PSP with trained assessors as alternative for descriptive analysis of a product with a complex sensory profile

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ABSTRACT

Rapid sensory profiling of a product over time presents a challenge in quality control, particularly when the product has a complex aroma and flavour profile. Polarized sensory positioning (PSP), based on the comparison of samples to fixed references, allows for rapid sensory profiling and data collection across multiple sessions. The efficacy of partial and global PSP for broad-based sensory profiling of honeybush infusions, prepared from five *Cyclopia* species (*C. genistoides*, *C. subternata*, *C. maculata*, *C. intermedia* and *C. longifolia*), was investigated. Trained assessors conducted partial PSP on aroma (P-PSP***a***) and palate (P-PSP***p***), as well as global PSP. A continuous scale and five poles, representing the respective *Cyclopia* species, were used to evaluate the honeybush infusions. Data, aggregated over three sessions per PSP variation, were subjected to multiple factor analysis (MFA). Similar product configurations were obtained when comparing the principal component analysis (PCA) bi-plot of the descriptive sensory analysis data and the MFA plots of partial and global PSP (RV coefficients $\geq$ 0.87). P-PSP***a*** was as effective as global PSP in discriminating between honeybush tea samples. *Cyclopia genistoides*, *C. longifolia* and *C. maculata* herbal teas formed one group, indicating that these herbal teas could be blended without losing sensory character. *Cyclopia subternata* and *C. intermedia* formed separate groups, indicating their suitability for species-specific marketing. Application of P-PSP***a*** by trained assessors is recommended as rapid method for quality control in the honeybush tea industry.

Keywords:

Rapid profiling; Polarized sensory positioning; Reference-based method; Multiple factor analysis; *Cyclopia* species

1. Introduction

Several rapid methodologies are available for global sensory characterisation of products (Varela & Ares, 2012). One such rapid method is projective mapping (PM), however, PM has the disadvantage that the entire sample set must be presented simultaneously for evaluation. This is problematic when evaluating large sample sets or when comparing data collected over multiple sessions, as is frequently the case in quality control by industry (Moelich, Muller, Joubert, Næs, & Kidd, 2017). Polarized sensory positioning (PSP) addresses this limitation (Teillet, Schlich, Urbano, Cordelle, & Guichard, 2010) by measuring the overall similarity or dissimilarity of products in relation to a physical reference sample or "sensory pole" (Teillet, 2014; Valentin, Chollet, Lelièvre, & Abdi, 2012) with data aggregation over multiple sessions.

Two PSP approaches have been proposed: PSP using a continuous scale and triadic PSP (t-PSP) (Teillet, 2014). In the case of continuous-scale PSP the panel of assessors need to indicate the similarity (or dissimilarity) of each sample relative to each pole using an unstructured line scale where 0 indicates perceived similarity and 100 indicates dissimilarity to the pole. Triadic PSP requires assessors to indicate the pole most similar to the sample and the pole least similar to the sample however no scale values are given in this variation of PSP.

The choice of poles is regarded as the most critical step when conducting PSP (Ares, Antúnez, Oliveira, Alcaire, Giménez, Berget, Næs, & Varela, 2015). Three poles, that are stable over time and represent the total sensory space of the product category in question are recommended (De Saldamando, Delgado, Herencia, Giménez, & Ares, 2013; Teillet, 2014). Prior knowledge of the sensory space is however necessary for the effective selection of poles (Teillet, 2014). Classical descriptive sensory analysis (DSA) has been regarded as the method of choice when it is important to fully characterise the sensory space (Lawless & Heymann, 2010; Nishida, Lestringant, Cantu, & Heymann, 2021) and to ultimately select suitable poles for PSP.

The application of PSP has delivered promising results, e.g. mineral water (Teillet et al., 2010), orange-flavoured drinks (Ares, De Saldamando, Vidal, Antúnez, Giménez, & Varela, 2013; De Saldamando et al., 2013), functional yoghurts (Cadena, Caimi, Jaunarena, Lorenzo, Vidal, Ares, Deliza, & Giménez, 2014), chocolate milk beverages (Antúnez, Salvador, De Saldamando, Varela, Giménez, & Ares, 2015; Ares et al., 2015) and food-grade astringent agents (Fleming, Ziegler, & Hayes, 2015). All of these studies, except that of Teillet et al. (2010), used consumers for PSP. However, a trained panel is recommended when quality control of a product is the objective (Ares & Varela, 2017). Research has shown that both global PSP and partial PSP deliver results highly correlated to that of DSA when using a trained panel (Varela, Svartebekk Myhrer, Næs, & Hersleth, 2014). With global PSP all sensory characteristics of the product are considered, whereas with partial PSP sub-categories (aroma, flavour or taste) are considered (Varela et al., 2014).

Cyclopia species, used to produce honeybush tea, not only differ in their aroma and flavour profiles, but also in their complexity (Joubert, De Beer, Malherbe, Muller, Louw, & Gelderblom, 2019). Some processors blend different *Cyclopia* species to supply in demand, whereas others prefer to produce species-specific honeybush tea. Irrespective of the final product, industry requires a rapid sensory method for global characterisation of production batches to ensure that the final product meets the required in-house sensory specifications.

