# Relating sensory profiles of canned amaranth (*Amaranthus cruentus*), cleome (*Cleome gynandra*), cowpea (*Vigna unguiculata*) and swiss chard (*Beta vulgaris*) leaves to consumer acceptance

Isiguzoro O. Onyeoziri, Marise Kinnear, and Henriëtta L. de Kock*

Department of Food Science and Institute for Food, Nutrition and Wellbeing, University of Pretoria, P O Box X20, Hatfield, Pretoria 0028, South Africa

*Corresponding author: riette.dekock@up.ac.za

## ABSTRACT

BACKGROUND: The younger generation of South Africans generally do not consume traditional meals prepared using African green leafy vegetables, primarily because they are regarded as bitter, "poverty" foods. Canning of these vegetables could create, value-added products that can be sold in the commercial market. Descriptive sensory evaluation and consumer acceptance testing with young females were used to assess the potential of such products.

RESULTS: The sensory attributes of amaranth, cleome and cowpea leaves canned in brine and in a cream sauce were described using 21 attributes grouped by aroma, taste, texture/mouthfeel and aftertaste. Amaranth and swiss chard products were described as sweet with a popcorn-like aroma. Cleome products were described as bitter, sour, pungent, chemical-tasting, astringent, sandy with a metallic mouthfeel and strong aftertaste. Cowpea products were described as having woody and tobacco aromas as well as a chewy and cohesive texture. Among the products canned with a cream sauce, young female consumers, preferred amaranth and swiss chard, cowpea was less liked, while cleome was least liked.

CONCLUSIONS: Canned amaranth leaves have potential as a commercial product that may be well liked by young consumers. The cowpea leaves product has consumer potential but the formulation needs revision, while canned cleome leaves need further research work.


*Keywords*: consumer preference, sensory profile, African leafy vegetables, canning

## INTRODUCTION

African leafy vegetables (ALVs) including various amaranth species (eg. *Amaranthus hybridus, A. cruentus*), cleome (*Cleome gynandra*), and cowpea (*Vigna unguiculata*) are nutritionally important vegetables on the African continent which are currently underutilized in South Africa, and have been targeted for conservation.[1] Amaranth is ubiquitous in the country, cowpea is widely cultivated across the continent, and cleome like amaranth, is popular as it is a pioneer plant which emerges naturally when soils are disturbed.[1] ALVs have been labelled as 'poverty food',[2] and this label has led to a reduction in the willingness of consumers, particularly the youth, to use and eat these vegetables.[3] Urbanization has created dietary changes typified by a lowered consumption of these traditional foods by consumers, in favor of 'exotic' vegetables (e.g., swiss chard).[1] ALVs are seasonal and highly perishable, resulting in issues of unavailability year-round and high postharvest losses. Preservation technologies (e.g. canning) can solve this problem, and will give consumers access to a wider choice of convenient, shelf stable, value-added, and modern products that appeal to urban dwellers.[4]

However, canning results in changes in the properties of a food, particularly the sensory properties. No reports on the sensory properties of canned ALVs were available.[5] Previously researchers,[6] have highlighted the need for conducting sensory tests on ALVs and ALV-derived products. The description of leafy vegetable characteristics by sensory analysis is important to establish the specificity or typicality of the vegetables.[7] The role of these sensory tests is to provide valid and reliable information about the perceived sensory properties of indigenous vegetables.[8]

In order to succeed, any food that is produced, no matter how nutritious, ultimately has to be eaten and found acceptable by consumers. A consumer sensory test can provide diagnostic information about consumers' perceptions about a product as well as points of superiority or shortcomings.[5] The appearance, flavor and texture of vegetables are the most important characteristics influencing consumers' acceptance and eventually

behavior towards buying or not buying.[6] The aims of this study were: to determine the descriptive sensory attributes of canned amaranth, cleome, and cowpea leaves in brine and cream sauce, for insight on similarities and differences; to determine consumer acceptance of canned amaranth, cleome, and cowpea leaves, utilizing a cream sauce as canning medium; and to determine the sensory attributes driving consumer acceptance of canned amaranth, cleome and cowpea leaves. Brine was used as a canning medium, so as to yield products that could be utilized as part of a relish or stew, with the addition of other ingredients, as commonly practiced in households. Cream sauce was used as a canning medium to yield products that could be consumed on their own, without adding anything else. For comparison, similarly canned swiss chard (*Beta vulgaris*) leaves were included in the study. Swiss chard or 'spinach' as it is locally known, is a well-known and popular exotic vegetable often served with a cream sauce in households and restaurants.

## EXPERIMENTAL

### Materials

Amaranth (*Amaranthus cruentus*), cleome (*Cleome gynandra*), cowpea (*Vigna unguiculata*) leaves, and swiss chard (*Beta vulgaris*) leaves as standard, were canned with either brine or cream sauce as canning media (formulation details are proprietary). Amaranth, cleome and cowpea were grown at the Agricultural Research Council Vegetable and Ornamental Plant Institute (ARC-VOPI), located in Roodeplaat, 30 km north-east of Pretoria, in the Gauteng Province, Republic of South Africa. These plants were grown during the summer months (November – April) with daytime temperatures of 25 – 30 °C, while night temperatures were on average 19 – 20 °C. Seeds of *A. cruentus* and *C. gynandra* were planted in seedling trays and transplanted to the field after four weeks of establishment. *V. unguiculata* seeds were planted directly in the field. Full irrigation was applied during the growing period to have a good stand, avoid flowering, and to keep the vegetable quality marketable. *Beta vulgaris* (sold under the trade name

**Table 1 Process information for retort processing of leafy vegetables with brine as canning medium in corrugated No. 1 (211 x 400) cans at processing temperature of 118 °C**

| Vegetable | Replicate | Initial temperature (°C) | Processing time (min) | Cooling time (min) | $F_0$ heating (min) | $F_0$ cooling (min) | $F_0$ total (min) | Recommended processing time (min) |
|---|---|---|---|---|---|---|---|---|
| Amaranth | 1 | 60.5 - 64.4 | 27 | 12 | 8.10 | 0.00 | 8.10 | 27 |
| | 2 | 62.5 - 65.6 | 24 | 18 | 7.70 | 0.00 | 7.70 | |
| | 3 | 64.6 - 80.2 | 22 | 18 | 8.17 | 0.01 | 8.19 | |
| Swiss chard | 1 | 58.0 - 64.0 | 20 | 15 | 7.51 | 0.40 | 7.55 | 20 |
| | 2 | 60.2 - 65.5 | 18 | 18 | 7.48 | 0.02 | 7.51 | |
| | 3 | 70.7 - 74.5 | 18 | 15 | 8.22 | 0.00 | 8.22 | |
| Cowpea | 1 | 60.0 - 64.8 | 32 | 27 | 8.37 | 0.20 | 8.56 | 32 |
| | 2 | 60.2 - 67.6 | 25 | 21 | 7.84 | 0.14 | 7.98 | |
| | 3 | 65.7 - 69.8 | 22 | 21 | 7.92 | 0.02 | 7.95 | |
| Cleome | 1 | 60.0 - 66.5 | 27 | 24 | 7.20 | 0.00 | 7.20 | 32 |
| | 2 | 63.9 - 65.5 | 32 | 18 | 8.21 | 0.00 | 8.21 | |
| | 3 | 68.5 - 76.8 | 26 | 21 | 7.97 | 0.02 | 7.98 | |

**Table 2 Process information for retort processing of leafy vegetables with cream sauce as canning medium in corrugated No. 1 (211 x 400) cans at processing temperature of 118 °C**

| Vegetable | Replicate | Initial temperature (°C) | Processing time (min) | Cooling time (min) | $F_0$ heating (min) | $F_0$ cooling (min) | $F_0$ total (min) | Recommended processing time (min) |
|---|---|---|---|---|---|---|---|---|
| [1]Amaranth | 1 | 62.9 - 65.4 | 76 | 45 | 8.61 | 0.09 | 9.56 | 77 |
| | 2 | 57.3 - 59.5 | 77 | 45 | 8.28 | 0.91 | 9.18 | |
| | 3 | 74.9 - 80.7 | 73 | 50 | 8.58 | 1.08 | 9.66 | |
| [1]Swiss chard | 1 | 66.7 - 62.1 | 74 | 45 | 10.1 | 0.14 | 10.2 | 76 |
| | 2 | 61.9 - 65.5 | 76 | 45 | 7.68 | 0.59 | 8.27 | |
| | 3 | 68.7 - 72.3 | 72 | 45 | 7.59 | 0.04 | 7.63 | |
| [2]Cowpea | 1 | 61.4 - 64.9 | 75 | 50 | 7.99 | 0.85 | 8.84 | 76 |
| | 2 | 56.1 - 60.2 | 75 | 45 | 7.59 | 1.31 | 8.90 | |
| | 3 | 65.6 - 69.4 | 76 | 50 | 7.82 | 0.17 | 7.99 | |
| [1]Cleome | 1 | 59.5 - 64.1 | 79 | 50 | 8.79 | 1.30 | 10.1 | 79 |
| | 2 | 56.8 - 65.2 | 77 | 45 | 7.75 | 0.29 | 8.04 | |
| | 3 | 68.3 - 71.0 | 70 | 45 | 7.17 | 0.28 | 7.45 | |

[1,2] Vegetables with the same numeral superscript had similar fill weights

Spinach) was obtained from McCain Foods South Africa, in frozen format (preblanched). Tables 1 and 2 give information on the canning parameters applied. Canning parameters were the same for canning of all the leafy vegetables. The differences in initial temperatures were due to variations in handling time during batch pre-canning operations of can filling, can exhausting and loading of cans into the retort. All eight canned products were subjected to descriptive sensory evaluation. Only the cream sauce products were used for consumer acceptance testing. An ambient commercial sterility test as described by Tucker and Featherstone[9], was carried out to ensure safety of products from the canning process. Ethical approval for the study was granted (EC130827-088) by the Ethics Committee of the Faculty of Natural and Agricultural Sciences at the University of Pretoria.

