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An investigation of the Pivot© Profile sensory analysis method using wine experts: Comparison with descriptive analysis and results from two expert panels

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ABSTRACT

The performance of the recently developed rapid sensory descriptive method Pivot© Profile (PP) was assessed with a set of 17 Shiraz/Syrah red wines using a group of 49 sommeliers and 11 winemakers. The PP results were compared to results from descriptive analysis (DA) performed by a trained panel. The PP from the two groups of experts gave similar sample configurations, although the terms used differed, with one notable difference being less detailed information on wine colour provided by the sommeliers. The data showed that the PP results from the two panels were also closely equivalent to that obtained from descriptive analysis, with similar sample space configurations, relatively high RV coefficient values and comparable attributes discriminating the samples. PP allowed interpretation of complex terms used by the two groups of experts, and gave insight into the major sensory differences discriminating the wines. DA provided better information regarding attributes that differed more subtly among the sample set, including bitterness. This study demonstrated for the first time that PP and DA provide similar insights into the sensory properties of products, and confirmed that PP with expert panellists allows a rapid understanding of the main sensory differences among samples, with some advantages over DA in obtaining a more holistic overview of each sample.

1. Introduction

Modern applied sensory science can be traced back to the middle of the 20th century with the creation and development of techniques such as the Flavour Profile method (Cairncross & Sjöstrom, 1963), the Texture Profile method (Brandt, Skinner, & Coleman, 1963), Quantitative Descriptive Analysis (Stone, Sidel, Oliver, Woolsey, & Singleton, 1974) and the Spectrum™ method (Meilgard, Civille, & Carr, 1991). Modern day descriptive analysis is generally based on the QDA and Spectrum™ methods and is employed throughout the world as the gold standard for robust, reliable and valid sensory analysis where the aim is to capture the intensity of those sensory properties that differ among a set of samples (Varela & Ares, 2012). However, the process of performing sensory descriptive analysis is time consuming and expensive, as participants or panellists must be screened and trained, which can take months (Lawless & Heymann, 2010), and studies can also take weeks or months to complete. Therefore, generally only large companies or academic institutions have the resources to employ, maintain and operate a descriptive analysis panel.

There has been increased interest in recent years in sensory methods that are quicker and easier to undertake. These methods have often been developed for application with untrained panellists or consumers. Involving panellists who do not require a training period drastically reduces the time and cost of running sensory experiments, as panellists are only required for the time it takes to complete the test. The first published of such rapid methods were the Free Choice Profiling (Williams & Langron, 1984) and Repertory Grid (Williams & Arnold, 1985) methods. Since then there has been an array of different techniques developed using untrained judges or consumers as panellists, including Sorting (Lawless, Sheng, & Knoops, 1995), Flash Profiling (Dairou & Sieffermann, 2002), Projective Mapping or its specific variant Napping® (Pagès, 2005; Risvik, McEvan, Colwill, Rogers, & Lyon, 1994), Check All That Apply (CATA) (Ares, Barreiro, Deliza, Giménez, & Gámbaro, 2010), Rate All That Apply (RATA) (Ares et al., 2014) and Polarised Sensory Positioning (Teillet, Schlich, Urbano, Cordelle, & Guichard, 2010). These methods involve a range of cognitive

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approaches by panellists in product assessment, with comparative, analytical or global processing required, and with different degrees of cognitive load (Ares & Varela, 2014).

Pivot Profile (PP) is a relatively new sensory method (Thuillier, Valentin, Marchal, & Dacremont, 2015) that has shown considerable promise as an alternative sensory method. With this method, panellists use an identified 'pivot' sample as a reference for assessing coded samples. Panellists refer to the pivot and then each of the samples, and write descriptors based on how the sample differs from the reference. The format for these descriptors is to use any term the panellist chooses; however the simple degree modifier 'less' or 'more' is used in conjunction with the descriptor. By controlling this degree modifier, the scope of the descriptors is moderated, to include only those that for each individual differentiate the samples from the pivot. By having to use either *less* x *than the pivot* or *more y than the pivot,* the panellist is obliged to fit the term into one of two categories but is still free to use their personal judgment to describe the sample.

