Validation of projective mapping as potential sensory screening tool for application by the honeybush herbal tea industry

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Abstract

Honeybush herbal tea is produced from several indigenous South African *Cyclopia* species. Production lags behind demand forcing marketers to use blends of available material to supply in local and international markets. The distinct differences in the sensory profiles of the different species, as well as processing conditions, require that special care is given to blending to ensure a consistent, high quality product. Although conventional descriptive sensory analysis (DSA) is highly effective in providing a detailed sensory profile of the different species, industry requires a method that is more time- and cost-effective. Recent advances in sensory science have led to the development of rapid profiling methodologies. The question is whether projective mapping can successfully be used for the sensory characterisation of *Cyclopia spp*. Trained assessors performed projective mapping to determine the validity of this technique for the sensory characterisation of infusions of five *Cyclopia* species. Similar product configurations were obtained when comparing results of DSA and global and partial projective mapping. Comparison of replicate sessions showed RV coefficients of >0.8, indicating that one session will be sufficient to supply a rapid sensory profile of the samples. Different similarity indices were calculated to determine assessor repeatability and are also discussed. Results indicate that projective mapping is a valid method for providing broad sensory characterisation of *Cyclopia* spp and would be suitable as a rapid quality control method of honeybush tea. Its application by the honeybush industry could improve the consistency of the sensory profile of blended products.

Keywords: Projective mapping, Descriptive sensory analysis, Panel performance, *Cyclopia* species, Multiple factor analysis, Similarity index

1. Introduction

Honeybush is an indigenous South African herbal tea (Joubert, Joubert, Bester, de Beer, & De Lange, 2011), produced in the coastal and mountainous regions of the Southern and Western Cape (Schutte, Vlok, & Van Wyk, 1995). Of the 23 *Cyclopia* spp. identified, only a few are currently of commercial interest (Joubert et al., 2011). The majority of the production comprises *C. intermedia*, mainly harvested from the wild, and to a lesser extent *C. subternata* and *C. genistoides*, both cultivated. Species under evaluation are *C. maculata* and *C. longifolia* (Joubert et al., 2011). The distinguishing sensory profile of this herbal tea is the result of "fermentation", a high temperature oxidation process (Du Toit & Joubert, 1999). The generic sensory profile of honeybush has been defined as "fynbos-floral", "woody" and "fynbos-sweet" aroma and flavour, with a sweet taste and slight astringent mouthfeel (Erasmus, Theron, Muller, van der Rijst, & Joubert, 2016). *Cyclopia* species are all associated with this generic sensory profile, however, each species shows higher intensities for specific sensory attributes, making it possible to distinguish one species form another. *C. genistoides* is associated with a strong "rose-geranium" flavour and perceptible bitter taste whereas *C. longifolia* has a similar sensory profile to that of *C. genistoides* but with less prominent "rose-geranium" flavour and no perceptible bitter taste (Erasmus et al., 2016). *C. subternata* and *C. maculata* both associate with "caramel" and "sweet-associated" aroma notes and a slight astringent mouthfeel.

The majority of the honeybush harvest is exported, a growing market with the possibility of expansion. The current production yield is insufficient to supply in the local and international demand for a product with a constant quality, forcing the honeybush industry to use blends of different species (Joubert et al., 2011). Unfortunately limited regulatory measures exist to control the quality of this export product, Rapid sensory profiling methods could find application here as there is a need in industry for sensory profiling methods that are efficient, flexible and less time consuming than the traditional descriptive sensory analysis.

Descriptive sensory analysis (DSA) is regarded as the most comprehensive and informative sensory tool (Lawless & Heymann, 2010; Murray, Delahunty, & Baxter, 2001) which provides results that are robust, consistent and reproducible within time and a specified sensory context (Moussaoui & Varela, 2010). Although DSA is regarded as a very useful sensory tool, one of the main drawbacks is the cost and time involved in maintaining well trained panels. This, together with the fact that highly trained assessors might perceive products differently than consumers, led to the development of sensory tools that have an holistic approach and are more flexible and less time consuming (Varela & Ares, 2014).

One of the alternatives to traditional sensory analysis is projective mapping (PM), a method originating from psychology and first introduced to the field of sensory science by Risvik and co-workers (Risvik, McEwan, Colwill, Rogers, & Lyon, 1994; Risvik, McEwan, & Rødbotten, 1997). PM entails that all products are presented simultaneously and assessors are asked to place products in a two-dimensional space according to perceived similarities and dissimilarities. Each assessor applies his own individual set of criteria, making this a relativly spontaneous procedure. The PM technique evolved to include an attribute collection step, similar to ultra-flash profiling (Perrin et al., 2008). A comparison of PM to DSA shows good agreement between these methods (Barcenas, Elortondo, & Albisu, 2004; Cadena et al., 2014; Dehlholm, Brockhoff, Meinert, Aaslyng, & Bredie, 2012; Hopfer & Heymann, 2013; Louw et al., 2013; Nestrud & Lawless, 2008; Nestrud & Lawless, 2010; Perrin et al., 2008).

Variations of PM have been proposed: global PM has a holistic approach where all attributes are taken into account, while partial PM can direct the assessor to focus on a specified sensory modality such as aroma (Dehlholm, 2014). PM is a comparative technique where all samples need to be presented simultaneously, thereby limiting the number of samples per session. PM studies reported that between 5 (Risvik et al., 1994) and 18 samples (Hopfer & Heymann, 2013) could be used; however, the optimum number of samples to include in a PM task is 12 (Pagès, 2005). Dehlholm (2012) and Hopfer and Heymann (2013) report on the effect of the geometrical shape on the product configuration and concluded that better results is obtained when using a rectangular space since assessors regard the horizontal axis as the main dimension to indicate dissimilarity between products. PM can be applied with assessors with different levels of training (Ares, Deliza, Barreiro, Giménez, & Gámbaro, 2010; Moussaoui & Varela, 2010; Nestrud & Lawless, 2008).

An important step in method development is to evaluate the validity of the method and to determine the stability of the results obtained. The validity of the product configuration of PM could in addition to RV coefficients also be determined by calculating a similarity index (SI) (Tomic, Berget, & Næs, 2015). This method entails projecting each assessor's product configuration onto the subspace defined by the consensus. The SI measures how well the consensus matrix represents each individual's product configuration. If the difference between the consensus configuration and the individual configuration is large, it would result in a higher SI for that specific assessor (Tomic et al., 2015). If the projected assessor product configuration is similar to the consensus product matrix, the SI will be zero.

The aim of the present study was thus to determine the validity of projective mapping (PM) for the rapid sensory profiling of honeybush infusions by comparing the sample configuration obtained with PM to that of descriptive sensory analysis (DSA). Secondly, a comparison of the product configurations of partial PM on aroma, palate and global PM to that obtained using DSA will be used to determine the validity of each of these variations. Based on these results, recommendations on the method most suitable for application in the herbal tea industry will be made. The effect of replication on the PM task and assessor repeatability will also be addressed.