**Descriptive sensory evaluation**

Descriptive sensory evaluation of the canned ALVs by a trained sensory panel (n=16) was carried out in the sensory laboratory of the Department of Food Science, at the University of Pretoria. The panel was trained over 20 h consisting of 2 h sessions per day according to the generic descriptive method described by Einstein.[10] During the training, panelists developed descriptive terms for the aroma, flavor, texture/mouth-feel and aftertaste of the canned leafy vegetables (Table 3). Panelists were also trained to use Compusense *five* ® release 4.8 (Compusense Inc., Guelph, ON, Canada), for data recording. Before the actual evaluation, panelists' performances were checked three times using Panelcheck® version 1.4.0 (Nofima Mat, Norway) and guidelines of Tomic, Luciano, Nilsen, Hyldig, Lorensen and Næs.[11]

Three cans of each product were opened and the contents of each can put into individual bain-marie containers (dimensions 145mm x 80mm x 100mm) and heated to 60-65 °C. For evaluation, portions (25-30g) were then served to the panelists in glass ramekin dishes, covered with foil, and evaluated at ± 55 °C. Panelists received all eight samples, consisting of a thorough mix of leaves and canning fluid, served one after

**Table 3 Lexicon of descriptive terms for canned green leafy vegetables as developed by a descriptive sensory panel**

| Descriptors | Definition | Reference used | Rating scale |
|---|---|---|---|
| Green-grassy/leafy | A green aromatic associated with newly cut grass, leaves and green leafy vegetables, characterized by sweet and pungent characters | Freshly cut grass | 0 = not intense; 10 = very intense |
| Woody | Brown, musty aromatics associated with very fibrous plants and bark | Wood chips | 0 = not woody; 10 = very woody |
| Earthy | Aromatics associated with damp, wet soil, characteristic of damp soil, wet foliage, or slightly undercooked boiled potato | Damp wet soil | 0 = not earthy; 10 = very earthy |
| Popcorn | The aromatic volatiles characteristic of popcorn | Freshly popped popcorn | 0 = not detected; 10 = very intense |
| Tobacco | The brown, slightly sweet, slightly pungent aromatic associated with cured tobacco | Camel Filter cigarettes. Break cigarette and place 0.2g of tobacco in a medium snifter, cover | 0 = not intense; 10 = very intense |
| Sweet | Aromatics associated with the impression of sweet substances such as asparagus | Canned asparagus stems | 0 = not sweet; 10 = very sweet |
| Sour | The fundamental taste sensation of acids of which citric acid is typical | 0.015% citric acid in $H_2O$ solution | 0 = not sour; 10 = very sour |
| Bitter | A fundamental taste factor of which caffeine is typical | 0.01% caffeine in $H_2O$ solution | 0 = not bitter; 10 = very bitter |

**Table 3 continued**

| Descriptors | Definition | Reference used | Rating scale |
|---|---|---|---|
| Salty | The fundamental taste of which sodium chloride in water is typical | 0.15% sodium chloride solution | 0 = not salty;<br>10 = very salty |
| Umami | The flat savory taste naturally occurring in food such as tomatoes | 0.2% solution of MSG | 0 = not intense;<br>10 = very intense |
| Astringent | The drying puckering sensation on the tongue and other mouth surfaces | Strong tea solution | 0 = not astringent;<br>10 = very astringent |
| Metallic | An aromatic and mouthfeel associated with tin cans or aluminum foil; flat chemical feeling stimulated on the tongue by metals | Aromatic feeling of coins on tongue | 0 = not metallic;<br>10 = very metallic |
| Peppery | Chemical feeling associated with high concentrations of irritants to the mucous membranes of the oral cavity, perceived as a burning sensation on the tongue and mouth surface | 0.4 ppm capsaicin solution | 0 = not detected;<br>10 = very intense |
| Buttery | Flavor associated with butter | Warm melted butter | 0 = not detected;<br>10 = very intense |
| Chemical | A very general term associated with many different types of compounds such as solvents and cleaning compounds | | 0 = not detected;<br>10 = very intense |

**Table 3 continued**

| Descriptors | Definition | References used | Rating scale |
|---|---|---|---|
| Viney | Aromatic volatiles associated with green wood/small young branch or stems of plants | Young stems and green branches of green leafy vegetables | 0 = not intense;<br>10 = very intense |
| Pungent | The sharp physically penetrating sensation in the nose reminiscent of radish and horseradish | Heinz white Vinegar (1 part vinegar with 8 parts of water) | 0 = not intense;<br>10 = very intense |
| Chewy | The amount of work to chew a sample, derived by counting the number of chews required to prepare for swallowing | Liquorice | 0 = not chewy;<br>10 = very chewy |
| Sandy | The textural sensation of sand crystals on the tongue | | 0 = not sandy;<br>10 = very sandy |
| Aftertaste | The perception of flavor which lingers in the mouth swallowing a sample | | 0 = not intense;<br>10 = very intense |

the other in a sequence following a Williams design. To avoid fatigue and facilitate sample preparation and presentation, there was a 2-min break between serving each sample. Filtered water as well as peeled and sliced fresh, raw carrots, was used as palate cleansers before and in between tasting of samples. Evaluation was carried out by first lifting a side of the foil covering and then sniffing the product for aroma attributes. A spoonful was then taken and chewed to evaluate for flavor and texture/mouth-feel properties. Aftertaste attributes were evaluated after swallowing of the sample. All evaluations were performed by panelists seated in individual evaluation booths with white day-light illumination. The sensory evaluation area was held at 23 °C and a positive airflow removed odors from the testing area.

A structured 10-point line scale was used to measure the intensities of the different attributes for each sample. Zero was indicative of an absence of the attribute being measured, while 10 was indicative of a high intensity of perception. Evaluation was carried out in triplicate over three sessions lasting 2 h per day.

**Consumer acceptance testing of canned ALVs in cream sauce**

The four canned leafy vegetables in cream sauce were presented to a group of South African, female, ethnic black consumers (n=96; age: 19-25 years), invited from amongst the general populace. All consumers were screened to include only persons who were willing to evaluate the products, had no food allergies and could use a computer independently. No training was required. Consumers received all four samples for testing all at once. Each sample was rated for degree of liking or disliking on a horizontal Simplified Labelled Affective Magnitude (SLAM) scale[12] with anchors "greatest imaginable like", neither like nor dislike, and "greatest imaginable dislike". The SLAM scale has the advantage of providing liking data on a psychological universal continuum allowing interpretation across products. The SLAM scale also has the advantage of allowing for adequate provision for responses at the extremes of the scale, thus potentially reducing the effects of end-use avoidance [2].

### Statistical analyses

The significance of each descriptive attribute in discriminating among the samples was investigated using a factorial analysis of variance (ANOVA), with main effects leafy vegetable species and canning medium, as well as the 2-way interaction of the factors using the general linear model (GLM) procedure STATISTICA 12 (Statsoft Inc. USA). This was followed by mean separation with the Fisher's least significant difference (LSD) test at $p<0.05$. Principal component analysis (PCA) was carried out on the multivariate data (attribute means calculated over all panelists over the three sessions) to help in further understanding or simplifying the variances among the products. The covariance matrix PCA (cov-PCA) was used because all the attributes were measured on the same scale.[13] The use of a covariance matrix allowed for a more accurate representation of the importance of each of the descriptive attributes (e.g. a longer vector generally indicates use of a wider range of the scale, typically, but not exclusively, because of greater discrimination among the samples).[14] The results of the consumer acceptance test were investigated using univariate ANOVA and the Fisher's LSD test, to determine the effect of product on acceptance. An extended internal preference map was constructed by regressing the information for the relevant products from the descriptive analysis onto the dimensions extracted from an internal preference map of the consumers rating using XLSTAT 2014.6, Addinsoft, New York USA. The data used were the individual scores for each product by each consumer for overall liking, and the means of the attribute scores from the descriptive evaluation, with products as rows, and consumers and attributes as variables or columns. The purpose was to understand what attributes were driving consumers liking or disliking of the canned leafy vegetables in cream sauce.