The aim of the current study was to evaluate the validity of continuous-scale PSP for the sensory profiling of honeybush tea produced from five *Cyclopia* species. A large database on the sensory qualities of the *Cyclopia* species, obtained through DSA, was available for effective pole selection. Trained assessors evaluated the herbal teas of the respective *Cyclopia* species using three variants of the PSP task, i.e. partial PSP on aroma (P-PSP***a***), partial PSP on palate (P-PSP***p***) and global PSP (all attributes). The use of PSP for the sensory characterisation of this herbal tea was validated by determining the similarity of the sample configurations obtained by PSP and DSA.

2. Materials and methods

The workflow for profiling a large set of samples using descriptive sensory analysis (DSA), subsequent selection of a sub-set of samples for polarized sensory positioning (PSP) and the data analysis of both sample sets is shown in Fig. 1. Trained assessors were used for both DSA and PSP.

2.1 Descriptive sensory analysis

2.1.1 Samples

Herbal tea infusions of a large sample set (n = 36), comprising of five *Cyclopi*a species, i.e. *C. genistoides*, (n = 7), *C. subternata* (n = 9), *C. maculata* (n = 6), *C. intermedia* (n = 8) and *C. longifolia* (n = 6) and processed at optimum "fermentation" (i.e. high-temperature oxidation) conditions (Erasmus, Theron, Muller, Van der Rijst, & Joubert, 2017; Bergh, Muller, Van der Rijst, & Joubert, 2017), were comprehensively profiled, using DSA.

2.1.2 Preparation of infusions

Infusions were prepared by pouring 1000 g freshly boiled distilled water onto 12.5 g of the sieved plant material, infused for 5 min and strained through a fine-meshed strainer into a pre-heated stainless steel thermos flask (Erasmus et al., 2017). The infusions were served in pre-heated white porcelain mugs coded with 3-digit random codes and arranged in random serving orders per assessor. The mugs were placed in temperature-controlled (65°C) water baths to ensure a consistent temperature during analysis.

2.1.3 Analysis

A panel of ten assessors (female assessors between the ages of 40 and 65) with several years of experience in DSA of honeybush tea was trained on the samples, as described by Lawless and Heymann (2010). Panel members completed an official consent form before commencing with DSA. Attribute intensities for aroma, flavour, taste and mouthfeel attributes (n = 43) were rated on unstructured line scales (0, none – 100, prominent), using the Compusense® five software program (Compusense®, Guelph, Canada). Assessors were seated at individual booths in a temperature- (21ºC) and light-controlled room.

Five samples, one sample per *Cyclopia* species, were presented in a random order to each assessor per session. Each set of five samples was evaluated in triplicate on the same day with a rest-period of 15 min between sessions. The full sample set was evaluated over seven days, however on the last day six samples were presented to include all samples batches. Unsalted water biscuits and still natural spring water were used as palate cleansers.

2.2 Polarized sensory positioning (PSP)

Three variants of the continuous-scale PSP, namely partial PSP on aroma (P-PSP**a**), partial PSP on palate (P-PSP**p**) and global PSP (all attributes) were conducted to determine the sensory profile of herbal teas of five *Cyclopia* species and ultimately the efficacy of PSP as alternative to DSA.

2.2.1 Sample and pole selection

The sample configuration obtained through principal component analysis (PCA) of the DSA data (based on the full sample set, n=36) was used to select a sub-set of samples for PSP (Fig. 1). This sub-set of samples was chosen to be representative of the five *Cyclopia* species (*C. genistoides, C. subternata, C. maculata, C. intermedia* and *C. longifolia*), thereby representing the total sensory space of this herbal tea.

Three batches were selected per *Cyclopia* species, resulting in a sub-set of 15 samples for PSP. Each of the three batches per *Cyclopia* species served as independent replicates (Table 1). Five poles, with each pole representing one of the five *Cyclopia* species, were prepared for the PSP task (Table 1). Each pole was prepared by blending equal amounts of the three selected batches of each *Cyclopia* species. In addition, two blind duplicates, identical to two of the poles, were used to evaluate panel performance (Falahee & MacRae, 1997; Lim & Lawless, 2005).

For each of the PSP-variants, the samples were evaluated in three consecutive sessions. Per session, each assessor received one sample per *Cyclopia* species and two blind duplicates, therefore a total of seven samples to evaluate against the set of five poles. The sample layout and sample codes used in the the three PSP tasks are presented in Table 1.

2.2.2 Partial and global PSP

The trained panel used for DSA also participated in the PSP task. The three variations of the PSP task, i.e. P-PSP***a***, P-PSP***p*** and global PSP, were performed on three consecutive days, with three sessions per PSP-variant per day. Coloured labels with letters G, I, S, M and L, representing *C. genistoides*, *C. intermedia*, *C. subternata*, *C. maculata* and *C. longifolia*, respectively, were used to identify the five poles. The test samples were marked with three-digit blinding codes and presented in a random order to each assessor. The poles and test samples were kept at a constant temperature of 65°C throughout evaluation. The PSP task was explained to the panel and the assessors were instructed to smell and/or taste each pole and thereafter evaluate the similarity or dissimilarity of each sample in comparison to each pole. A questionnaire was provided on which assessors had to indicate similarity or dissimilarity on an unstructured 100 mm line scale where 0 indicated that a test sample was perceived to be similar to the pole (same) and 100 indicated dissimilarity to the pole (different). Assessors were requested to take a 15 min break between sessions to avoid panel fatigue. Unsalted water biscuits and still natural spring water were used as palate cleansers. Assessors were seated in a temperature- (21°C) and light-controlled room at individual tables for sufficient space. All the assessors

