	22 ^{ab}			36 ^{ab}	17 ^a	30 ^{ab}	40 ^b	29 ^{ab}
Onion***	43 ^{ab}	52 ^b		47 ^b	45 ^b	47 ^b	41 ^{ab}	39 ^{ab}	30 ^{ab}			52 ^b	21 ^a	33 ^{ab}	47 ^b	39 ^{ab}
Bitter Aftertaste***	30 ^{abc}	17 ^a		20 ^{ab}	28 ^{abc}	25 ^{ab}	18 ^a	49 ^{cd}	41 ^{bc}			22 ^{ab}	65 ^d	17 ^a	24 ^{ab}	33 ^{abc}
Bitter***	38 ^{cde}	11 ^a		14 ^{ab}	23 ^{abcd}	31 ^{abcde}	12 ^a	42 ^{de}	45 ^e			25 ^{abcde}	67 ^f	17 ^{abc}	24 ^{abcde}	34 ^{bcde}
Potato***	25 ^{ab}	41 ^b		27 ^{ab}	27 ^{ab}	23 ^{ab}	16 ^a	29 ^{ab}	21 ^a			26 ^{ab}	20 ^a	17 ^a	31 ^{ab}	22 ^{ab}
Tomato***	18 ^a	30 ^{ab}		15 ^a	23 ^a	26 ^{ab}	27 ^{ab}	19 ^a	25 ^a			32 ^{ab}	22 ^a	46 ^b	17 ^a	25 ^a
Stalky***	18 ^{ab}	22 ^{abc}		25 ^{abc}	25 ^{abc}	28 ^{abc}	23 ^{abc}	18 ^{ab}	38 ^c			33 ^{abc}	21 ^{abc}	18 ^{ab}	17 ^a	37 ^{bc}
Soft***	27 ^{ab}	24 ^{ab}		17 ^{ab}	24 ^{ab}	36 ^b	32 ^{ab}	26 ^{ab}	13 ^a			21 ^{ab}	32 ^{ab}	35 ^b	20 ^{ab}	13 ^a
Sweet***	18 ^{ab}	24 ^{ab}		24 ^{ab}	19 ^{ab}	24 ^{ab}	24 ^{ab}	12 ^{ab}	7 ^a			14 ^{ab}	10 ^{ab}	27 ^b	22 ^{ab}	8 ^a
Metallic Aftertaste***	12 ^{ab}	4 ^a		5 ^a	9 ^{ab}	8 ^{ab}	9 ^{ab}	16 ^{ab}	10 ^{ab}			7 ^a	21 ^b	7 ^a	7 ^a	6 ^a

***Indicates significant differences among samples according to Cochran's Q test at $p \leq 0.001$ **Indicates significant differences among samples according to Cochran's Q test at $p \leq 0.01$ *Indicates significant differences among samples according to Cochran's Q test at $p \leq 0.05$ ^{NS}Indicates no significant difference among samples according to Cochran's Q test at $p > 0.05$

Hiscock et al. (2018) suggest adding additional ingredients to boiled *Amaranthus* leaves to mask undesirable taste attributes. Even though the bitter taste still emerged among the stewed leaves, with specific genotypes, the frequency of use was considerably less, compared to boiled *Amaranthus* leaves. In contrast to the boiled leaves, the stewed leaves were also characterised by a sweeter taste. The frequency of use for the attribute “sweet” differed significantly ($p \leq 0.001$) between genotypes TOT 4151, Ames 22680 and A5. Additionally, the use of the term “sweet aftertaste” also differed significantly ($p \leq 0.01$) for genotypes P1477913, Ames 22680, Thohoyandou, A5 and TOT 4151. The increase in sweetness amongst the boiled and stewed leaves can be attributed to the addition of sugar

Furthermore, the frequency of use for the term “onion” and “onion aftertaste” differed significantly ($p \leq 0.01$; $p \leq 0.001$) between genotype TOT 2266 and Thohoyandou. Table 3 shows significant differences among genotypes, including TOT 4151 and TOT 2266, which obtained high values for “sweet”, “sweet aftertaste”, “onion” and “onion aftertaste” and lower values for “bitter” and “bitter aftertaste”. These all differed from Thohoyandou. Thus, regardless of the additional ingredients, which contributed to taste and overall acceptability, genotype Thohoyandou was still predominantly described as “bitter”, with a “bitter aftertaste”.