2. Materials and methods

2.1 Descriptive sensory analysis

2.1.1 Samples and sample selection

Randomly selected, independent batches of five *Cyclopia* species namely *C. genistoides*, (n=7) *C. subternata* (n=9), *C. maculata* (n=6), *C. intermedia* (n=8) and *C. longifolia* (n=6) of harvest year 2014/2015 were obtained. All samples, except those of *C. intermedia*, were processed on laboratory-scale at the Post-Harvest and Wine Technology Division of ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa, using optimum conditions for characteristic aroma development (Erasmus et al., 2016). Samples of *C. intermedia* were sourced from a commercial processor. All samples were sieved to obtain the "tea bag" fraction (<12 mesh and > 40 mesh) as described by Theron et al. (2014). The sieved plant material was stored at ambient temperature (21ºC) in sealed glass jars, until analysed (Theron et al., 2014). The *Cyclopia* spp., and representing samples codes are shown in Table 1.

2.1.2 Sample preparation

Infusions were prepared by pouring freshly boiled distilled water (1000 g) onto the sieved plant material (12.5 g) and infused for 5 min. each infusion was strained through a fine-mesh stainless steel strainer directly into a 1 L pre-heated stainless steel thermos flask (Woolworths, Bellville, South Africa). The infusions were served in white porcelain mugs coded with 3 digits. The mugs were pre-heated in an industrial oven (Hobart, France) at 70°C before aliquots of each infusion (ca. 100 mL) were poured into the mugs and covered with plastic lids to prevent loss of volatiles. The mugs were arranged in a random order per assessor and served in temperature controlled (65°C) water baths (Scientific Manufacturing Company, Cape Town, South Africa).

2.1.3 Descriptive sensory analysis

An existing sensory panel consisting of 9 trained panellists (all female between the ages of 40 and 65) were selected. The panel have several years of experience in the sensory analysis of infusions prepared from rooibos (Jolley, Van der Rijst, Joubert, & Muller, 2016; Koch, Muller, Joubert, Van der Rijst, & Næs, 2012) and honeybush (Erasmus et al., 2016; Theron et al., 2014). Panel members completed an official consent form before commencing with DSA. The panel were further trained on the samples and the generic DSA technique, as described by Lawless and Heymann (2010), during eight one-hour sessions. The attributes and references generated during the development of the revised honeybush sensory wheel were used as basis for the training (Erasmus, 2015) and consisted of 22 aroma, 17 flavour, 4 taste and mouthfeel attributes (Table 2). Aroma was defined as the aromatics perceived through orthonasal analysis, flavour as the retronasal perception and taste as the basic taste modalities. Astringency was described as the tactile sensation that occurred in the oral cavity caused by the precipitation of salivary proteins (Green, 1993). Attribute intensities were rated on an unstructured line scale (0 – 100), using the Compusense® five software program (Compusense, Guelph, Canada). Five samples, one sample per *Cyclopia* species, were presented in a random order to each assessor. The samples were analysed in three consecutive sessions per day. All samples were evaluated in triplicate to test for assessor reliability. Assessors were requested to take a 10 min break between sessions to avoid panel fatigue. Unsalted water biscuits (Woolworths, Stellenbosch, South Africa) and still natural spring water (Woolworths, Stellenbosch, South Africa) were used as palate cleansers between each sample. Assessors were seated at individual booths in a temperature (21ºC) and light controlled room.

2.2 Projective mapping

2.2.1 Samples and sample selection

Two batches per species were selected, guided by the sample configuration obtained through principal component analysis of the DSA data. Batches that could be regarded as most representative of the respective species were selected for inclusion in the PM task. Two blind duplicate samples (INT_B3 and LON_B2) were included to aid in evaluating the panel performance. This resulted in a total of 12 samples presented simultaneously for evaluation per session. The infusions were prepared and served in a random order per assessor in the same manner as for DSA.

2.2.2 Partial and global projective mapping

A panel consisting of 10 trained assessors (all female between the ages of 40 and 65), the same panel used for the DSA with one additional panel member, participated in the PM task. A short explanation of the PM method followed by a training exercise as described by Hopfer and Heymann (2013) was used to introduce the panel to this technique. Some assessors had previous experience of this method. Three variations of PM were applied: partial PM according to aroma, partial PM according to palate attributes and global PM (all attributes). Partial PM on palate included all flavour attributes as well as sweet, sour and bitter as taste attributes and astringency as mouthfeel attribute. The three variations of PM were performed on three consecutive days, with three replications per method per day. The panel was provided with the same list of attributes as used for the DSA and was asked to place the samples on a rectangular piece of paper (60 cm x 40 cm) according to perceived similarities or dissimilarities. The PM task was followed by an ultra-flash profiling task where attributes were added, as described by Perrin et al. (2008). Assessors were asked to place sample containers back into the water bath after tasting to ensure that the temperature of the infusions remained constant during the session. Assessors placed “sticky notes”, each representing a specific coded sample container, onto the paper. Assessors were requested to take a 10 min break between replicates to avoid panel fatigue. Unsalted water biscuits (Woolworths, Stellenbosch, South Africa) and still natural spring water (Woolworths, Stellenbosch, South Africa) were used as palate cleansers. Assessors were seated in a temperature- (21°C) and light-controlled room, at individual tables rather than booths as this provided enough space for the water bath and the sheet of paper. All the assessors completed the three replicates of the PM task within a 2-hour period of time.

Data collection was done by measuring the coordinates for each sample placement per assessor using a ruler. The lower left corner of the paper was regarded as the zero point (0, 0). The data were constructed in such a manner where one row represented one sample and column 1 the repetition, column 2 the sample name, the next column the assessor name followed by the x and y coordinates per assessor x sample for all 10 assessors. The assessor coordinates of the data table were followed by an attribute block where each column represent an attribute. Occurrence of attributes were indicated per sample x assessor in rows. A value of 1 was allocated to a sample if the descriptor was used for that sample and a value of 0 if the descriptor was not used. Citations of descriptors by assessors were summed.

2.3 Statistical procedures

2.3.1 Descriptive sensory analysis

PanelCheck Software (Version 1.3.2, http://www.panelcheck.com/) was used to monitor DSA panel performance. The reliability of the panel was determined by test-retest analysis of variance (ANOVA) of the DSA data using SAS® software (Statistical Analysis System 2006, Version 9.2, SAS Institute Inc., Cary, NC, USA). The Shapiro-Wilk test was performed to test for non-normality of residuals (Shapiro & Wilk, 1965). In the event of significant non-normality ($P \leq 0.05$), outliers were identified and residuals greater than 3 were removed. Principal component analysis (PCA), using the correlation matrix, was conducted using XLStat (Version 7.5.2, Addinsoft, New York, USA) to visualise and elucidate the relationships between the samples and the attributes (Naes, Brockhoff, & Tomic, 2010).