Kommentert [TN1]:
I am not sure I understand fully, but my understanding is:

You select 15 sample for testing in addition to 5 poles from the 36. Then you identify three samples for each species (15 in total) and use them as replicates~~. These 15 samples come in addition to the above 15~~? Is each of the replicates 100% identical to one of the 15 test samples. No Is all this correct? Please be even more clear at this point which is critical for understanding the rest.

An indication of the criteria used for selection could be emphasised more either here or later.

Kommentert [TN2]: This means that all samples to be tested (36) were tested in each session

Kommentert [TN3]: Do you mean the 3 plus the two replicates. The two replicates are identical to two of the first three?

Kommentert [TN4]: This is also a bit unclear to me. Please work a bit more with this which is critical for understanding of he rest.

Kommentert [MN[5]: Tormod, RE the comments above, Samples were selected based on species typicality as well as samples that represented the total sensory space associated with this sample set.

To explain further, sample selection and serving of samples per session:
Per session, each assessor received 12 samples: 5 poles (representing the 5 species), one sample per species (5 species) and 2 blind duplicates. Blind duplicates and poles were identical for all sessions.

We expanded Table 1 to address your comments above, does it make better sense?

completed the three sessions of each PSP-variant within a 2-hour period. The data of each assessor were captured by measuring the distance between 0 and 100 on the continuous scale for each sample.

2.3 Statistical analysis of data

2.3.1 Descriptive sensory analysis

The performance of the DSA panel was monitored during training using PanelCheck Software (Version 1.3.2, http://www.panelcheck.com/). DSA data were pre-processed to test for panel reliability by means of a univariate ANOVA model that includes assessor, replication and sample effects and interactions (Næs, Brockhoff, & Tomic, 2010). For each sensory attribute, observations with studentised residuals larger that three were pinpointed as outliers and removed. Following confirmation of panel reliability and normality of data, subsequent statistical analyses were performed on sample means over triplicate infusions and assessors. All univariate analyses were performed using SAS® software (Statistical Analysis System 2006, Version 9.4, SAS Institute Inc., Cary, NC, USA). Principal component analysis (PCA), using the correlation matrix, was conducted using XLStat software (Addinsoft, New York, USA) to visualise and elucidate the relationship between samples and attributes (Næs, Brockhoff, & Tomic, 2010).

2.3.2 Polarized sensory positioning

Data of the three consecutive sessions per PSP-variant were combined, as done in previous PSP studies (Ares et al., 2013; Cadena et al., 2014; De Saldamando et al., 2013), resulting in a data matrix consisting of the 21 samples (three replicates each for the five species and two blind duplicates) in rows and the 50 ratings (five poles for each of the ten assessors) in columns. PSP data were analysed using multiple factor analysis (MFA) where data from each assessor were considered as a separate group of variables. By using this approach, individual data of assessors are preserved. This approach compensates for individual assessor differences when scoring differences between products and poles (Teillet, 2014). Confidence ellipses were calculated using parametric bootstrapping (Dehlholm, Brockhoff, & Bredie, 2012).

2.3.3 Comparison of methodologies

The degree of similarity between product configurations in the first two components of the PCA of the DSA data and MFA of PSP data for the sub-set of samples were compared using RV coefficients. The RV coefficient is a multivariate similarity coefficient that can be used to measure the extent to which two product configurations are similar (Abdi, Valentin, Chollet, & Chrea, 2007). The RV coefficient depends on the relative position of the points in the configuration and is therefore not influenced by rotation and translation (Robert & Escoffier, 1976). An RV coefficient close to 1 indicates high similarity between configurations for the dimensions under question and 0 indicates unrelated configurations. RV coefficients $\geq$ 0.7 are often considered indicative of an acceptable level of similarity (Cartier, Rytz, Lecomte, Poblete, Krystlik, Belin, & Martin, 2006; Nestrud & Lawless, 2008). Data analyses were performed using R 3.2.0 (R Core Team, 2015). FactoMineR was used to perform MFA and to compute RV coefficients (Lê, Josse, & Husson, 2008).

3. Results

3.1 Selection of sub-set of samples for PSP

Principal component analysis (PCA) was conducted, using the DSA data of the full sample set (n = 36), to visualise the relationship between samples and attributes (Fig. 2) and to ultimately select the sub-set of samples (n = 15) for the PSP task. A clear differentiation between *C. subternata* and *C. intermedia* was observed on principal component 1 (PC1). *Cyclopia subternata* samples associated with 'cooked apple', 'sweet spice/cassia', 'woody' and 'walnut' aroma and flavour and a 'dusty' aroma. *Cyclopia intermedia* samples associated with 'fynbos floral', 'rose perfume' and 'rose geranium' aroma and flavour and 'pine', 'fynbos sweet' and 'caramel' aroma. Samples of *C. genistoides*, *C. maculata* and *C. longifolia* formed one group on PC1. These samples associated with astringency, bitter and sour taste, as well as 'hay/dried grass', 'green grass' and 'cooked vegetable' aroma and flavour, and to a lesser extent with the positive aroma and flavour attibutes generally associated with this herbal tea. Samples regarded as representative of the respective *Cyclopia* species as well as the sensory space for this herbal tea, were selected for the PSP task and are indicated on the PCA bi-plot (Fig. 2).