Pivot Profile could be considered a variant of flash profiling, free choice profiling and the open ended question approach, in that panellists use their own criterion for comparative evaluation of a set of samples, and has some relationship to polarised sensory positioning, in that each sample is assessed in comparison to a reference. Similar to flash profiling, it is of particular suitability for panellists with a pre-existing lexicon available to them, so PP has been recommended when working with product category experts (Varela & Ares, 2012), who have a strong frame of reference for naming detailed sensory responses (Bredie, Liu, Dehlholm, & Heymann, 2018). The cognitive basis for methods involving free choice vocabularies has been outlined (Bredie et al., 2018), and especially for those relating to pairs of samples, arises from the personal construct theory proposed by Kelly (1955), where it was put forward that an individual's approach to sensory information of any type involves comparative judgement between aspects of pairs of items. While PP utilises a set of individual attributes, for each sample it is up to the individual to decide on salient characters that differentiates the sample from the reference. In PP panellists must consider each sample as a whole, and then decide on sensory attributes that differentiate the sample from the reference. In conventional descriptive analysis, once an attribute list is developed, panellists adopt an analytical mind-set, and the task is to characterise the sample based only on the attribute list.

For wine studies, the ability to make use of highly experienced expert assessors in sensory characterisation without the need for consensus would mean outcomes from production trials can be determined. Wine experts are experienced in using free description and can be disinclined to use conventional sensory evaluation methods (Thuillier et al., 2015). The approach of using experts' personal/individual attributes to describe complex products such as wine, rather than applying extensive training and familiarisation to align concepts of attributes and intensities as applied in descriptive analysis (DA), also has advantages in retaining individual differences to allow potentially more detailed, rich and informative profiles appropriate to each sample (Thuillier et al., 2015).

An issue with PP, in common with other free choice methods, is the interpretation of the descriptive terms used by the panellists. When applying this method to a product such as wine and using wine professionals from a similar background as judges, there will be a degree of alignment in descriptive terms (Thuillier et al., 2015). The PP method was highlighted as particularly suitable for products such as wine, where there is a commonly used lexicon of terms applied by experts with the same type of background, and this is especially so for those who are highly familiar with the sensory properties of wines from a particular region or of a specific style. The original report of the method used wine experts from the Champagne region, assessing a set of Champagne wines. When analysing the data, the investigators completing the analysis should also have a good understanding of the product being assessed, so that they can effectively and consistently interpret and group the descriptors used. The semantic interpretation can nevertheless be complicated. However, the large number of wide ranging terms used means that the core attributes that describe the samples can be well covered, as previously found for Flash Profiling, where core attributes can be clearly evident from results from individuals from different cultural backgrounds or speaking different languages (Varela & Ares, 2012). Free choice methods can thus be suitable for cross cultural studies, including exploring language used by experts with different backgrounds.

Comparisons of PP with other sensory methods have been reported only to a very limited extent. The original description of PP using a set of sparkling wines did not provide any other sensory data for the samples, limiting comparison to other sensory methods. The PP method has been applied with consumers in comparison to a free-choice comments method (Fonseca et al., 2016), which indicated that PP had good ability to characterise ice-creams. A semi-trained panel used PP to assess a large number of honey samples over multiple sessions (Deneulin, Reverdy, Rébénaque, Danthe, & Mulhauser, 2018), and demonstrated that PP results showed good discriminating ability and advantages when assessing large sample sets but did not report a comparison to other methods. A study involving yoghurts (Esmerino et al., 2017) used 100 consumers in an assessment of PP compared to projective mapping and CATA, and found that the methods gave similar results. No follow-up studies have been reported investigating expert panellists' use of the method, and no study to our knowledge has compared PP to DA.

This study's aim was to determine the discriminating ability of the PP method with expert panellists to characterise sensory differences among samples with complex sensory properties, compared to results from descriptive analysis using trained panellists. In addition, the reliability of the method was investigated by considering results from two groups of expert assessors, differing in size and professional background. The experts were a group of highly experienced international professional sommeliers, with a separate group of Australian wine-makers.

2. Materials and methods

2.1. Samples

Seventeen commercially produced high priced Shiraz/Syrah wines were studied, with retail prices of the wines ranging from AUD $45 to $250, and vintages from 2013 to 2015 (Table 1). The investigation was part of a larger study assessing regional sensory differences in Shiraz

Table 1
Sample codes and details of the 17 wines used, together with the pivot wine.