2.3.2 Projective mapping

Data obtained with PM were analysed using multiple factor analysis (MFA) as described by Escofier and Pagès (1994). The co-ordinate data of each assessor were regarded as a separate data table, i.e. the 10 assessors participating in the PM task resulted in 10 data tables with two variables per assessor (x, y co-ordinates) in the MFA calculation. The table with descriptor citations were added as supplementary data. When adding descriptor citations as supplementary data, the product configuration is based on the individual configurations of assessors and the product configuration is therefore not determined by the number of citations of descriptors.

RV coefficients were calculated to determine correlations between the PCA bi-plot of the DSA and the MFA product configuration of the different variations of PM. The RV coefficient is a multivariate similarity coefficient used to measure the extent to which two product configurations are similar (Abdi, Valentin, Chollet, & Chrea, 2007; Louw et al., 2013). RV coefficients range between 0 and 1, with values closer to 1 indicating a higher degree of similarity (Abdi et al., 2007). Researchers regard a RV coefficient of 0.7 as an indication of an acceptable level of similarity (Cartier et al., 2006; Nestrud & Lawless, 2008).

The effect of replication on the MFA product configuration was also measured by calculating RV coefficients for the three replications of each PM method. RV coefficients were further calculated to compare assessors' repeatability over replications. RV coefficients between assessors and the MFA consensus plot of >0.5 were regarded as sufficient consensus. In the event where insufficient consensus between an assessor and the overall MFA map were obtained, the assessor's data were removed and the data recalculated. If the subsequent product configuration differed considerably from the original, the assessor's data were excluded from the final data analysis. Data analyses were performed in R (R Foundation for Statistical Computing., 2011) using the FactoMineR package. The repeatability of the panel was measured by calculating a people performance index (PPI) as described by Hopfer and Heymann (2013). Two similarity indices, one based on MFA and the second based on generalised Procrustes analysis (GPA) were calculated to test assessor repeatability over replications of the PM task (Tomic et al., 2015). A third index to measure assessor repeatability, 1-PANOVA, was also calculated. The 1-PANOVA index is expressed as a value between 0 and 1 where the residual sum of squares is expressed as a percentage of the total sum of squares. It gives an indication of the repeatability of assessors over replications where a value of 1 would indicate similar configurations over replications.

3. Results and discussion

Data analysis of the PM data using MFA was performed using two approaches: firstly, the conventional approach where descriptors are added as supplementary data, and secondly, where descriptors are added as a table of variables. The explained variance for the two methods of analyses was almost identical. The total explained variance for analysis of PM according to the first and second approach was 62.8% and 62.7%, respectively. The same results were obtained for MFA of partial PM aroma and partial PM palate. Results for MFA with attributes added as supplementary data will therefore be reported.

3.1 Validation of partial and global projective mapping

Validation of the PM results was done by visually comparing the product configurations obtained for the different PM tasks with that of the DSA results, as presented in the PCA bi-plot. The validity was further determined by comparing the RV coefficients for the product configurations of the PCA bi-plot of the DSA data with those of the different PM configurations.

3.1.1 Descriptive sensory analysis results

PCA bi-plot (Fig. 1) obtained from the DSA data show a product configuration with clear differentiation between the different *Cyclopia* spp. *Cyclopia intermedia* samples formed a group to the upper right quadrant of the PCA plot, which is associated with floral and sweet aromas and flavours, including "rose geranium". *Cyclopia subternata* samples, grouped in the lower right quadrant of the PCA plot, are associated with a "woody", "cooked apple", "sweet spice/cassia" and "dusty" aroma and flavour, a "honey" and "walnut" aroma and a sweet taste. *Cyclopia genistoides* samples grouped to the upper left quadrant and are associated with the aroma attributes "apricot/apricot jam" and "rotting plant water", as well as with a bitter and sour taste and an astringent mouthfeel. *Cyclopia maculata* and *C. longifolia* samples grouped together in the lower left quadrant, and are associated with the aroma and flavour attributes "burnt caramel", "green grass" and "cooked vegetables", as well as with "hay/dried grass" aroma and "rotting plant water" flavour. These attributes ("burnt caramel", "green grass", "cooked vegetables", "hay/dried grass" and "rotting plant water") are regarded as taints (Theron et al., 2014) and not desirable in the commercial product.

The main differentiation between samples on the first principal component (PC1) is therefore the floral, sweet and spicy notes toward the positive end, and the green and vegetative notes, as well as bitter and sour taste and astringent mouthfeel towards the negative side of PC1. The first 2 components explained 71.71% of the variability, describing the most important sensory attributes associated with this set of samples. These results are in accordance with the findings of Erasmus et al. (2016) in a study on high-temperature oxidation of *Cyclopia* spp.

3.1.2 Global projective mapping

The product configuration obtained with DSA of samples selected for the PM task, is presented in Fig. 2. Figure 3 shows the product configuration and associated correlation circle on attributes obtained from the average of three global PM evaluations by 10 trained assessors. Dimension 1 accounts for 46% of the explained variance. The samples on the positive side of dimension 1, namely *C. subternata* (Sub_B2, Sub_B3) and *C. intermedia* (Int_B1 and Int_B) are associated with the floral, fruity, spicy, woody and sweet-associated attributes. Samples to the negative side of dimension 1, namely *C. genistoides* (Gen_B1 & Gen_B4), *C. longifolia* (Lon_B2 & Lon_B5) and *C. maculata* (Mac_B1 & Mac_B2), are associated with the attributes "apricot/apricot jam", "hay/dried grass", "green grass" and "cooked vegetable", as well as with bitter and sour taste and an astringent mouthfeel. When comparing the sample configuration plots obtained for DSA (Fig. 2) and global PM (Fig. 3), similar sample configurations and association of samples with attributes are evident. This is in accordance to work by a number of researchers showing similar product plots for PM and DSA (Dehlholm et al., 2012; Hopfer & Heymann, 2013; Kennedy & Heymann, 2009; Risvik et al., 1994).

3.1.3 Partial projective mapping on aroma

Figure 4 represents the product configuration and the associated correlation circle on attributes obtained for three replications of partial PM, based on the aroma of the *Cyclopia* infusions. Dimension 1 and 2 account for 46.3% and 15.2% of the explained variance. *Cyclopia subternata* and *C. longifolia* samples, placed towards the positive end of dimension 1, were associated with the floral, fruity and spicy attributes described as "rose perfume", "fynbos-floral", "sweet spice/cassia" and "cooked apple". The herbal teas towards the negative end of dimension 1 were associated with the green and vegetative notes represented by "green grass", "hay/dried grass" and "cooked vegetables", as well as with "apricot/apricot jam" and "burnt caramel". These observations were similar to the selected DSA results as presented in Fig. 2.