Kommentert [TN6]: More on how. Both for the test samples and poles.

Kommentert [MN[7R6]: Tormod, see the last sentence of this paragraph

3.2 Polarized sensory positioning

MFA was performed on the data of the three PSP-variants, i.e. P-PSP***a***, P-PSP***p*** and global PSP. The first and second dimensions of the MFA plots explained 54.7% (Fig. 3), 54.5% (Fig. 4) and 58.6% (Fig. 5) of the variance, respectively. The sample configurations for P-PSP***a*** and global PSP were similar on dimension 1 (Figs. 3 and 5, respectively). For both PSP-variants, three separate groups of samples were observed with a clear distinction between *C. subternata* and *C. intermedia* samples and no overlap of confidence ellipses. The differentiation between groups of samples were less distinct for P-PSP***p***, indicated by an overlap of confidence ellipses for *C. subternata* and *C. intermedia* samples (Fig. 4).

3.3 Validation of polarized sensory positioning

A PCA bi-plot (Fig. 6) of the DSA data of the selected samples (n = 15) was compared visually with that of the MFA plots of the three PSP-variants (Figs. 3, 4 and 5), showing similar product configurations. Both the PCA bi-plot and the MFA product maps showed three groups representing the *C. subternata* and *C. intermedia* samples as two distinct groups and a third group consisting of *C. genistoides*, *C. maculata* and *C. longifolia*. RV coefficients for assessment of the similarity of product configurations obtained with DSA and MFA of partial and global PSP were calculated (Table 2), taking the first two dimensions of the respective plots into account. RV coefficients place the greatest emphasis on the dimension with the largest explained variance and should therefore be interpreted with caution (Tomic, Berget, & Næs, 2015) and not in isolation. The RV coefficients between MFA of the three variations of the PSP task and PCA of DSA data were high ($RV \geq 0.87$) (Table 2).

For assessment of panel reliability, two blind duplicates were included: Dupl_INT and Dupl_LON were the duplicate samples for Pole_I (pole *C. intermedia*) and Pole_L (pole *C. longifolia*), respectively. Inspection of the respective MFA product configuration obtained for three PSP-variants (Figs. 3, 4 and 5) showed that

Kommentert [TN8]: Are these visible in the plots?

Kommentert [MN[9R8]: Tormod, yes, indicated as Dupl_INT and Dupl_LON on the plots the respective blind duplicate samples were in close proximity of the corresponding poles. Furthermore, the MFA plots also showed an overlap of confidence ellipses for the two samples and their blind duplicates, indicating panel reliability.

4. Discussion

The current research evaluated the effectiveness of the PSP task for sensory characterisation of honeybush tea. This herbal tea represents a complex product with a wide range of sensory attributes. Promising results were obtained, and the validity of this method was confirmed by comparing the PSP results to that of DSA. The relevance of partial and global PSP for the sensory characterisation of honeybush infusions and implications for application within the honeybush herbal industry needs to be considered.

Descriptive sensory analysis has been used extensively to characterise the full sensory profile of honeybush tea within the research environment, especially in studies investigating the effect of processing on a wide range of attributes (Joubert et al., 2019). DSA has also been used to distinguish between different *Cyclopia* species used for the production of honeybush tea. However, such a detailed approach is not feasible for the honeybush industry, considering the time-consuming nature of DSA (Nishida et al., 2021). This creates a need for a broad-based profiling method to rapidly distinguish between *Cyclopia* species and product batches evaluated over time. PSP, a reference-based method, has potential in this context.

DSA and PSP gave similar product configurations as indicated by high RV coefficients, especially for P-PSP***a*** (RV = 0.94) and global PSP (RV = 0.95). RV coefficients ≥0.7 are regarded as an indication of a good level of agreement (Cartier et al., 2006; Nestrud & Lawless, 2008), indicating that either P-PSP***a*** or global PSP could be used for broad-based sensory profiling of infusions of *Cyclopia* species, despite of the complexity of their sensory profiles. A previous study on Norwegian cheeses and formulated lamb and sheep meat products, also using trained assessors, demonstrated that both partial and global PSP delivered product configurations highly correlated with that of quantitative descriptive analysis (QDA®) (Varela et al., 2014). In a study on yogurt, using consumers as assessors, similar product configurations and relatively high RV coefficients (0.86) were achieved when comparing QDA® and PSP (Cadena et al., 2014). In the latter study, three poles based on the sucrose content of the yogurt were used.