## RESULTS

### Descriptive sensory evaluation

Tables 4 - 6 show the effects of vegetable species, canning medium and their interaction

effects on the sensory attributes of the eight canned leafy vegetables as evaluated by the trained sensory panel.There was a significant interaction effect of vegetable species and canning medium (p=0.03) for perceived intensities of green-grassy/leafy aroma among the products (Table 4.6). Amaranth an swiss chard in cream sauce had a less intense green grassy/leafy aroma than the in brine products while this attribute was similar in thw two types of cleome and cowpea leaves. There were no differences in the intensity of earthy aroma among the products. Cream sauce products had a more intense popcorn aroma than the corresponding brine products. Amaranth products had more intense popcorn aroma, than the other products. Products with cream sauce generally had a less intense woody aroma than the in brine products. Cleome products had a more intense woody aroma than the others. Cowpea and cleome products had similar intensities of tobacco aroma, but significantly more intense tobacco aroma than amaranth and swiss chard products with similar intensities.

Amaranth and swiss chard products were sweetest, more than cowpea leaves which in turn was sweeter than cleome which was most bitter, pungent, astringent and with more intense chemical flavour (Table 4.5) and metallic mouthfeel (Table 4.6). In cream sauce products were significantly sweeter and with more buttery, umami and pepper flavours but less salty than in brine products. Cleome products were most sour followed by cowpea, swiss chard, and amaranth.

In cream sauce products were less cohesive than the in brine products (Table 4.6). Cowpea products felt most cohesive. Cleome, amaranth, and swiss chard were significantly less cohesive in that order. Cleome products had a more sandy texture, followed by amaranth and cowpea, and then swiss chard products. The in brine products were more chewy than the in cream sauce products. Cowpea products were the chewiest, followed by cleome, amaranth and swiss chard products in that order. Cleome products provoked the most intense overall aftertaste. The aftertaste of swiss chard and cowpea products were less

**Table 4 Effects of vegetable species, canning medium and its interaction on the aroma attributes of canned green leafy vegetables, as evaluated by a trained descriptive sensory panel**

| Comparisons | Attributes | | | | |
|---|---|---|---|---|---|
| | Green grassy/leafy | Earthy | Popcorn | Woody | Tobacco |
| Effect of vegetable species | | | | | |
| Amaranth | 6.15 (±2.65) | 3.79 (±3.25) | 2.79 (±2.56)[b] | 3.05 (±3.26)[a] | 2.23 (±2.95)[a] |
| Swiss chard | 5.78 (±2.96) | 3.84 (±3.54) | 2.02 (±2.44)[a] | 3.04 (±3.20)[a] | 2.49 (±3.37)[a] |
| Cleome | 5.99 (±3.11) | 4.58 (±3.12) | 1.41 (±2.33)[a] | 4.05 (±3.25)[b] | 4.11 (±3.47)[b] |
| Cowpea | 5.17 (±3.06) | 3.88 (±3.10) | 1.49 (±2.06)[a] | 3.04 (±3.20)[a] | 4.08 (±3.44)[b] |
| p-value | 0.11 | 0.30 | <0.001 | 0.03 | <0.001 |
| Effect of canning medium | | | | | |
| Brine | 6.25 (±3.03)[b] | 4.21 (±3.38) | 1.62 (±2.36)[a] | 3.96 (±3.47)[b] | 3.41 (±3.47) |
| Cream sauce | 5.30 (±2.82)[a] | 3.84 (±3.13) | 2.24 (±2.42)[b] | 3.16 (±3.12)[a] | 3.04 (±3.36) |
| p-value | <0.001 | 0.27 | 0.01 | 0.02 | 0.27 |
| Interaction effect of vegetable species * canning medium | | | | | |
| Amaranth in brine | 6.79 (±2.70)[c] | 4.20 (±3.38) | 2.69 (±2.84) | 3.51 (±3.40) | 2.40 (±3.05) |
| Swiss chard in brine | 6.87 (±2.67)[c] | 4.14 (±3.78) | 1.43 (±2.10) | 2.97 (±3.29) | 2.02 (±3.00) |
| Cleome in brine | 5.83 (±3.26)[abc] | 4.49 (±3.08) | 1.38 (±2.32) | 4.44 (±3.26) | 4.60 (±3.44) |
| Cowpea in brine | 5.49 (±3.29)[ab] | 3.99 (±3.15) | 0.97 (±1.77) | 4.92 (±3.68) | 4.64 (±3.57) |
| Amaranth in cream sauce | 5.51 (±2.47)[ab] | 3.39 (±2.88) | 2.89 (±2.27) | 2.60 (±3.01) | 2.07 (±2.86) |
| Swiss chard in cream sauce | 4.68 (±2.86)[a] | 3.53 (±3.30) | 2.61 (±2.64) | 3.10 (±3.15) | 2.96 (±3.67) |
| Cleome in cream sauce | 6.14 (±2.98)[bc] | 4.67 (±3.19) | 1.44 (±2.36) | 3.65 (±3.22) | 3.61 (±3.48) |
| Cowpea in cream sauce | 4.86 (±2.81)[a] | 3.76 (±3.08) | 2.02 (±2.21) | 3.31 (±3.00) | 3.51 (±3.25) |
| p-value | 0.03 | 0.74 | 0.24 | 0.34 | 0.12 |

abc = means in a row with different letters differed significantly ($p < 0.05$).

**Table 5 Effects of vegetable species, canning medium and their interaction on the flavor attributes of canned green leafy vegetables as evaluated by a trained descriptive sensory panel**

| Comparisons | Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Sweet | Sour | Salty | Umami | Bitter | Pungent |
| Effect of vegetable species | | | | | | |
| Amaranth | 3.94 (±3.43)[c] | 0.83 (±1.37)[a] | 4.06 (±2.44) | 3.45 (±3.28) | 0.80 (±1.79) [a] | 1.15 (±1.93)[a] |
| Swiss chard | 3.33 (±2.95)[c] | 1.12 (±1.68)[ab] | 3.90 (±2.46) | 3.42 (±3.11) | 1.43 (±2.68)[a] | 1.92 (±2.81)[b] |
| Cleome | 0.97 (±1.59)[a] | 3.20 (±3.41)[c] | 4.01 (±2.91) | 2.97 (±3.48) | 6.29 (±3.22)[c] | 4.48 (±3.18)[c] |
| Cowpea | 2.40 (±2.65)[b] | 1.53 (±2.02)[b] | 4.00 (±2.54) | 3.37 (±3.20) | 2.59 (±3.21)[b] | 1.94 (±2.45)[b] |
| p-value | <0.001 | <0.001 | 0.98 | 0.16 | <0.001 | <0.001 |
| Effect of canning medium | | | | | | |
| | 2.27 (±2.76)[a] | 1.70 (±2.58) | 4.32 (±2.62)[b] | 3.01 (±3.22)[a] | 2.99 (±3.62) | 2.24 (±2.93) |
| Cream sauce | 3.05 (±3.09)[b] | 1.64 (±2.58) | 3.67 (±2.51)[a] | 3.89 (±3.29)[b] | 2.56 (±3.36) | 2.50 (±2.89) |
| p-value | 0.01 | 0.81 | 0.02 | 0.01 | 0.13 | 0.35 |
| Interaction effect of vegetable species * canning medium | | | | | | |
| Amaranth in brine | 3.52 (±3.41) | 0.77 (±1.35) | 4.42 (±2.31) | 3.52 (±3.35) | 0.86 (±1.91) | 1.01 (±1.92) |
| Swiss chard in brine | 2.98 (±2.85) | 0.89 (±1.41) | 4.33 (±2.54) | 3.03 (±2.94) | 1.45 (±2.71) | 1.36 (±2.39) |
| Cleome in brine | 0.81 (±1.44) | 3.22 (±3.57) | 4.17 (±3.04) | 2.55 (±3.37) | 6.54 (±3.31) | 4.59 (±3.41) |
| Cowpea in brine | 1.78 (±2.13) | 1.70 (±2.27) | 4.35 (±2.63) | 2.93 (±3.24) | 3.11 (±3.39) | 2.01 (±2.42) |
| Amaranth in cream sauce | 4.37 (±3.43) | 0.89 (±1.41) | 3.71 (±2.54) | 4.54 (±3.19) | 0.73 (±1.68) | 1.28 (±1.95) |
| Swiss chard in cream sauce | 3.67 (±3.05) | 1.14 (±1.41) | 3.47 (±2.32) | 3.82 (±3.26) | 1.40 (±2.68) | 2.49 (±3.10) |
| Cleome in cream sauce | 1.14 (±1.73) | 3.17 (±3.29) | 3.84 (±2.79) | 3.39 (±3.57) | 6.03 (±3.14) | 4.36 (±2.95) |
| Cowpea in cream sauce | 3.01 (±2.98) | 1.35 (±1.76) | 3.66 (±2.42) | 3.80 (±3.13) | 2.07 (±2.97) | 1.86 (±2.51) |
| p-value | 0.72 | 0.90 | 0.92 | 1.00 | 0.60 | 0.27 |