Code	Region	Vintage	Alcohol (% v/v)
HV	Hunter Valley, NSW	2014	13.5
MV1	McLaren Vale, SA	2014	14.5
MV2	McLaren Vale, SA	2014	14.5
FR1	Crozes-Hermitage, Rhone Valley, France	2015	13.0
FR2	Cornas, Rhone Valley, France	2013	13.0
CV	Clare Valley, SA	2014	13.7
EV	Eden Valley, SA	2014	14.5
BV	Barossa Valley, SA	2013	14.4
CB	Canberra, ACT	2014	14.0
HC	Heathcote, Vic	2015	15.0
BE	Beechworth, Vic	2013	13.5
YV1	Yarra Valley, Vic	2015	13.0
YV2	Yarra Valley, Vic	2015	13.5
AH	Adelaide Hills, SA	2014	14.0
GR	Grampians, Vic	2014	14.0
NZ	Hawkes Bay, NZ	2013	13.1
GE	Geelong, Vic	2014	13.5
Pivot	Limestone Coast, SA	2015	14.5

ACT: Australian Capital Territory, NSW: New South Wales, NZ: New Zealand, SA: South Australia, Vic: Victoria.

Table 2
Attributes, definitions and reference standards for the sensory descriptive analysis.

Attribute	Definition/Synonyms	Reference standard composition[1]
Appearance		
Opacity	The degree to which light is not allowed to pass through a sample	
Purple Tinge	The degree of purple hue	
Brown Tinge	The degree of brown hue	
Aroma		
Overall fruit	Intensity of the fruit aromas	
Dark fruits	Intensity of the aroma of dark fruits and berries: blackberries, plums, cherries, blueberries, black currants	3 × frozen blueberries, 1 × frozen blackberry (Sara Lee brand)
Red fruits	Intensity of the aroma of red fruits and berries: raspberries, strawberries and cranberries.	3 × frozen raspberries (Sara Lee brand)
Confection	Intensity of the aroma of confectionary, lollies	3 raspberry lollies, no wine (Natural Confectionary Company brand)
Floral	Intensity of the aroma of flowers: violets, rose and blossoms	80 μL of 100 mg/L linalool, 10 μL of 200 mg/L 2-phenyl ethanol
Vanilla	Intensity of the aroma of vanilla	1/8 tsp vanilla paste (Queen brand)
Sweet Spice	Intensity of the aroma of sweet spices: cinnamon, nutmeg, cloves	50 mg each mixed spice, nutmeg, cinnamon and 1 clove (Masterfoods brand)
Liquorice	Intensity of the aroma of liquorice, aniseed	¼ tsp aniseed
Pepper	Intensity of the aroma of black pepper, white pepper, peppercorns	3 grinds fresh black pepper (Saxa brand)
Woody	Intensity of the aroma of wood, oak, cedar, smoky oak	1 tsp French oak chips
Stalky	Intensity of the aroma of green stalks, green herbs, eucalypt	2 pc fresh tomato stalk, no wine
Green Bean	Intensity of the aroma of green beans, green vegetables, spinach, green olives, capsicum	4 × 1 cm pieces fresh green bean, 10 μL of 500 μg/L isobutylmethoxypyrazine
Earthy	Intensity of the aroma of dust, dry earth, wet earth, mud and compost	30 μL of 1 mg/L geosmin
Cooked Vegetable	Intensity of the aroma of cooked vegetables, cooked vegetable water, drains	2 tsp of liquid from tinned mixed vegetables (Edgell brand)
Barnyard	Intensity of the aroma of barnyards, Band-Aid	10 μL of 100 mg/L 4-ethyl guaiacol, 30 μL of 500 mg/L 4-ethyl phenol
Nail Polish Remover	Intensity of the aroma of nail polish remover, vinegar	30 μL of 100 mg/L ethyl acetate
Pungent	Intensity of the aroma and effect of alcohol	4 mL ethanol (SVR, Tarac Technologies)
Palate		
Overall Fruit	Intensity of fruit flavours in the sample.	
Dark Fruit	Intensity of the flavour of blackberries, plums, cherries, black currants and blueberries.	
Red Fruit	Intensity of the flavour of raspberries, strawberries, cranberries	
Vanilla	Intensity of the flavour of vanilla	
Spice	Intensity of the flavour of spice, including sweet spices, liquorice, aniseed	
Pepper	The intensity of the flavour of peppercorns	
Stalky	Intensity of the flavour of green stalks, capsicum, fresh green beans and other green vegetables	
Sweet	Intensity of sweet taste	8 g/L white sugar (Coles brand) in water
Viscosity	The perception of the body, weight or thickness of the wine in the mouth. Low = watery, thin mouth feel. High = oily, thick mouth feel.	1.5 g/L carboxymethylcellulose sodium salt (Sigma Aldrich) in water
Acid	Intensity of acid taste	2 g/L L-(+)-tartaric acid (Chem-Supply) in water
Hotness	The intensity of alcohol hotness Low = warm; High = hot, burning.	8% v/v food grade ethanol (Tarac Technologies) in water
Astringency	The drying and mouth-puckering sensation in the mouth. Low = coating teeth; Medium = mouth coating & drying; High = puckering, lasting astringency.	0.43 g/L aluminium sulfate (Ajax fine Chem Supply) in water
Bitter	The intensity of bitter taste	0.15 g/L quinine sulfate (Sigma Aldrich) in water
Fruit AT	The lingering fruit flavour perceived in the mouth after expectorating.	