In the current study, *C. genistoides*, *C. longifolia* and *C. maculata* formed one group on the MFA plots, despite the use of three poles representing each of these three *Cyclopia* species. This indicates that the honeybush tea, produced from these three *Cyclopia* species, share the same broad-based sensory profile. This grouping was also evident from the DSA results, despite using DSA as comprehensive profiling method. In a previous study, *C. maculata* in comparison to *C. genistoides*, *C. longifolia* and *C. subternata*, showed no distinct sensory profile. All the sensory attributes of *C. maculata* were regarded as 'common' when compared to the latter three *Cyclopia* species (Erasmus et al., 2017). In the current research, the honeybush tea samples from *C. intermedia* and *C. subternata* formed two groups, both for the DSA and PSP results. This has implication for the selection of poles, one of the major factors in the successful application of PSP. Ares et al. (2015) recommended that the poles should clearly represent specific characteristics of the sensory space in question and that the poles should be perceptibly different. Based on the results of the current study, the use of one pole could be sufficient for the broad-based sensory characterisation of *C. genistoides*, *C. maculata* and *C. longifolia*, given that these herbal teas are not distinctly different, thus overlapping in sensory characteristics. Either of these *Cyclopia* species or a blend thereof could thus be used as a pole. Two separate poles are however required for *C. subternata* and *C. intermedia.* An advantage of reducing the number of poles is that sensory and cognitive fatigue of the assessors is reduced (Ares et al., 2015). In most cases, three poles are sufficient to obtain a stable sample configuration, but this requires careful selection of poles covering the sensory space (Ares et al., 2013; Cadena et al., 2014; De Saldamando et al., 2013; Teillet et al., 2010).

Kommentert [TN10]: Maybe soften this statement. It is very string.

Kommentert [MN[11R10]: Tormod – softened a bit

Another aspect that needs consideration is the use of partial PSP compared to global PSP (Varela et al., 2014). In the current study, the two partial PSP tasks, P-PSP***a*** and P-PSP***p***, allowed assessors to focus on one modality at a time. P-PSP***a*** illustrated better discriminative ability than P-PSP***p***, as indicated by their RV coefficients. This was evident for *C. subternata* and *C. intermedia* from the MFA configurations for P-PSP***a*** (Fig. 3), but not for the MFA configurations for P-PSP***p*** (Fig. 4). The lower discriminative ability of P-PSP***p*** could be a result of substantially lower intensities of several of the flavour attributes than their aroma counterparts (Bergh et al., 2017; Erasmus et al., 2017). Furthermore, the tighter group formation observed for P-PSP***a*** and global PSP, suggests a higher degree of similar evaluations among assessors.

In the context of the current research, the result for P-PSP***a*** is of interest. Ares et al. (2015) suggested that assessors select one or two attributes most representative of each pole ('key attributes') and evaluate similarity of test samples by comparing the key attributes of the poles and test samples. Aroma, and not palate attributes, appears to be the main driver for differentiation of honeybush tea, produced from different *Cyclopia* species, notwithstanding that two of the *C. genistoides* samples associated with bitter taste and astringency (Fig. 6). Herbal tea from batches of *C. longifolia* could also be perceived as bitter (Alexander, Moelich, De Beer, Muller, Walczak, & Joubert, 2020), although not evident for the samples used in the current study. By focussing on aroma only, the PSP task should be easier to perform and would also minimise sensory fatigue of assessors.

5. Conclusions

PSP could be used for global sensory categorisation of honeybush herbal tea, a product with a complex sensory profile. Partial PSP based on aroma (P-PSP***a***) was as effective as global PSP in discriminating between honeybush tea samples, depending on *Cyclopia* species. *Cyclopia genistoides*, *C. longifolia* and *C. maculata* herbal teas formed one group, while those of *C. subternata* and *C. intermedia* formed separate species-specific groups. This result may indicated that only three poles would be necessary for PSP of this group honeybush tea species, one pole for the former three *Cyclopia* species and one pole each for *C. subternata* and *C. intermedia.* PSP could find valuable application in the honeybush industry in quality control programs given the need for a reference-based method that would ensure consistent results across multiple sessions.

Kommentert [TN12]: I would rather say 'may indicate.'

Kommentert [MN[13R12]: Changed as suggested

CRediT authorship contribution statement

E.I. Moelich: Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **M. Muller:** Conceptualisation, Supervision, Writing – review & editing. **M. Kidd:** Formal analysis. **M. van der**

Rijst: Formal analysis, Writing – review & editing. **T. Næs:** Conceptualization, Supervision, Writing – review & editing. **Elizabeth Joubert:** Conceptualization, Supervision, Resources, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors hereby acknowledge the National Research Foundation (NRF) of South Africa for a Scarce Skills Doctoral Scholarship to EM (grant 97060) and a Research & Technology Fund grant to EJ (grant 98695). Funding was also supplied by the Department of Science and Technology (contract DST/CON 0023/2015) to the ARC. Funders played no role in study design; collection, analysis and interpretation of data; writing of the manuscript; decision to submit the manuscript for publication. Marlise Joubert and George Dico of ARC Infruitec-Nietvoorbij, Stellenbosch assisted with harvesting and processing of plant material, respectively. The authors thank the South African honeybush industry for supplying plant material. We also acknowledge the Research Council of Norway for financially supporting scientific exchange.