**Table 5 continued**

| Comparisons | Attributes | | | | |
|---|---|---|---|---|---|
| | Chemical | Peppery | Viney | Buttery | Astringent |
| Effect of vegetable species | | | | | |
| Amaranth | 1.08 (±1.97)[a] | 0.15 (±0.57) | 5.23 (±3.23) | 3.40 (±3.35)[bc] | 2.00 (±2.62)[a] |
| Swiss chard | 1.55 (±2.72)[a] | 0.34 (±0.95) | 5.03 (±3.53) | 3.84 (±3.48)[c] | 2.21 (±2.85)[a] |
| Cleome | 4.24 (±3.26)[b] | 0.22 (±0.51) | 5.36 (±3.05) | 1.59 (±2.45)[a] | 4.75 (±3.36)[b] |
| Cowpea | 1.62 (±2.44)[a] | 0.38 (±0.94) | 4.67 (±3.20) | 2.93 (±3.12)[b] | 2.64 (±2.81)[a] |
| p-value | <0.001 | 0.15 | 0.49 | <0.001 | <0.001 |
| Effect of canning medium | | | | | |
| Brine | 2.12 (±2.91) | 0.16 (±0.53)[a] | 5.41 (±3.20)[b] | 0.97 (±1.89)[a] | 3.01 (±3.10) |
| Cream sauce | 2.13 (±2.91) | 0.39 (±0.94)[b] | 4.73 (±3.28)[a] | 4.92 (±3.08)[b] | 2.79 (±3.13) |
| p-value | 0.95 | <0.001 | 0.04 | <0.001 | 0.45 |
| Interaction effect of vegetable species * canning medium | | | | | |
| Amaranth in brine | 0.99 (±1.80) | 0.08 (±0.29) | 5.71 (±3.19) | 1.09 (±1.94)[a] | 2.00 (±2.64) |
| Swiss chard in brine | 1.22 (±2.39) | 0.07 (±0.22) | 5.54 (±3.47) | 1.35 (±2.04)[a] | 2.26 (±2.84) |
| Cleome in brine | 4.59 (±3.30) | 0.19 (±0.46) | 5.20 (±3.08) | 0.56 (±1.44)[a] | 4.80 (±3.46) |
| Cowpea in brine | 1.66 (±2.47) | 0.31 (±0.86) | 5.20 (±3.12) | 0.87 (±2.03)[a] | 3.00 (±2.66) |
| Amaranth in cream sauce | 1.17 (±2.15) | 0.23 (±0.75) | 4.75 (±3.24) | 5.71 (±2.83)[cd] | 2.01 (±2.64) |
| Swiss chard in cream sauce | 1.89 (±3.01) | 0.61 (±1.27) | 4.52 (±3.54) | 6.33 (±2.77)[d] | 2.17 (±2.89) |
| Cleome in cream sauce | 3.89 (±3.21) | 0.25 (±0.56) | 5.51 (±3.05) | 2.63 (±2.81)[b] | 4.70 (±3.30) |
| Cowpea in cream sauce | 1.58 (±2.44) | 0.45 (±1.01) | 4.14 (±3.22) | 4.99 (±2.63)[c] | 2.28 (±2.93) |
| p-value | 0.36 | 0.12 | 0.40 | <0.001 | 0.82 |

abc = means in a row with different letters differed significantly ($p < 0.05$).

**Table 6 Effects of vegetable species, canning medium and their interaction on the texture/mouthfeel and overall aftertaste of canned green leafy vegetables as evaluated by a trained descriptive sensory panel**

| Comparisons | Attributes | | | | |
|---|---|---|---|---|---|
| | Metallic | Cohesive | Sandy | Chewy | Overall aftertaste |
| Effect of vegetable species | | | | | |
| Amaranth | 2.07 (±2.74)[a] | 4.24 (±2.77)[b] | 3.00 (±3.18)[b] | 4.61 (±2.69)[b] | 2.03 (±2.43)[a] |
| Swiss chard | 2.65 (±3.03)[a] | 1.60 (±1.80)[a] | 0.59 (±1.13)[a] | 2.22 (±1.90)[a] | 2.66 (±2.90)[a] |
| Cleome | 3.94 (±3.09)[b] | 5.18 (±2.67)[c] | 4.30 (±3.23)[c] | 5.93 (±2.47)[c] | 6.01 (±2.77)[b] |
| Cowpea | 2.62 (±2.93)[a] | 7.83 (±2.45)[d] | 2.44 (±2.92)[b] | 8.45 (±2.04)[d] | 2.69 (±2.36)[a] |
| p-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Effect of canning medium | | | | | |
| Brine | 2.94 (±3.04) | 5.11 (±3.33)[b] | 2.61 (±2.99) | 5.74 (±3.15)[b] | 3.31 (±3.15) |
| Cream sauce | 2.70 (±3.00) | 4.32 (±3.24)[a] | 2.56 (±3.12) | 4.88 (±3.22)[a] | 3.38 (±2.94) |
| p-value | 0.43 | <0.001 | 0.87 | <0.001 | 0.80 |
| Interaction effect of vegetable species * canning medium | | | | | |
| Amaranth in brine | 2.12 (±2.76) | 4.92 (±2.64) | 3.11 (±3.11) | 5.15 (±2.50) | 1.87 (±2.38)[a] |
| Swiss chard in brine | 2.46 (±2.84) | 1.68 (±1.77) | 0.66 (±1.25) | 2.57 (±1.99) | 2.06 (±2.62)[a] |
| Cleome in brine | 4.46 (±3.28) | 5.69 (±2.63) | 4.14 (±3.09) | 6.53 (±2.39) | 6.52 (±2.69)[c] |
| Cowpea in brine | 2.72 (±2.79) | 8.14 (±2.53) | 2.52 (±2.99) | 8.70 (±2.06) | 2.79 (±2.48)[ab] |
| Amaranth in cream sauce | 2.01 (±2.75) | 3.57 (±2.75) | 2.88 (±3.28) | 4.08 (±2.79) | 2.19 (±2.48)[a] |
| Swiss chard in cream sauce | 2.83 (±3.22) | 1.52 (±1.84) | 0.53 (±1.01) | 1.87 (±1.76) | 3.25 (±3.06)[b] |
| Cleome in cream sauce | 3.43 (±2.82) | 4.68 (±2.64) | 4.46 (±3.40) | 5.34 (±2.43) | 5.50 (±2.79)[c] |
| Cowpea in cream sauce | 2.53 (±3.08) | 7.52 (±2.37) | 2.37 (±2.88) | 8.21 (±2.01) | 2.58 (±2.25)[ab] |
| p-value | 0.43 | 0.37 | 0.90 | 0.70 | 0.03 |

abc = means in a row with different letters differed significantly ($p < 0.05$).

intense, while amaranth products had the least intense aftertaste. Among all the retort processed products, cleome in brine and cleome in cream sauce had a more intense overall aftertaste than swiss chard in cream sauce, cowpea in brine, and cowpea in cream sauce, all of which in turn, had a more intense overall aftertaste than amaranth in cream sauce, swiss chard in brine, and amaranth in brine.

**Principal component analysis**

The principal component analysis (PCA) of the descriptive attributes across canned leafy vegetable samples is shown in Figs 1 and 2. The first three factors of the PCA described 90 % of the total variance. The biplots show the mapping space of the loadings of attributes (A) and the mapping space of the samples (B). The first principal component (PC), shown in Fig 1, which accounted for 54.8 % of the variance, contrasted amaranth, swiss chard, and cowpea leaves in cream sauce on the right, from cleome leaves in brine and in cream sauce on the left. Amaranth in cream sauce was characterized by sweet, umami, popcorn, and buttery, in contrast to cleome in brine and cleome in cream sauce, both of which were characterized by bitter, astringent, sour, and chemical flavors. Swiss chard in cream sauce, and cowpea in cream sauce, which were pairwise close to amaranth in cream sauce on this component, had the same flavor attributes as well. The second principal component (22.1% of the variance) separated swiss chard in brine and amaranth in brine, at the top, which were characterized by more intense green-grassy, viney aromas and salty taste, from swiss chard in cream sauce, and cowpea in cream sauce at the bottom, characterized by a buttery flavor. The third principal component (13.1% of variance) shown in Fig 2, separated cowpea in brine, and cowpea in cream sauce from all the other products, both products being characterized as chewy and cohesive.