3.1.4 Partial projective mapping on palate attributes

Figure 5 represents the product configuration and corresponding attribute correlation circle for three replications of partial PM of *Cyclopia* infusions, according to palate attributes. The product configuration in Fig. 5 is similar to that of DSA (Fig. 2). *Cyclopia subternata* samples are associated with the attributes "cooked apple", "sweet spice/cassia" and "woody", positioned towards to positive end of dimension 1 and 2. *Cyclopia intermedia* samples are associated with floral and lime-like attributes. As previously reported, the remaining three species, *C. genistoides, C. longifolia* and *C. maculata*, are associated with green and vegetative notes represented by "hay/dried grass" and "green grass", as well as "apricot/apricot jam" and "burnt caramel". These samples are also associated with a bitter and sour taste and an astringent mouthfeel. These observations were similar to the DSA results as presented in Fig. 2.

3.1.5 Comparison of the product configurations using RV coefficients

The RV coefficients for the product configurations according to results for DSA, global PM, partial PM on aroma and partial PM on palate are presented in Table 3. A RV coefficient of 0.7 is regarded as an indication of a good level of agreement (Cartier et al., 2006; Nestrud & Lawless, 2008). The RV coefficients between the three variations of PM and DSA were high (RV≥0.86), indicating that any of these PM variations are valid methods for the sensory profiling of infusions of *Cyclopia spp*. Although the RV coefficients of all three PM methods were higher than 0.8, the global PM method showed the highest RV coefficient (RV = 0.90), indicating that this method results in a reliable product configuration when evaluating all attributes associated with infusions of *Cyclopia spp*. This contradicts the results by Dehlholm and co-workers (Dehlholm et al., 2012) who found higher RV coefficients for partial PM when comparing partial PM and global PM to conventional profiling. When profiling a larger sample set of brandies, Louw et al. (2013) also concluded that better results were obtained using partial PM.

3.2 Panel performance

3.2.1 Positioning of blind duplicates

Two blind duplicate samples were included to determine assessors' variability and the difficulty in performing the PM task (Hopfer & Heymann, 2013). In the overall MFA product configurations, as presented in Fig. 3 to 5, samples Lon_B2 and Lon_B2_dup and Int_B3 and Int_B3_dup represented the blind duplicate samples. Samples and their blind duplicates were positioned close to each other for global PM (Fig. 3) and partial PM on palate (Fig. 5), but the *C. longifolia* blind duplicates were further apart for partial PM on aroma (Fig. 4). A good level of accuracy could therefore be obtained when applying global PM and partial PM on palate while partial PM on aroma seemed to be less accurate.

The researchers were of the opinion that the panel would find partial PM on aroma easier to conduct and therefore high panel performance was expected. A possible explanation for the lower accuracy of PM on aroma is that all the samples to the left of the product map were associated with the green notes and possible taints and assessors possibly found it more difficult to distinguish between these slightly tainted samples. PM is regarded as a spontaneous, easy to conduct task, however, it seemed that some assessors might have found it difficult to perform. Critique against PM is that assessors might find it difficult to place complex, multidimensional products using only two-dimensions (Tomic et al., 2015). Honeybush herbal tea is a complex, multidimensional product, and more than two dimensions might be necessary to differentiate between the samples.

Inclusion of blind duplicate samples could furthermore be valuable to measure the accuracy of individual assessors. Bertuccioli (2011) as cited by Hopfer and Heymann (2013) proposed the use of the people performance index (PPI) to test repeatability of assessors. The PPI is the ratio of the Euclidian distance between two replicated products and the maximum Euclidian distance between two different products on a PM plot. The PPI ranges between 0 and 1 and a smaller value indicates that the assessor placed identical products together on the map. Table 4 show the calculated PPI values per assessor for the three variations of PM. PPI 1 were calculated for the Int_B3 sample while PPI 2 were calculated for the Lon_B2 sample. The majority of assessors can be regarded as accurate as the PPI values for both PP1 1 and PPI 2 were low for all assessors except for assessor 2 and 7. Assessor 2 showed a PPI 1 value of 0, indicating similar placements for this duplicate sample. This assessor, however, struggled with the placement of the second duplicate sample for both global and partial PM on aroma. Assessor 7 showed high PPI values for both PPI 1 and PPI 2 for global PM and the highest PPI value for partial PM on palate. These results indicate that this assessor had difficulty in executing the PM task.

3.2.2 Consistency of assessors using RV coefficients

The consistency of assessors over replications can be evaluated by comparing the RV coefficients of assessors per replication. RV coefficients between individual assessors and the MFA consensus plot per replication of >0.5 was regarded as sufficient consensus (Louw et al., 2013). RV coefficients for the MFA configurations of assessors for three replicates of global PM, partial PM on aroma and partial PM on palate compared to the overall MFA configuration per task were calculated and are presented in Table 5. Of ten assessors, six were introduced to the PM task for the first time (assessors 1, 2, 3, 7, 9 and 10).

The RV values for the majority of assessors were above 0.5 indicating a high similarity between replicate sessions of the respective PM tasks for these assessors. Assessor 2 and 7, however, showed low RV coefficients for all replications of PM on aroma, as well as some replications of the other two variations of PM. Assessor 3 showed low RV coefficients for global PM and partial PM on palate. The lower RV coefficients for assessors unfamiliar to the PM task, could be an indication that these assessors found the task difficult or used different placing criteria when carrying out replications of the task. Removing the data of assessors with low RV coefficients did not influence the overall MFA configuration and data for all the assessors were therefore included in the final analysis.

3.2.3 Repeatability of assessors using similarity indices

The repeatability of the assessors over three replications was measured using three different similarity indices namely Procrustes analysis of variance similarity index (PANOVA SI), generalised Procrustes of variance similarity index (GPA SI) and the multiple factor analysis similarity index (GPA SI). The PANOVA SI values for global PM and partial PM on aroma are >0.7 for all assessors except for assessor 3 and 7, indicating high repeatability for the rest of the assessors. Comparison of the PANOVA SI for partial PM on palate, however, show high repeatability for all assessors except for assessor 2, 3 and 8 (Table 6). This indicates low repeatability for assessor 3 for all variations of the PM task. When comparing RV coefficients for replicate sessions, this assessor also showed low repeatability.