Kommentert [TN14]: For me,

Kommentert [MN15R14]: Tormod, we added Norway's contribution

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Table 1

Sample layout for the three PSP variants[1] (P-PSP***a***, P-PSP***p*** and global PSP). Each PSP variant was conducted over three sessions using one sample batch per *Cyclopia* species and two blind duplicates per session.

***Cyclopia* species**	**Sample batches (B) selected per *Cyclopia* spp.[5]**	**Poles[2]**	**Sample batches[3] and blind duplicates[4] for each of the three sessions per PSP task** **Session 1**	**Session 2**	**Session 3**
Cyclopia genistoides (GEN)	GEN_B1 GEN_B3 GEN_B4	Pole_G	GEN_B1	GEN_B3	GEN_B4
Cyclopia subternata (SUB)	SUB_B2 SUB_B3 SUB_B5	Pole_S	SUB_B2	SUB_B3	SUB_B5
Cyclopia maculata (MAC)	MAC_B1 MAC_B2 MAC_B5	Pole_M	MAC_B1	MAC_B2	MAC_B5
Cyclopia longifolia (LON)	LON_B2 LON_B3 LON_B5	Pole_L	LON_B2	LON_B3	LON_B5
Cyclopia intermedia (INT)	INT_B1 INT_B3 INT_B5	Pole_I	INT_B1	INT_B3	INT_B5
			Blind duplicates		
			Dupl_INT	Dupl_INT	Dupl_INT
			Dupl_LON	Dupl_LON	Dupl_LON

[1] P-PSP***a*** = Partial PSP on aroma; P-PSP***p*** = Partial PSP on palate; global PSP (all attributes).

[2] Each pole was prepared by blending equal amounts of the selected batches per *Cyclopia* species (e.g., Pole_G consisted of equal amounts of the sample batches GEN_B1, GEN_B3 and GEN_B4). The five poles were kept contant over all PSP variants and sessions.

[3] Two blind duplicates (Dupl_INT en Dupl_LON) were served to test panel reliability. The blind duplicates were similar to the poles of the corresponding *Cyclopia* spp. The two blind duplicates were kept contant over all PSP variants and sessions.

[4] Similar batch (B) codes (e.g., GEN_B1) denote similar sample batches within the respective *Cyclopia* spp. These batch codes were used in both PSP and DSA.

Kommentert [TN16]: As said above, you should be more clear about how you selected.

Why are 1, 3 and 4 used here while 2, 3 and 5 are used for SUB?

Tormod: B1, B3 and B4 of C genistoides denotes the three batches selected for PSP

Kommentert [TN17]: For each session you say hat you present the poles and the five sample plus 2 replicates. The replicates are not visible here. See also comment about how the replicates were selected.

Kommentert [MN[18R17]: Tormod –For each session the 5 samples + 2 blind duplicates were presented to be evaluated against the 5 poles . Is this now clear from the Table?

Table 2

RV coefficients for the correlation between the product configurations obtained with PCA of DSA data and MFA of partial PSP on aroma and palate (P-PSPa and P-PSPp, respectively) and PSP on global attributes of five *Cyclopia* species.

PSP variant (PCA vs MFA)	**RV coefficients**
Partial PSP on aroma (P-PSP***a***)	0.94
Partial PSP on palate (P-PSP***p***)	0.89
Global PSP	0.95

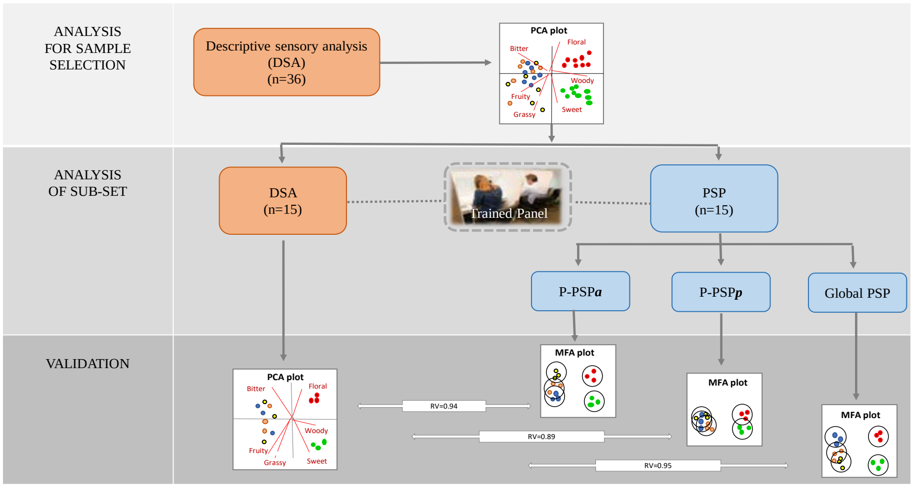

Fig. 1. Workflow diagram for descriptive sensory analysis (DSA), selection of samples for the three variants of polarized sensory positioning (PSP) and data analysis.