**Consumer acceptance**

Table 7 shows the results of the consumer acceptance test carried out on the African green leafy vegetables in cream sauce canned products. There was a significant

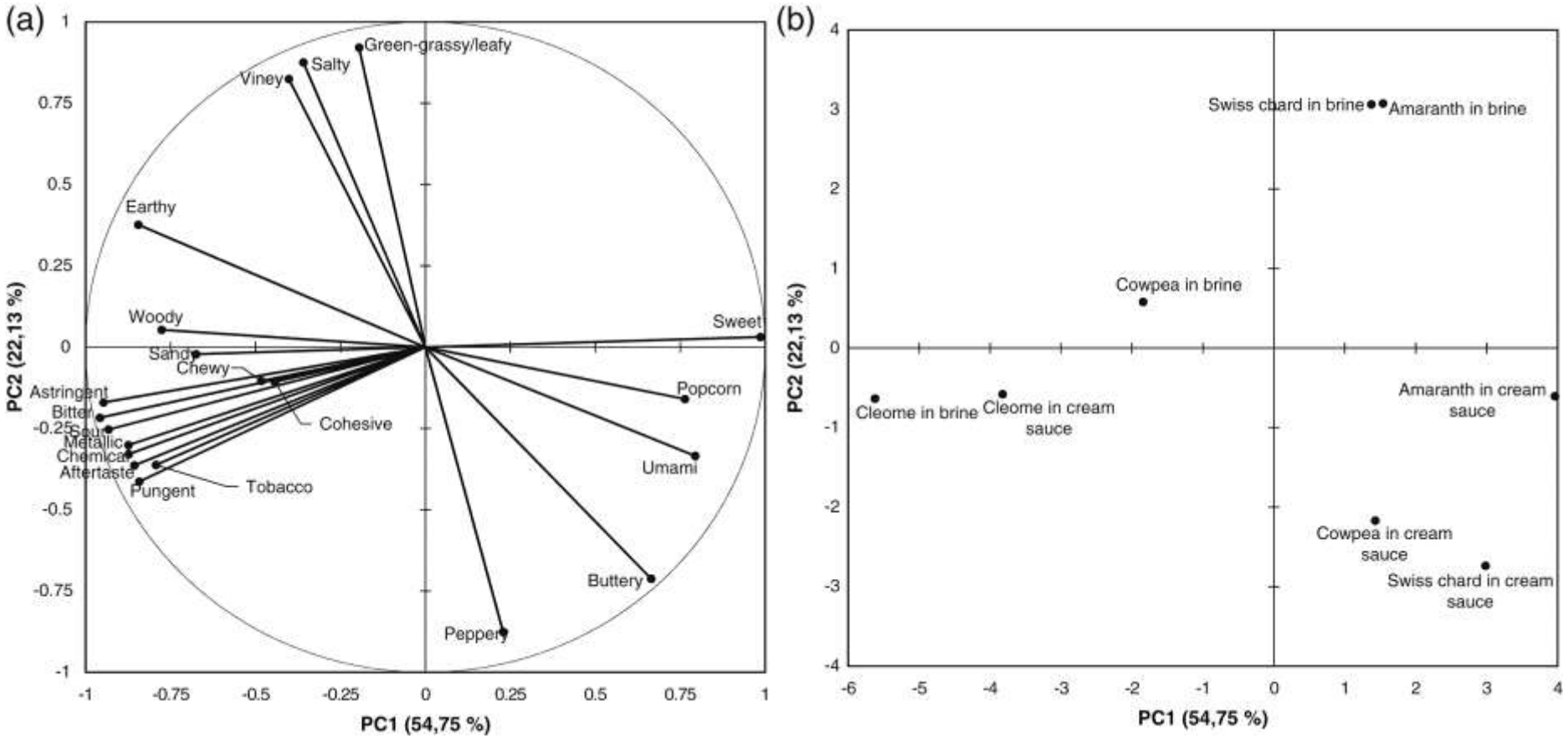


**Figure 1: PCs 1 and 2 of a cov-PCA for sensory attributes of canned green leafy vegetables in brine and cream sauce:**
A= map of attribute space depicting loadings of descriptors; B= score plot depicting loadings of samples

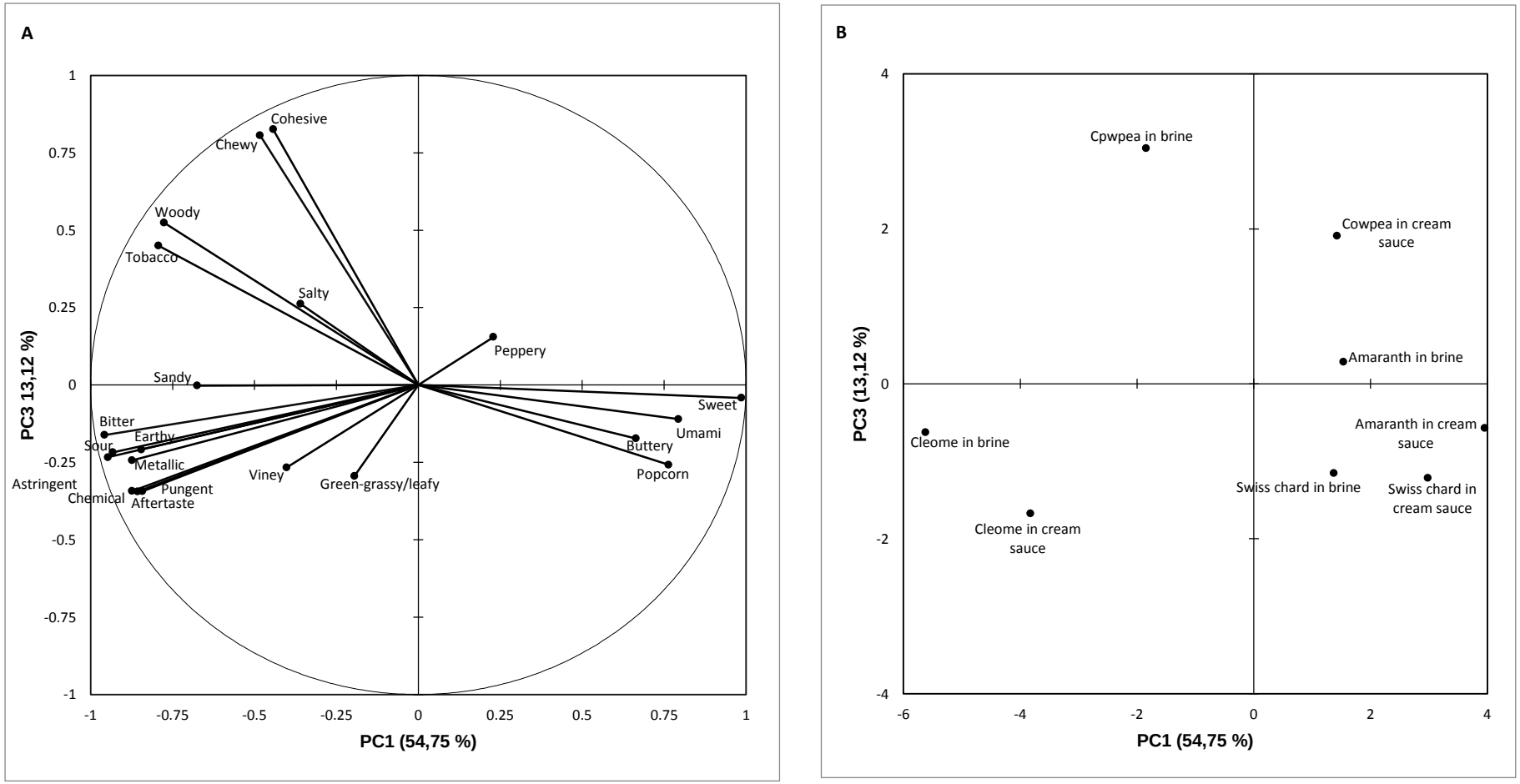


**Figure 2: Principal components 1 and 3 of a covariance-principal component analysis (Cov-PCA) for sensory attributes of canned green leafy vegetables in brine and cream sauce**.

A= map of attribute space depicting loadings of descriptors; B= score plot depicting loadings of samples

difference ($p < 0.001$) in consumer liking among the different products.

**Table 7 Consumer acceptance of four green leafy vegetables retort-processed in cream sauce as evaluated by young females (n= 96; ages: 19-25 years) using the Simplified Labelled Affective Magnitude (SLAM) scale (0= greatest imaginable dislike, 50= neither like nor dislike, 100= greatest imaginable like)**

| Product | Liking |
|---|---|
| Amaranth | 64 (±37)[c] |
| Swiss chard | 58 (±37)[c] |
| Cleome | 29 (±35)[a] |
| Cowpea | 47 (±33)[b] |

The amaranth and swiss chard products were liked more than the cowpea product, which in turn was liked more than the cleome product. The cleome product was liked the least and received a very low mean score.