Tomic et al. (2015) propose the use of a *similarity index* (SI) to measure the degree to which the consensus product configuration represents each assessor’s product matrix. In the current study, the similarity index as proposed by Tomic et al.(2015) were modified to determine assessor repeatability over replications. It measures the degree to which the consensus map per assessor represents the product maps of the three replications. The SI will be zero if the projected product configuration per replication is similar to the consensus product matrix. Two similarity indices were calculated, one based on generalised Procrustes analysis (GPA SI) and the second based on multiple factor analysis (MFA SI). A SI value of <0.7 were regarded as sufficient consensus between the projected configuration of a replication and the consensus matrix per assessor.

The similarity indices for the repeatability per assessors over three replications of global PM, partial PM on aroma and partial PM on palate are represented in Table 6. When calculating assessor repeatability using GPA SI, product configurations of assessor 3 and 7 are not well represented by the consensus matrix per assessor for global PM. A comparison on GPA SI for partial PM on aroma and partial PM on palate, showed that replicate sessions are not well represented in the consensus configuration for assessors 2, 3 and 7. These assessors might have used different placement criteria for the three replications within a PM method. Comparison of the PANOVA SI also showed low repeatability for assessors 3 and 7.

The calculated MFA SI for global PM showed a low degree of similarity between replicate sessions and the consensus configuration for assessors 2, 3, 7 and 9. According to the MFA SI values presented in Table 6, assessors found the PM task on aroma more difficult since five assessors showed low similarity over replications when applying this index. MFA SI values for partial PM on aroma showed low repeatability for assessors 2, 3, 4, 7 and 9. These assessors might have used different placement criteria for the different replications of partial PM on aroma. The MFA SI values were higher for partial PM on palate in comparison to that of partial PM on aroma. Three assessors (assessor 2, 3 and 7) showed low similarity in replicate sessions for this variation of PM. A comparison of MFA SI values for the three variations of PM indicated that assessors were more consistent when executing global PM and PM on palate.

When comparing the results for the three calculated similarity indices as presented in Table 6, as well as RV coefficients and the calculated PPI, low repeatability for the same three assessors is clear. Assessor 3 and 7, and assessor 2 to a lesser extent, showed low repeatability. This was the first introduction to the PM task for these assessors. The PM task is regarded as spontaneous and easy to conduct, but these assessors might have found the task quite intricate. Furthermore, these assessors could have used different placement criteria in the replicate sessions of the PM task. Removal of the data of these assessors did not change the consensus product configuration.

The similarity indices as presented in Table 6 showed lower SI values for GPA than for MFA. GPA is based on the principle to reduce the average differences between the individual and consensus matrices to be as small as possible. The SI values calculated using GPA would therefore be smaller for GPA compared to MFA (Tomic et al., 2015).

3.3 Effect of replications

RV coefficients, as presented in Table 7, were calculated between each of the three replicates for global PM, partial PM on aroma and partial PM on palate attributes. The RV coefficients for a set of replications within a PM method were >0.8, indicating good repeatability. The similarity of the product configurations for the different replications was also evident from visual inspection of the respective spatial maps obtained for a PM method. Considering the high RV coefficients (>0.8) for replications of the different variations of the PM task, one could argue that one replicate per PM task would be sufficient to obtain a valid product configuration. The samples in the current study showed distinct sensory differences and assessors could distinguish between samples on the main attributes. If the aim is therefore to apply a rapid method for profiling of samples that have distinct differences, one replication would be sufficient. When samples are very similar, i.e. only subtle differences are evident, more replications would be advisable. Hopfer and Heymann (2013) recommend replicated PM studies to ensure that judges can identify similarities and dissimilarities in repeated sessions. Future research needs to address the efficacy and validity of PM for the rapid profiling of samples with only subtle differences in sensory profile.

4. Conclusions

Product configurations of global PM, partial PM on aroma and partial PM on palate were similar to that of DSA. The association of descriptors to products for the different PM tasks were also similar to the attributes associated with samples in DSA. High repeatability over replications within a PM variation was obtained with this set of samples that were distinctly different in sensory profiles. Different similarity indices to determine assessor repeatability have been calculated. The PANOVA SI, GPA SI and MFA SI showed agreement although the degree of similarity over replications was generally lower when calculated with MFA. A comparison of the variations of PM indicated that global PM is the most effective method for the rapid sensory profiling of herbal tea infusions; therefore, this method is recommended as a tool in QC programmes in the herbal tea industry.

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Table 1

Cyclopia species with sample codes used for DSA and PM tasks.

Cyclopia spp,	Sample code
Cyclopia genistoides	Gen_B1, Gen_B4
Cyclopia subternata	Sub_B2, Sub_B3
Cyclopia maculata	Mac_B1, Mac_B2
Cyclopia longifolia	Lon_B2, Lon_B5
Cyclopia intermedia	Int_B1, Int_B3
Blind duplicates	Lon_B2_dup, Int_B3_dup

Table 2

Sensory lexicon describing aroma characteristics of infusions of *Cyclopia* species.

Aroma attributes	Descriptors	Flavour, taste and mouthfeel attributes	Descriptors
Floral	Fynbos-floral[a]	*Floral*	Fynbos-floral[a]
	Rose geranium		Rose geranium
	Rose/Perfume		Rose/Perfume
Fruity	Lemon/Lemongrass	*Fruity*	Lemon/Lemongrass
	Apricot jam/Apricot		Apricot jam/Apricot
	Apple cooked		Apple cooked
Woody	Woody	*Woody*	Woody
	Pine		Pine
Sweet-associated	Fruity-sweet	*Spice*	Sweet spice / Cassia
	Caramel		Coconut
	Honey	*Taints*	Dusty
	Fynbos-sweet		Medicinal
Spice	Sweet spice / Cassia		Burnt caramel
Nutty	Walnut		Rotting plant water
	Coconut		Hay/dried grass
Taints	Dusty		Green grass
	Medicinal		Cooked vegetables
	Burnt caramel		
	Rotting plant water	*Taste*	Sweet
	Hay/dried grass		Sour
	Green grass		Bitter
	Cooked vegetables	*Mouthfeel*	Astringent

[a]Fynbos is natural shrubland vegetation growing in the Western Cape, South Africa

Table 3

RV coefficients for the correlation between the product configurations obtained with DSA, global PM, partial PM on aroma and partial PM on palate of five *Cyclopia* species.

	DSA	Global PM	Partial PM aroma	Partial PM palate
DSA	1.00	0.90	0.89	0.86
Global PM	0.90	1.00	0.93	0.95
Partial PM aroma	0.89	0.93	1.00	0.95
Partial PM palate	0.86	0.95	0.95	1.00

Table 4

People performance indices (PPI) for all assessors for three variations of PM.