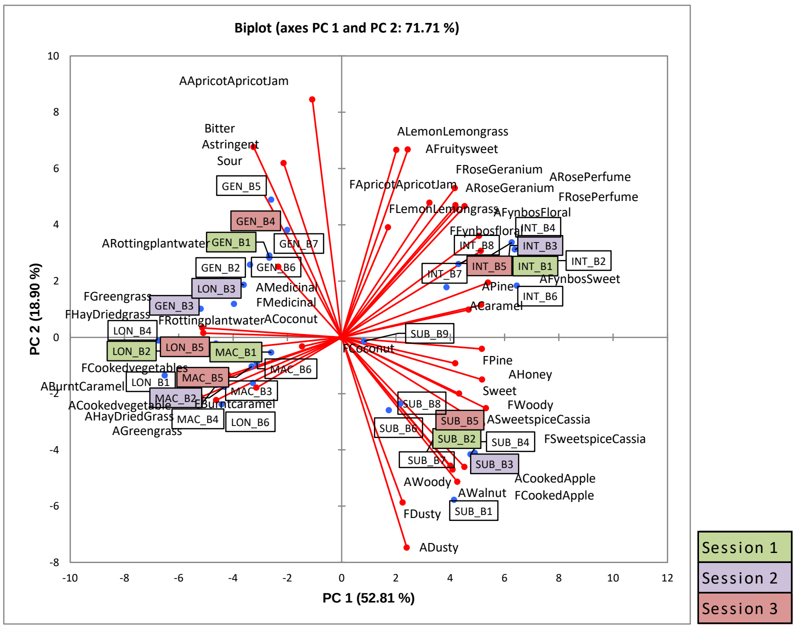

Fig. 2. PCA bi-plot obtained with DSA of five *Cyclopia* species using the total sample set (n = 36). Samples selected for inclusion in replication 1, 2 and 3 of the PSP task are marked with green, purple and red, respectively. Capital letters added to attributes indicate A: aroma (orthonasal) and F: flavour (retronasal). The abbreviations GEN, MAC, LON, SUB and INT refer to *C. genistoides*, *C. maculata*, *C. longifolia*, *C. subternata* and *C. intermedia*, respectively. B refers to batches, 1–9 refer to batch number.

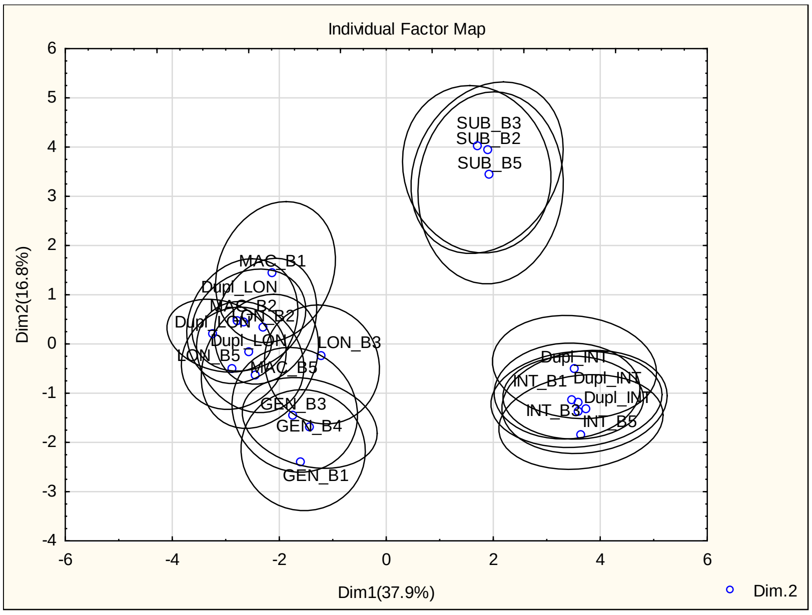

Fig. 3. Sample configuration of five *Cyclopia* species in the first two dimensions of multiple factor analysis performed on data from partial polarized sensory positioning based on aroma (P-PSP***a***). The abbreviations GEN, MAC, LON, SUB and INT refer to *C. genistoides, C. maculata, C. longifolia, C. subternata* and *C. intermedia,* respectively. B refers to batches, 1–5 refer to the batch number. Dupl_INT refers to the sample identical to pole I, Dupl_LON refers to the sample identical to pole L.

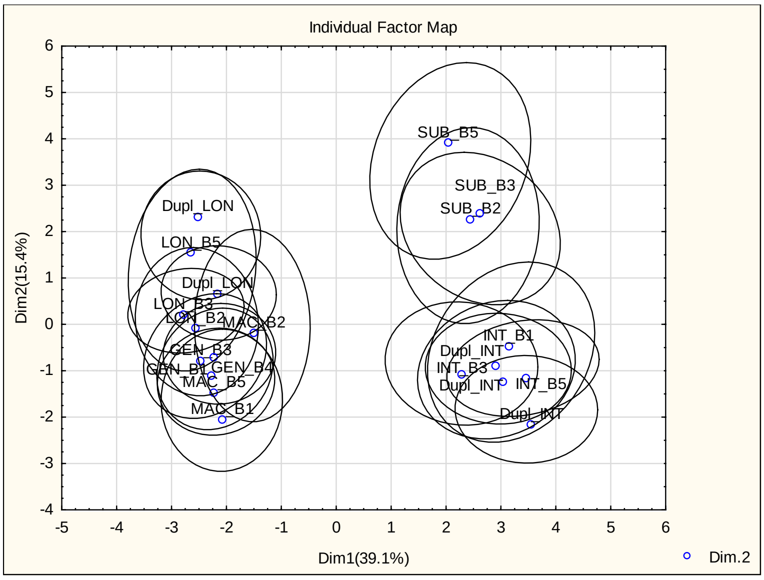

Fig. 4. Sample configuration of five *Cyclopia* species in the first two dimensions of multiple factor analysis performed on data from partial polarized sensory positioning based on palate (P-PSP***p***). The abbreviations GEN, MAC, LON, SUB and INT refer to *C. genistoides, C. maculata, C. longifolia, C. subternata* and *C. intermedia*, respectively. B refers to batches, 1–5 refer to the batch number. Dupl_INT refers to the sample identical to pole I, Dupl_LON refers to the sample identical to pole L.