***Extended internal preference mapping***

To understand the sensory attributes driving consumer liking/disliking of these products, an extended internal preference mapping was conducted on the data matrix (Figs 3 and 4).

Fig 3 and 4 give an overall picture of how the sensory characteristics of the canned leafy vegetables drove consumer preferences. The consumer vectors indicate the direction and position of greatest preference for the four products. If a vector is extended in the opposite direction, that would indicate the direction of lower preference for that consumer. The first and second principal dimensions, PD1 and PD2, (Fig 3) explained 51 % and 26 % of the variance respectively, and these showed that the

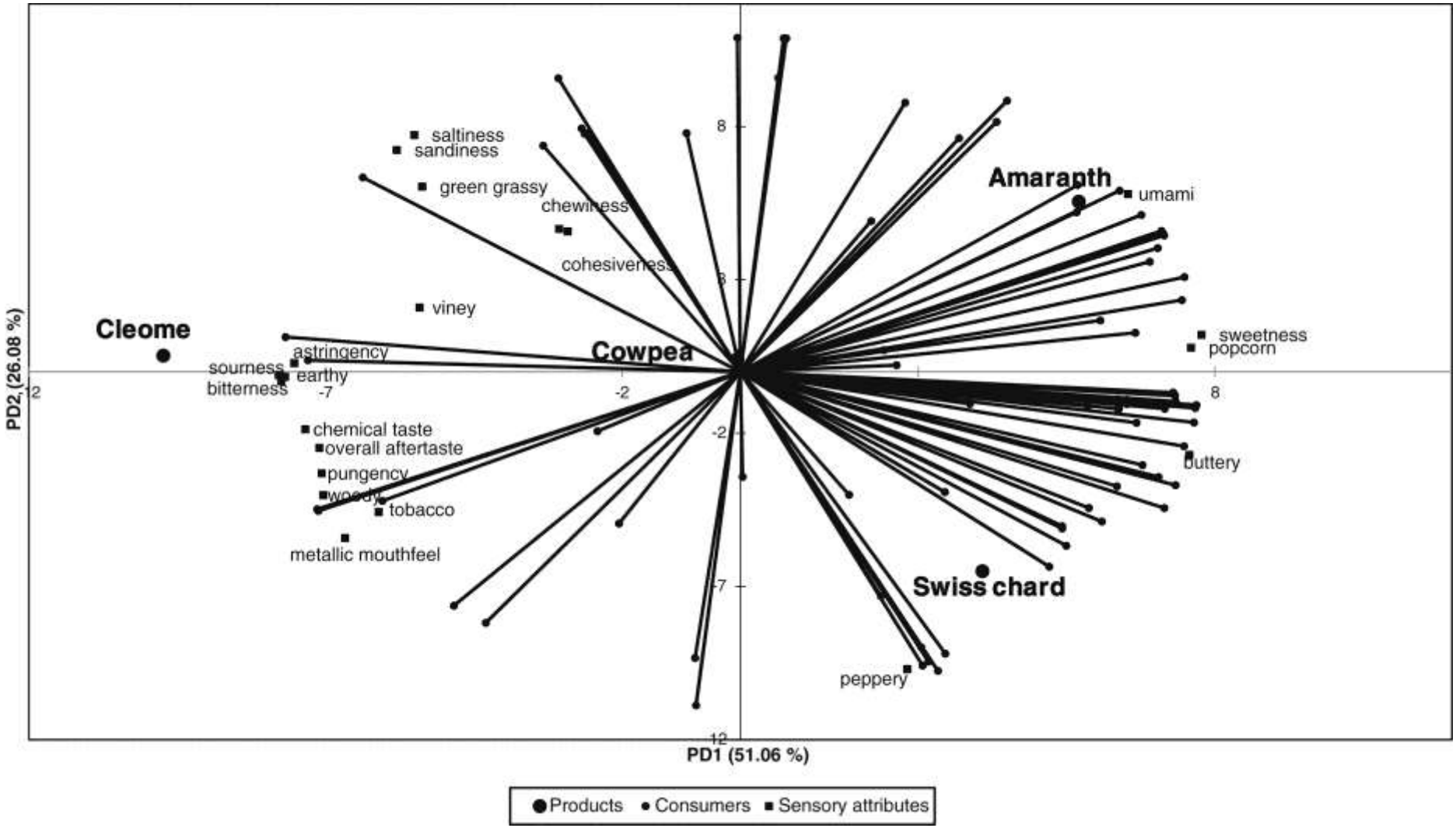


**Figure 3** : **First and second principal dimensions of an extended internal preference map for retort-processed amaranth, cowpea, cleome, and Swiss chard leaves in cream sauce as evaluated by female consumers (*n* = 96).**

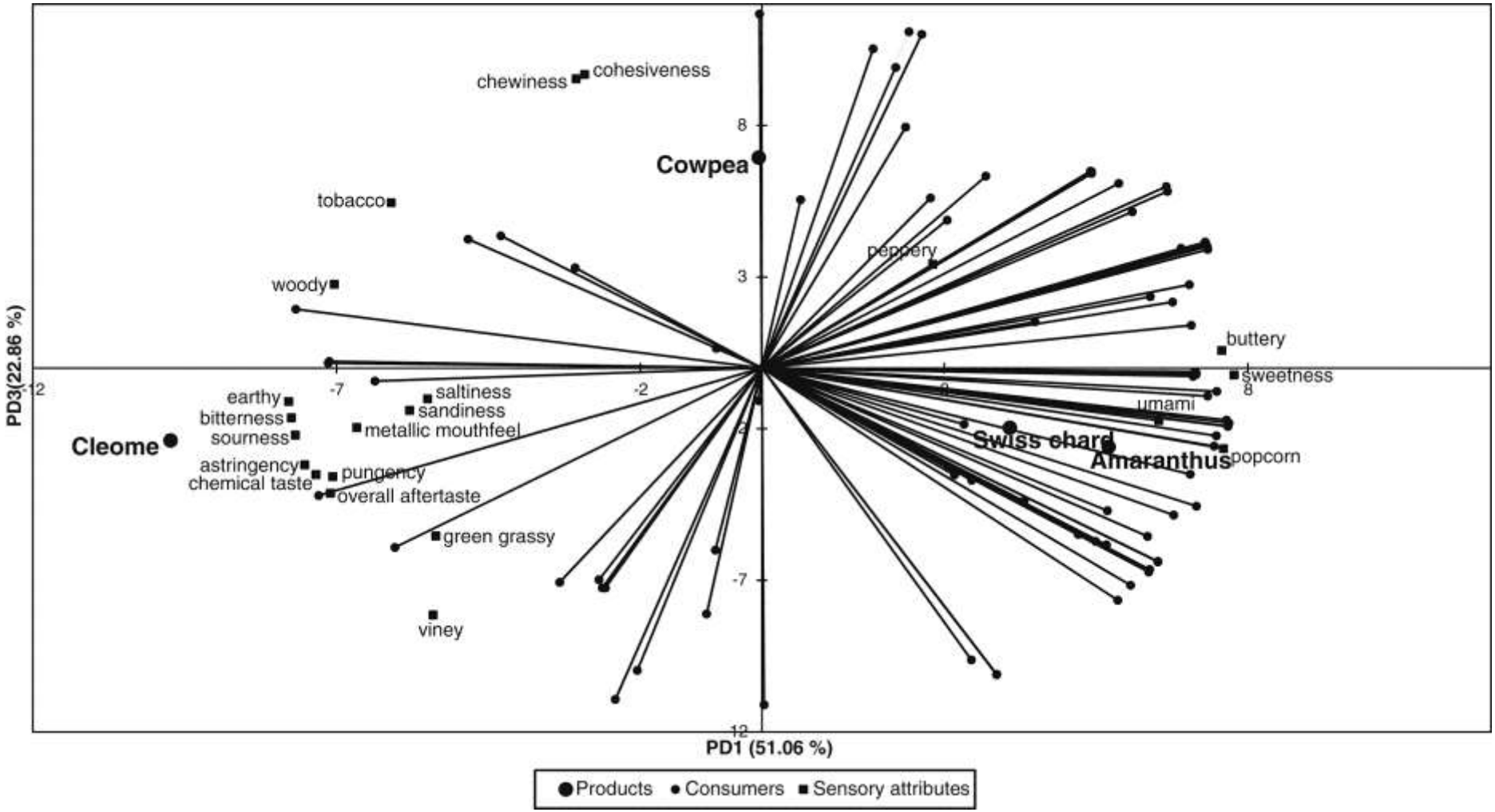


**Figure 4 : First and third principal dimensions of an extended internal preference map for retort-processed amaranth, cowpea, cleome, and Swiss chard leaves in cream sauce as evaluated by young female consumers (*n* = 96).**

higher liking for the amaranth and swiss chard products could be attributed to their sweet, umami and buttery flavors, as well as their popcorn aroma. The map also show that the greater dislike for the cleome product could be attributed to its sour, bitter, chemical, astringent and pungent flavors, as well as its woody aroma. Interestingly PD1 also showed a very small number of consumers (n = 13) who preferred the cleome product. The third principal dimension PD3 (Fig 4) explained an additional 23 % of the variance and it identified a small number of consumers (n = 20) that preferred the cowpea product. The preference for cowpea by some consumers could probably be attributed to its chewy and cohesive texture. Overall acceptance was better correlated with texture and flavor attributes than with aroma and aftertaste attributes.