Judge	Global PM		Partial PM on aroma		Partial PM on palate	
	PPI 1[a]	PPI 2[a]	PPI 1[a]	PPI 2[a]	PPI 1[a]	PPI 2[a]
1*	0.00	0.20	0.05	0.05	0.00	0.41
2*	0.00	0.55	0.16	0.63	0.25	0.15
3*	0.41	0.31	0.46	0.47	0.26	0.15
4	0.21	0.30	0.24	0.32	0.22	0.19
5	0.00	0.18	0.06	0.11	0.00	0.23
6	0.14	0.13	0.04	0.28	0.16	0.19
7*	0.71	0.66	0.27	0.47	0.37	0.43
8	0.00	0.17	0.00	0.00	0.00	0.00
9*	0.00	0.25	0.00	0.03	0.00	0.40
10*	0.05	0.09	0.15	0.15	0.03	0.14

*First introduction to the PM task for these assessors

[a]PPI 1, PPI calculated for Int_B3; PPI 2, PPI calculated for Lon_B2

Table 5

RV coefficients for the correlation of MFA configurations of assessors for three replications of global PM, partial PM on aroma and partial PM on palate compared to the overall MFA solution per task (projective mapping PM, replicate 1,2,3).

	MFA PM global			MFA PM aroma			MFA PM palate		
Judge	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
1*	0.83	0.83	0.86	0.75	0.72	-	0.63	0.79	0.87
2*	0.72	0.61	0.49	0.49	0.43	0.29	0.54	0.18	0.82
3*	0.40	0.32	0.25	0.56	0.34	-	0.41	0.67	0.28
4	0.79	0.70	0.72	0.49	0.72	0.77	0.70	0.79	0.75
5	0.80	0.79	0.79	-	0.73	0.73	0.82	0.89	0.84
6	0.76	0.80	0.77	0.76	0.80	0.84	0.71	0.81	0.82
7*	0.17	0.55	0.35	0.31	0.27	0.34	0.52	0.39	0.50
8	0.83	0.66	0.75	0.67	0.75	0.77	0.73	0.72	0.76
9*	0.62	0.83	0.72	0.78	0.76	0.76	0.70	0.81	0.76
10*	0.65	0.44	0.56	0.70	0.67	0.83	0.62	0.50	0.43

*First introduction to the PM task for these assessors

Table 6

Similarity indices (SI) for the repeatability of assessors over three replications of global PM, partial PM on aroma and partial PM on palate.

	Global PM			Partial PM on aroma			Partial PM on palate		
Judge	PANOVA SI	GPA SI	MFA SI	PANOVA SI	GPA SI	MFA SI	PANOVA SI	GPA SI	MFA SI
1*	0.95	0.22	0.26	0.88	0.36	0.50	0.83	0.45	0.50
2*	0.79	0.51	**1.01**	0.64	**0.75**	**1.03**	**0.59**	**0.83**	**1.04**
3*	**0.38**	**1.28**	**1.34**	**0.47**	**1.05**	**1.20**	**0.55**	**0.89**	**1.10**
4	0.83	0.45	0.59	0.70	0.65	**0.80**	0.88	0.36	0.57
5	0.98	0.16	0.21	0.93	0.26	0.38	0.98	0.16	0.23
6	0.89	0.35	0.45	0.88	0.36	0.48	0.90	0.34	0.36
7*	**0.57**	**0.87**	**1.02**	**0.52**	**0.96**	**1.13**	0.67	**0.70**	**0.84**
8	0.89	0.35	0.36	0.99	0.07	0.14	**0.10**	0.05	0.08
9*	0.89	0.35	**0.73**	0.94	0.24	**0.89**	0.85	0.42	0.56
10*	0.95	0.22	0.40	0.95	0.23	0.44	0.90	0.32	0.49

*First introduction to the PM task for these assessors

Table 7

RV coefficients for the correlation between the product configurations per PM technique and replicate sessions of global PM, PM on aroma and PM on palate (replicate 1, 2, 3) of five *Cyclopia* species.

	Global PM				Partial PM Aroma				Partial PM Palate		
	Rep 1	Rep 2	Rep 3		Rep 1	Rep 2	Rep 3		Rep 1	Rep 2	Rep 3
Rep 1	1.00	0.86	0.89	Rep 1	1.00	0.88	0.94	Rep 1	1.00	0.84	0.84
Rep 2	0.86	1.00	0.90	Rep 2	0.88	1.00	0.90	Rep 2	0.84	1.00	0.92
Rep 3	0.89	0.90	1.00	Rep 3	0.94	0.90	1.00	Rep 3	0.84	0.92	1.00