Fig. 2 Dendrogram of the AHC, indicating the presence of three clusters of consumers' overall hedonic acceptability of stewed *Amaranthus* samples

Correspondence analysis (CA)

To illustrate the association between samples and terms, CA was carried out on the contingency table to obtain a sensory map of the stewed samples (Fig. 1). The first two dimensions on the map explained 72.4% of the experimental data variability, representing 52.0% (D1) and 20.4% (D2), respectively.

As indicated in Fig. 1, genotypes TOT 4151, Potch and TL, positioned in the upper left quadrant, were described as “sweet”, with a “sweet aftertaste” and a “soft” texture. In the upper right quadrant, P1477913 and Thohoyandou were described as “bitter”, with a “bitter aftertaste” and “metallic aftertaste”. Genotypes TOT 2295 and TOT 2275, situated in the bottom left quadrant, had a “firm” texture with an “onion” aroma, and according to the attributes selected, it was also “sweet” with a “sweet aftertaste”. Lastly, in the bottom right quadrant, Ames 22680 was described as “coarse”. Participants also frequently used the attribute “bitter” to describe this genotype. In the same quadrant, A5 was described as “sandy” and “stalky”.

Agglomerative hierarchical clustering (AHC) and external preference mapping (EPM)

As indicated in Fig. 2, the dendrogram, which was comprised of variable demographic groups, is presented in Table 1. Cluster one consisted of 30 black (75%) female (79%) participants aged between 30 and 39 years. Cluster two, with eight participants, consisted of 80% black female participants aged between 40 and 49 years. This cluster had the smallest number of white (15%) male (20%) participants. Lastly, cluster three comprised 12 participants, mostly black (72%) females (79%) aged between 40 and 49 years.

External preference mapping shows cluster one, situated in the blue region of the plot, consisting of genotypes Ames 22680, TOT 2266, TOT 2295, TOT 2275, A5 and IP5 (Fig. 3). Genotypes TOT 2266 (*A. dubius*) and AC16 (*A. caudatus*), which differed significantly from each other, were both located in the blue region, with a 20–40% preference. This implied that small groups of consumers liked these two genotypes and gave high hedonic scores (XLSTAT 2018). Also located in the cold region, but not

Fig. 3 Contour plot of the EPM of consumers on the stewed *Amaranthus* leaves

assigned to any clusters, were Thohoyandou, P1477913 and AC 16. These three genotypes were not preferred and were mainly characterised as “bitter”, with a “bitter aftertaste”. The remaining two clusters were situated in the orange area, with acceptance values between a 60–80% preferences (XLSTAT 2018). Cluster two indicated a clear preference for genotypes Potch and TOT 4151, while cluster three preferred TL and Kobie.

Conclusion

The results of the present investigations suggest that a stewing method, containing ingredients, such as potatoes, tomatoes and onions, was able to mask the bitterness of *Amaranthus* genotypes and increased acceptability. Consumer hedonic evaluation and sensory characteristics differed significantly between *Amaranthus* genotypes and species. Genotypes in the same species revealed both similar and contradictory sensory characteristics. Thus, there was no strong association between specific species, genotypes and sensory descriptors.

The results of this study may be helpful for investigating components responsible for the bitter taste and sandy texture of *Amaranthus* leaves. As stated by Onyeoziri et al. (2018), additional methods that mask the bitterness of this LGV should be considered, as this may lead to commercially viable products that are acceptable to the target population. This may help to promote the consumption of *Amaranthus* leaves, create employment opportunities for small-scale farmers and promote the conservation of this indigenous LGV.

Acknowledgements The authors are thankful to the Agricultural Research Council for providing the funding to conduct the research (No. P0900020-04).

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