## DISCUSSION

Descriptive profiling separated the amaranth and swiss chard products from the cleome and cowpea products. Both amaranth and swiss chard were sweeter and more buttery, while cleome was bitterer, sourer, more pungent, astringent with a chemical flavour, metallic mouthfeel, sandy texture and more intense overall aftertaste. Canned cowpea leaves in brine and cream sauce were more chewy and cohesive. Sweetness, bitterness, sourness and astringency differentiated the products more than the other flavor attributes. Canned cowpea and cleome leaves were both more bitter than amaranth and swiss chard, but cleome was by far the most bitter of all the leafy vegetable species. This suggests that there must be a difference in the type, structure or concentration of bitterness-inducing compounds between the two vegetables, with cleome probably having a higher concentration of such compounds. Research on bitterness has shown that there is a wide range of bitter compounds in nature e.g. plant alkaloids, isoflavones, and glucosinolates, and besides this bitter taste is very specific to isomers of similar molecular structure.[15] Small structural variations can change the taste profile or strongly influence the bitter taste detection threshold.[15] As examples, the amino acid L-tryptophan is bitter but the D-enantiomer shows a distinct sweet taste; the hesperitin rutinoside

(hesperidin) is tasteless but the positional isomer hesperetin neohesperidoside (neohesperidin) is strongly bitter.[15] The negative correlation between the leafy vegetable judged to be sweet against bitter, is supported by work done to describe flavor of fresh leafy vegetables such as spinach, swiss chard, lettuce and kale, by Talavera- Bianchi *et al.*.[16] Their results suggested that when leafy vegetable samples were bitter and astringent, they were not considered as sweet overall or vice-versa.

The different vegetable species were seen to have characteristic sensory attributes that described them. Amaranth was characterized by the attributes of sweet taste, green-grassy aroma, and a popcorn aroma. Swiss chard, in brine or cream sauce, was similarly characterized by the attributes of sweet taste, green grassy/leafy aroma but less of a popcorn aroma. In addition, amaranth had an extremely soft texture. This soft texture could have been due to a combination of freeze damage during freezing, leading to softening of tissues, and a similar effect caused by retort processing. It must be noted that cowpea leaves were the only leaves not adjudged to be soft. Canned cowpea leaves were characterized by bitter taste, cohesive and chewy texture, as well as having strong tobacco and woody aroma. The cohesive and chewy texture of the cowpea leaves could be attributed to their high cellulose and pectin contents.[17] The tobacco aroma could be attributed to the degradation of carotenoids present in the cowpea leaves. Norisoprenoids, also known as ionones, are 13-carbon compounds resulting from the oxidative 9, 10 bond-degradation of carotenoids like β- carotene, zeaxanthin, astaxanthin and lutein.[18] This degradation gives rise to several ionones and their derivatives, such as β-damascenone and megastigmatrienones, all of them typical components of tobacco aroma.[18]. Ionones could also be responsible for the woody aroma, as β-ionone and α-ionone have been identified as contributing to woody aroma in tea leaves.[19] Canned cleome leaves in brine or cream sauce, were characterized by intense bitterness and overall aftertaste, as well as being astringent, sour tasting, and pungent. Astringency, defined as a drying or puckering mouth feel detectable

throughout the oral cavity, may be due to a complexing reaction between polyphenols and proteins of the mouth and saliva.[20] This could indicate that the astringent tasting cleome leaves might have had a higher concentration of polyphenols than the others. A phytochemical screening of *Cleome gynandra* leaves indicated an abundance of gallic tannins, and anthocyanins. [21] Organic acids are significant components responsible for sour tastes,[22] and the high intensity of sourness characterizing cleome leaves, could indicate the presence of organic acids. In addition, cleome was texturally perceived as being sandy. The sandy mouth-feel noticed in the cleome products may be due to some crystals observed in the product after canning. These crystals could be as a result of the interaction of calcium and oxalic acid in the vegetable, to form calcium oxalate, or yellow crystals of glucosides found naturally in vegetables. Cleome leaves have been reported to contain oxalates up to 0.088g $kg^{-1}$ edible portion.[23]

All the canned products had a green-grassy/leafy aroma as well as an earthy aroma and viney flavor. These attributes have been reported to be present in green leafy vegetables, but in varying intensities among samples (green swiss chard, spinach, beet, among other vegetables).[16] Various volatile aldehydes and alcohols with six carbon atoms and corresponding hexyl ester derivatives have been reported to contribute primarily to perceived green odor or aroma.[24] Hexanal and closely related compounds, in particular have been most commonly associated with green characteristics such as cut grass.[24]

Cream sauce as a canning medium had the effect of increasing sweet taste and buttery flavor, as well as the popcorn aroma. The presence of a popcorn aroma and its prominence in the cream sauce products could be attributed to the corn starch which was used in the cream sauce. The presence of the corn component could have led to the production of characteristic popcorn volatiles such as 2-acetyl pyrazine, 2-acetyl 1 pyrroline, and *N*-furfuryl pyrrole (which interestingly also has a green hay-like aroma) by a Strecker degradation reaction.[25-28] Conversely, there was a reduction in green-

grassy/ leafy, viney, and woody aroma. The lower intensities of green-grassy/leafy, viney, and woody aroma in products canned in cream sauce could be attributed to the reduced volatility of the responsible lipophilic aroma compounds in the more viscous cream sauce than in the less viscous brine. The increase in sweetness of the leafy vegetables in cream sauce could be attributed to the sweetening effect of sugars in the cream sauce, from ingredients such as milk powder, and wheat flour. Also fat from the vegetable fat and milk could have had the effect of increasing sweetness and buttery flavor. Similar results have been reported elsewhere for cauliflower and broccoli.[29]

Texture of the leaves was also affected by canning medium, as the longer retort-processing times for products with cream sauce as the canning medium compared to the in-brine products could have led to the greater softening of leaf tissues. Brine as a canning medium had an effect on saltiness. The brine products were saltier that the cream sauce products. This was expected as the salt concentration in the brine (1.5%) was higher than that of the cream sauce (1.2%).

The consumer evaluation and preference mapping showed that the flavor attributes of sweetness, umami, and buttery as well as popcorn aroma, were the driving factors for consumer liking. Understanding which sensory attributes drive consumer acceptance of food and beverage products is critical to the food and beverage industries.[14] Cleome samples which were characterized as bitter, sour and astringent were the least liked, and this is supported by previous work reporting that bitter taste is one of the important reasons for rejection of ALVs.[3] Although the expectation was that the use of a cream sauce as canning medium would reduce the bitterness, sourness, and astringency of canned ALVs, the differences across vegetable species were much more noticeable than the between canning medium effects. Ares, Barreiro, Deliza and Gámbaro,[30] in their work on the effect of milk in reducing bitterness and astringency of polyphenolic extracts from some Uruguayan plants, found that milk was very effective in reducing the bitterness and astringency of the extracts. However this effect was not observed in

this study. In general, there are three approaches to suppressing bitterness: physio-chemical interactions (ingredient/compound) in a food or beverage matrix, oral peripheral physiological interactions with receptor cells (e.g., via receptor inhibitors), and central cognitive mixture suppression (e.g., via taste-taste and taste- aroma interactions).[31] It had been expected that with use of cream sauce as canning medium, the milk lipids would have had a physico-chemical influence on bitterness, in addition to the components of fats, fatty acids, also modifying bitterness via interactions in the oral periphery.[32] This is particularly relevant considering that it is already known that people in rural areas boil these leaves in milk in order to reduce the bitterness.[33] The bitterness inducing compounds could preferentially partition into the fat-phase of the emulsion thereby diluting the concentration in the aqueous phase. Tastants in the fat phase would be less able to access taste receptors, and thus less effective at reaching and activating bitter taste receptors.[31] The very high bitterness of cleome, in brine, and in cream sauce, as well as the great consumer dislike for the cleome in cream sauce product, driven partly by bitterness, suggests that the concentration of bitterness inducing components in cleome was probably too high to observe the expected bitterness reduction with use of a cream sauce canning medium.