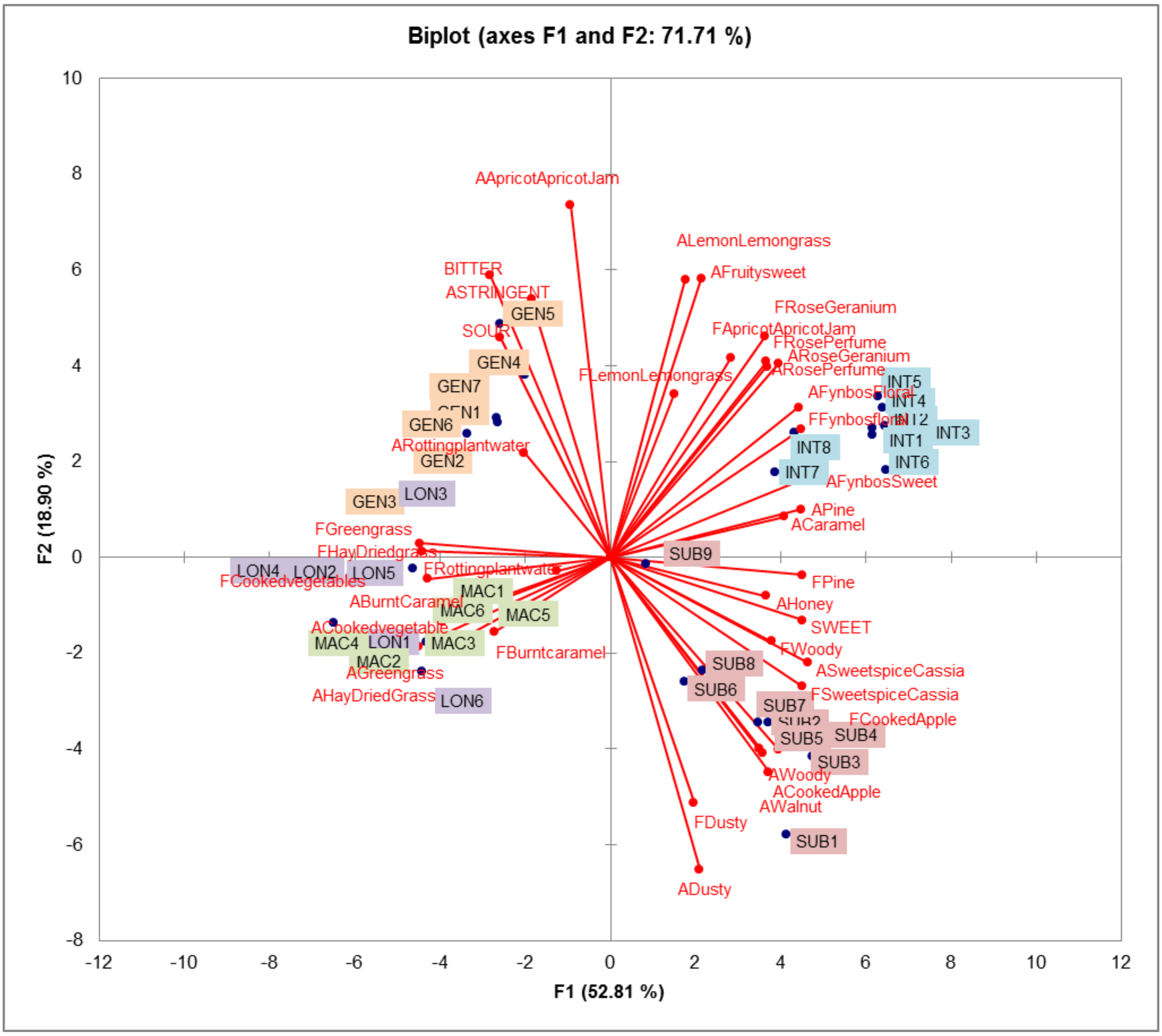

Fig. 1. PCA bi-plot representing the differentiation between five *Cyclopia species* obtained with DSA (total sample set). Extensions to attributes indicate A: aroma (orthonasal) and F: flavour (retronasal).

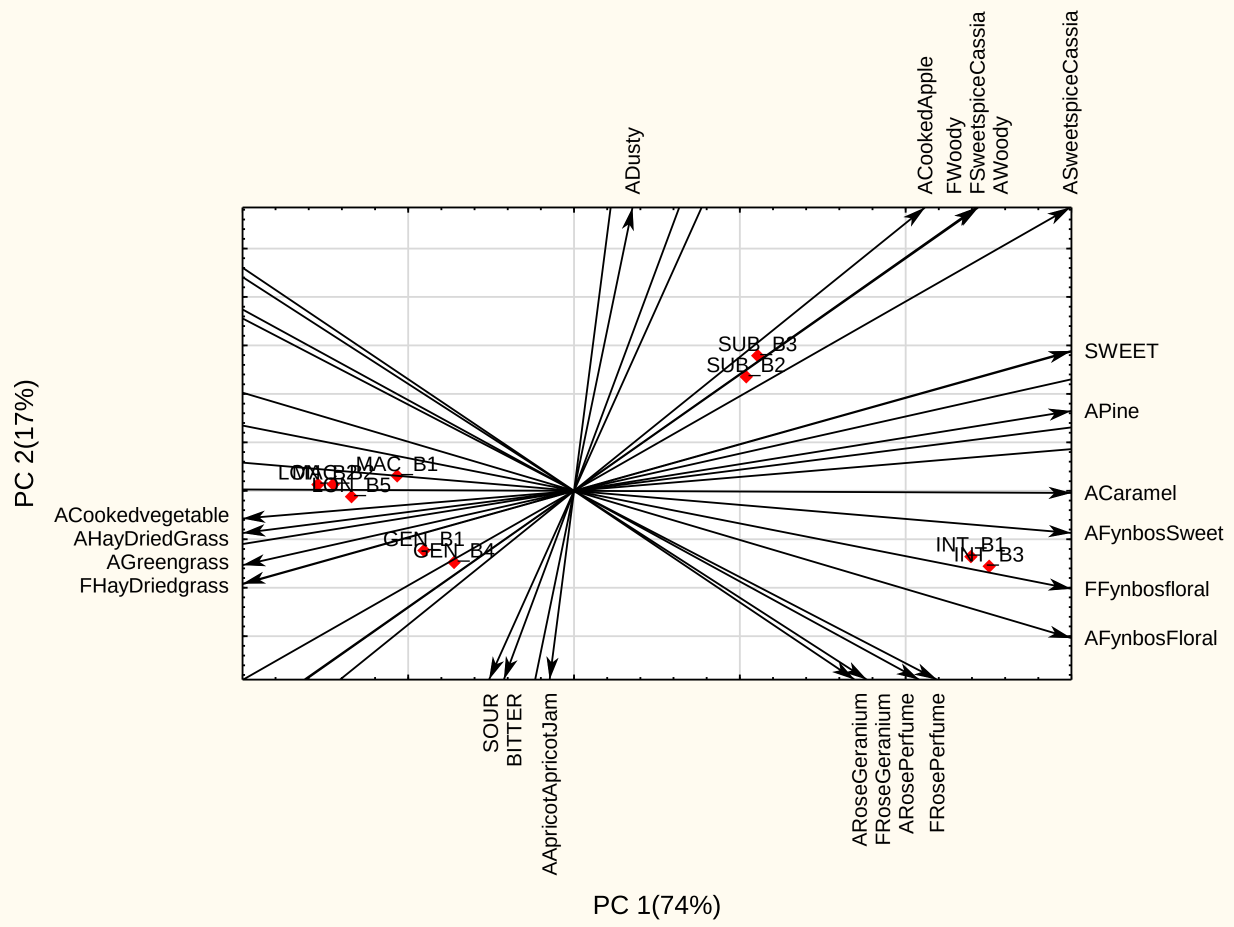

Fig. 2. PCA bi-plot representing the differentiation between five *Cyclopia species* obtained with DSA. Samples selected for PM task included. Extensions to attributes indicate A: aroma (orthonasal) and F: flavour (retronasal).