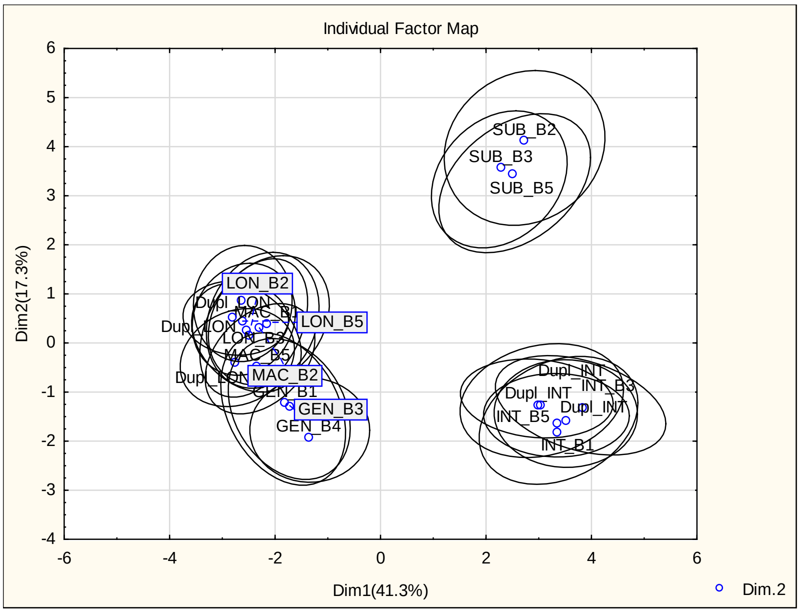

Fig. 5. Sample configuration of five *Cyclopia* species in the first two dimensions of multiple factor analysis performed on data from polarized sensory positioning based on all attributes (PSP global). The abbreviations GEN, MAC, LON, SUB and INT refer to *C. genistoides, C. maculata, C. longifolia, C. subternata* and *C. intermedia,* respectively. B refers to batches, 1–5 refer to the batch number. Dupl_INT refers to the sample identical to pole I, Dupl_LON refers to the sample identical to pole L.

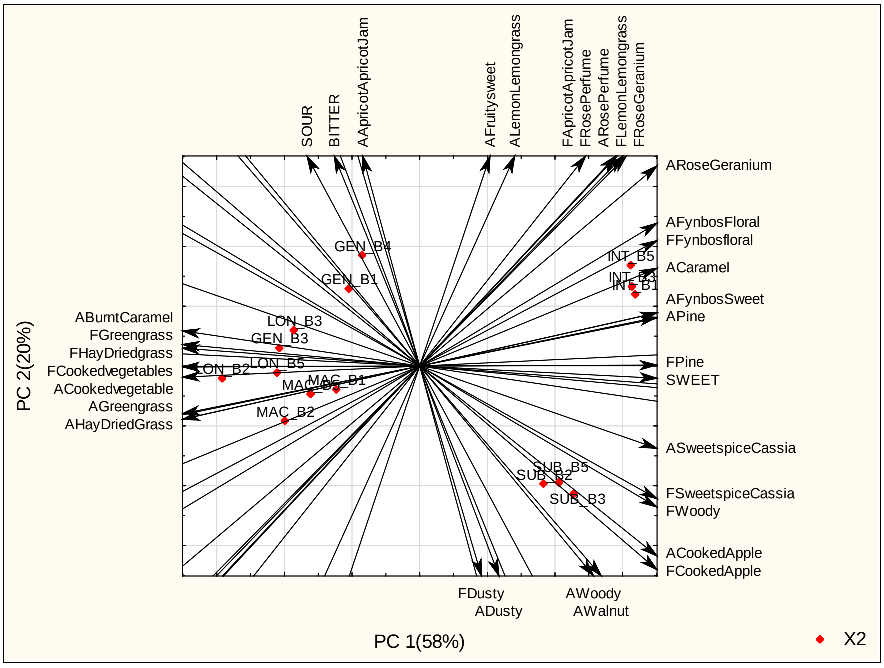

Fig. 6. PCA bi-plot obtained with DSA representing the differentiation among five *Cyclopia* species. Samples selected for the PSP task are included. Capital letters added to attributes indicate A: aroma (orthonasal) and F: flavour (retronasal). The abbreviations GEN, MAC, LON, SUB and INT refer to *C. genistoides*, *C. maculata*, *C. longifolia*, *C. subternata* and *C. intermedia*, respectively. B refers to batches, 1–5 refer to the batch number.