## CONCLUSIONS

Differences across the canned African green leafy vegetable species are much more noticeable than differences between in cream sauce and in brine canning mediums. Canned amaranth and swiss chard leaves have similar sensory profiles, which are different from canned cowpea leaves, and even more so than canned cleome leaves. Swiss chard and amaranth leaves are characterized by sweetness, and buttery flavor, as well as a popcorn aroma. Canned cowpea leaves are characterized by woody, and tobacco aromas, as well as a chewy and cohesive texture. Cleome leaves are characterized by bitterness, sourness, pungency, and chemical taste, as well as woody and tobacco aroma, astringency, sandiness and metallic mouthfeel, and intense overall

aftertaste.

Young, female consumers preferred amaranth and swiss chard leaves, canned in cream sauce, similarly and rated these higher than cowpea leaves which are in turn rated higher than cleome leaves. This shows the potential of amaranth and swiss chard leaves for commercialization as a canned relish targeted at young consumers. Hedonic ratings for cowpea leaves in cream sauce suggest that some product reformulations, e.g. increased fat content of the cream sauce, to enhance bitter masking would be required to increase chances of a commercially viable product. Cleome leaves in cream sauce, are rated so low that it is obvious that more research has to be carried out to identify and quantify the bitterness inducing compounds in the leaves, as well as develop methods or culinary preparations to reduce this bitterness, before they could be used in a commercially canned relish targeted at young consumers. The results of this study, should form the basis of further research into the bitterness inducing compounds in cleome, and methods of reducing the bitterness in canned products using these leaves, to aid the development of commercially viable products that are acceptable to consumers. The utilization of indigenous leafy vegetables in acceptable, commercial, shelf-stable products could aid in the conservation of these plant species; increase consumption of these vegetables by a younger generation of Africans; and could provide new food business opportunities .

## ACKNOWLEDGEMENT

The authors wish to acknowledge the Centre for Scientific and Industrial Research (CSIR), and the Agricultural Research Council (ARC) for the provision of African green leafy vegetables used in this study. The paper is dedicated to the memory of Prof Amanda Minnaar who contributed greatly to the planning and execution of the research.

# REFERENCES


1. Van Rensburg WJ, Van Averbeke W, Slabbert R, Faber M, Van Jaarsveld P, Van Heerden I, Wenhold F and Oelofse A, African leafy vegetables in South Africa. *Water SA* **33**:317-326 (2007).
2. Voster IH, Van Rensburg WJ, Van Zijl J and Venter SL, Re-Creating awareness of traditional leafy vegetables in communities. *African Journal of Food, Agriculture, Nutrition and Development* **7**:132-136 (2007).
3. Vorster IH, Van Rensburg WJ, Van Zijl J and Venter SL, The importance of traditional leafy vegetables in South Africa. *African Journal of Food, Agriculture, Nutrition and Development* **7**:49-60 (2007).
4. Acedo A, Postharvest technology for leafy vegetables, in *AVRDC-ADB Postharvest Projects*, Ed by Mecozzi M. AVRDC-The World Vegetable Center, Taiwan, p 67 pp. (2010).
5. Lawless HT and Heymann H, *Sensory evaluation of food: Principles and practices*. Springer, New York, USA (2010).
6. Venter SL, Van Rensburg Willem J, Vorster HJ, Van Den Heever E and Van Zijl J, Promotion of African leafy vegetables within the Agricultural Research Council - Vegetable and Ornamental Plant Institute: The impact of the project. *African Journal of Food Agriculture Nutrition and Development* **7**:144-149 (2007).
7. Cayot N, Sensory quality of traditional foods. *Food Chem* **102**:445-453 (2007).
8. Macintyre U, Kruger H, Venter C and Vorster H, Dietary intakes of an African population in different stages of transition in the North West Province, South Africa: the THUSA study. *Nutrition Research* **22**:239-256 (2002).
9. Tucker GS and Featherstone S, *Essentials of thermal processing*. Wiley-Blackwell, Oxford UK (2011).
10. Einstein M, Descriptive techniques and their hybridization, in *Sensory Science Theory and Applications in Foods*, ed. by Lawless HT and Klein B. Marcel Dekker Inc., New York, pp 317-338 (1991).
11. Tomic O, Luciano G, Nilsen A, Hyldig G, Lorensen K and Næs T, Analysing sensory panel performance in a proficiency test using the PanelCheck software. *European Food Research and Technology* **230**:497-511 (2010).
12. Lawless HT, Cardello AV, Chapman KW, Lesher LL, Given Z and Schutz HG, A comparison of the effectiveness of hedonic scales and end-anchor compression effects. *Journal of Sensory Studies* **25**:18-34 (2010).
13. Borgognone MaG, Bussi J and Hough G, Principal component analysis in sensory analysis: covariance or correlation matrix? *Food quality and preference* **12**:323-326 (2001).
14. Guinard J-X, Uotani B and Schlich P, Internal and external mapping of preferences for commercial lager beers: comparison of hedonic ratings by consumers blind versus with knowledge of brand and price. *Food Quality and Preference* **12**:243-255 (2001).
15. Ley JP, Masking bitter taste by molecules. *Chemosensory Perception* **1**:58-77 (2008).
16. Talavera-Bianchi M, Chambers Iv E and Chambers DH, Lexicon to describe flavor of fresh leafy vegetables. *Journal of Sensory Studies* **25**:163-183 (2010).
17. Nyambaka H and Ryley J, Multivariate analysis of the sensory changes in the dehydrated cowpea leaves. *Talanta* **64**:23-29 (2004).
18. Maldonado-Robledo G, Rodriguez-Bustamante E, Sanchez-Contreras A, Rodríguez-Sanoja R and Sanchez S, Production of tobacco aroma from lutein. Specific role of the microorganisms involved in the process. *Applied microbiology and biotechnology* **62**:484-488 (2003).
19. Lv H-P, Zhong Q-S, Lin Z, Wang L, Tan J-F and Guo L, Aroma characterisation of Pu-erh tea using headspace-solid phase microextraction combined with GC/MS and GC–olfactometry. *Food Chemistry* **130**:1074-1081 (2012).
20. Drewnowski A and Gomez-Carneros C, Bitter taste, phytonutrients, and the consumer: a review. *The American Journal of Clinical Nutrition* **72**:1424-1435 (2000).
21. Ahouansikpo E, Atanasso J, Dansi A, Adjatin A, Azize O and Sanni A, Ethnobotany,

phytochemical screening and toxicity risk of *Cleome gynandra* and *Cleome viscosa*, two traditional leafy vegetables consumed in Benin. *International Journal of Current Microbiology and Applied Sciences* **5**:813-829 (2016).
22. Salles C, Nicklaus S and Septier C, Determination and gustatory properties of taste-active compounds in tomato juice. *Food Chemistry* **81**:395-402 (2003).
23. Van Den Heever E and Venter S, Nutritional and medicinal properties of Cleome gynandra, in *I International Conference on indigenous vegetables and legumes Prospectus for fighting poverty, hunger and malnutrition*, Ed by Chadha MI, Gowda CLL and Kuo G. International Society for Horticultural Science, Hyderabad, India, pp 127-130 (2006).
24. Hongsoongnern P and Chambers EI, A lexicon for green odor or flavor and characteristics of chemicals associated with green. *Journal of Sensory Studies* **23**:205-221 (2008).
25. Buttery RG, Ling LC and Stern DJ, Studies on popcorn aroma and flavor volatiles. *J Agric Food Chem* **45**:837-843 (1997).
26. Hofmann T and Schieberle P, New and convenient syntheses of the important roasty, popcorn-like smelling food aroma compounds 2-acetyl-1-pyrroline and 2-acetyltetrahydropyridine from their corresponding cyclic α-amino acids. *J Agric Food Chem* **46**:616-619 (1998).
27. Van Boekel MaJS, Formation of flavour compounds in the Maillard reaction. *Biotechnol Adv* **24**:230-233 (2006).
28. Walradt JP, Lindsay RC and Libbey LM, Popcorn flavor: identification of volatile compounds. *J Agric Food Chem* **18**:926-928 (1970).
29. Meinert L, Frøst MB, Bejerholm C and Aaslyng MD, Enhancing the sensory quality of vegetables by decreasing some less-desired sensory properties with low-fat pork gravy. *Journal of Culinary Science & Technology* **9**:113-131 (2011).
30. Ares G, Barreiro C, Deliza R and Gámbaro A, Alternatives to reduce the bitterness, astringency and characteristic flavour of antioxidant extracts. *Food Research International* **42**:871-878 (2009).
31. Keast RSJ, Modification of the bitterness of caffeine. *Food Quality and Preference* **19**:465-472 (2008).
32. Koriyama T, Wongso S, Watanabe K and Abe H, Fatty acid compositions of oil species affect the 5 basic taste perceptions. *J Food Sci* **67**:868-873 (2002).
33. Van Rensburg WJ, Cloete M, Gerrano AS and Adebola PO, Have you considered eating your weeds? *American Journal of Plant Sciences* **05**:1110-1116 (2014).