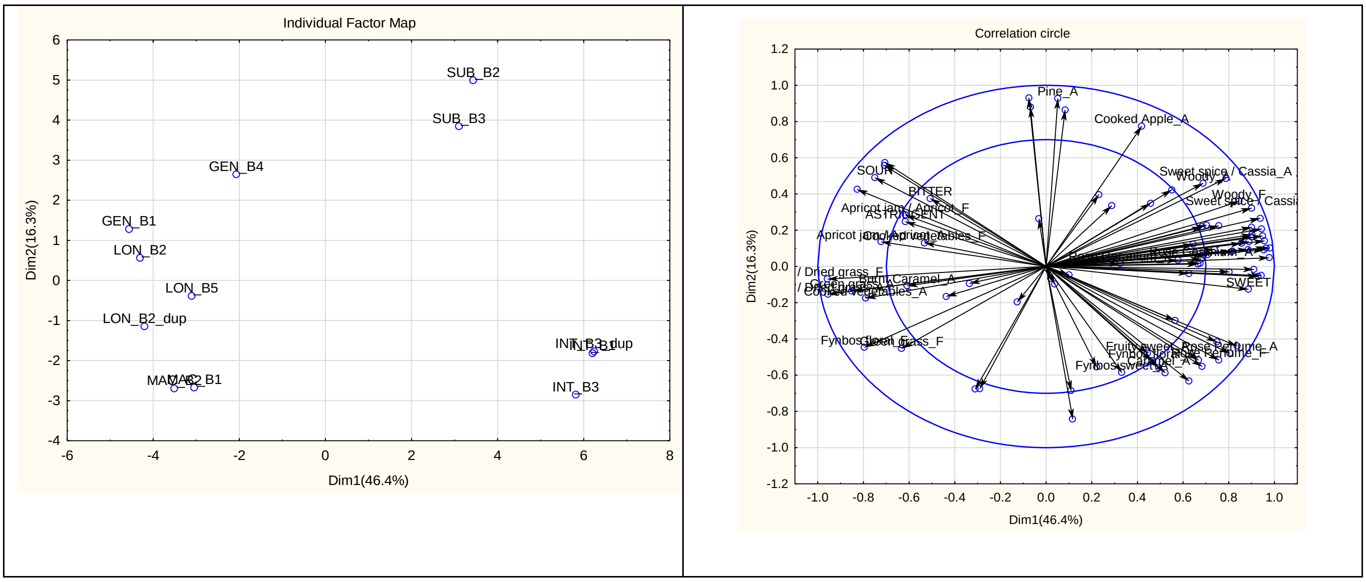

Fig. 3. Individual factor map and correlation circle of attributes obtained from global PM of five *Cyclopia spp*. Extensions to attributes indicate A: aroma (orthonasal) and F: flavour (retronasal).

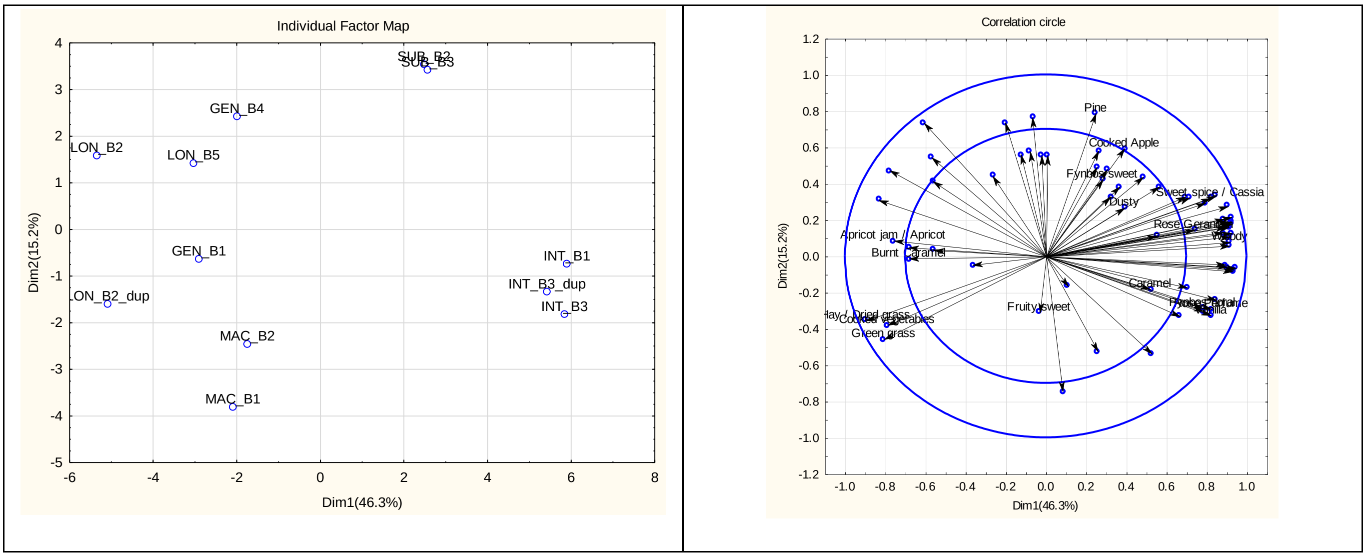

Fig. 4. Individual factor map and correlation circle of attributes obtained from partial PM on aroma of five *Cyclopia spp*.

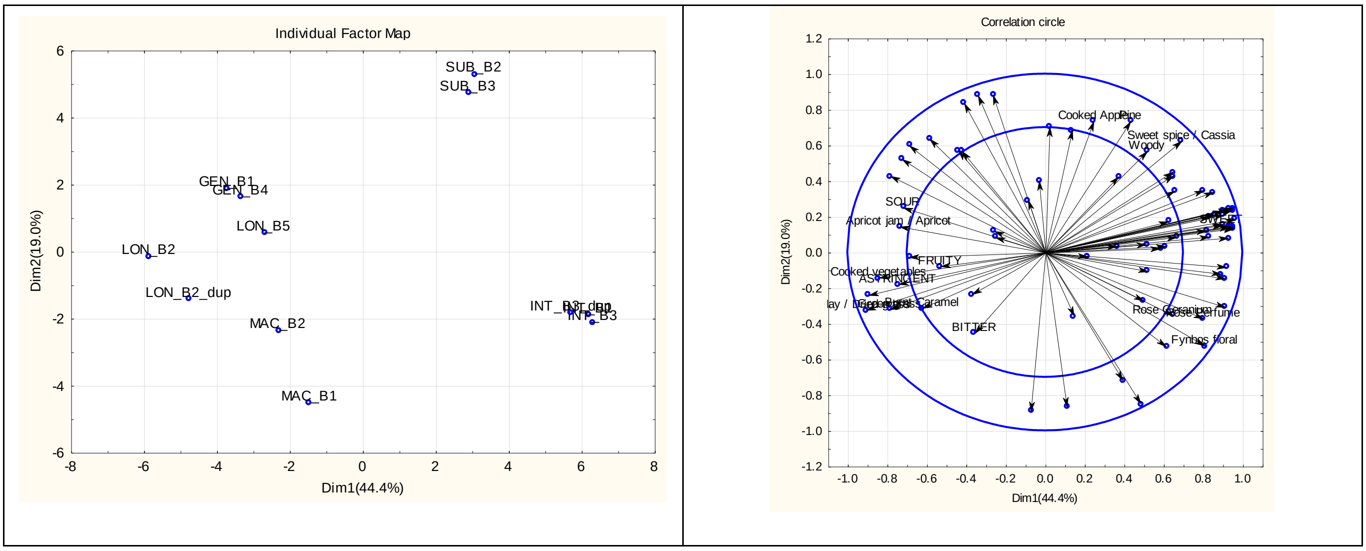

Fig. 5. Individual factor map and correlation circle of attributes obtained from partial PM on palate attributes of five *Cyclopia spp*.