[1]Prepared in bag-in-box 2017 Shiraz wine unless otherwise noted.

red wines.

The set of 17 wines evaluated were predominantly Australian wines with some international examples included. The wines were selected to have relatively wide variation in sensory properties while all being of the one grape variety, to reflect common tasks required for wine sensory studies. They were selected from 12 Australian regions, with one wine from Hawkes Bay in New Zealand and two from the Rhone Valley in France. The wines from France and from New Zealand were included to ensure there were sufficiently large differences in the sample set. The wines were pre-screened to include wines with sensory attributes that were as generally expected for high priced wines of each region. This meant that a few wines were selected that could be considered to have a minor off-odour or off-flavour, notably Brettanomyces/Dekkera related flavour (medicinal, barnyard), volatile acidity (acetic acid, solvent-like) or sulfidic notes. Seven wines were sealed under cork, with one wine sealed under a glass stopper, and the remainder under screwcap. Cork-sealed wines were examined by several experienced judges prior to sensory assessment, with one bottle being rejected for cork taint.

Shiraz wines generally have a strong red colour, intense dark fruit (blackberry, plum) aroma and flavour, and are rich in flavour, moderately astringent and with moderate acidity (Robinson, Harding, & Vouillamoz, 2012). The pivot wine was selected in a preliminary assessment by a group of Australian Wine Research Institute assessors highly experienced in Shiraz wine sensory properties. It was chosen on the basis of exhibiting sensory characters that were typical of the Shiraz/Syrah variety, while not having very strong or dominating key characteristics such as dark fruit, astringency, colour intensity, 'green' flavour, oak flavour, or any off-flavour. It was produced in high volumes and had been awarded a gold medal at a recent Australian capital city wine competition. Lelièvre-Desmas, Valentin, and Chollet (2017) compared the effect of several types of pivot samples on the results of PP using trained panellists and concluded that the type of pivot sample may be less important than the degree of heterogeneity among the samples.

2.2. Sensory methodology

2.2.1. Pivot Profile

Panellists were presented with 50 mL of each of the 17 wines in Riedel Overture red wine tulip shaped stemware, marked with three-

digit codes and presented in randomized order at ambient room temperature. Panellists received 100 mL of the pivot wine. The assessments were administered in an open plan room on tables with all samples presented at once. Verbal and written instructions on how to perform the exercise were given to the judges prior to the assessment. Panellists completed the evaluation in 60 min. None of the panellists had previously used the PP method. Data was collected on A4 paper ballots with spaces for writing *more* or *less* than the pivot for appearance, aroma and palate attributes (Appendix 1).

The sommelier session involved 49 panellists (28 male, 21 female) who were professional sommeliers from Australia (12), New Zealand (10), the United Kingdom (8), the United States (7), China (4), Japan (2), Thailand (2), Spain (1), South Korea (1), Singapore (1) and Denmark (1). The session was held in a function room of a major hotel. The winemaker PP session was held in a separate session with eleven panellists (ten male, one female) who were all employed as winemakers in South Australia. The session was held in a meeting room at the AWRI. It should be noted that the environmental conditions of the two sessions, while similar, were not identical.

2.2.2. Descriptive analysis

A panel of twelve panellists (one male) was convened, all of whom were part of the AWRI trained external descriptive analysis panel with extensive wine descriptive analysis experience. Each panellist had completed a minimum of five wine descriptive analysis studies over the previous 12 months. The AWRI's wine sensory descriptive analysis panel is run approximately 45 weeks of the year, with sessions three times per week. Details of the protocols and training for the descriptive analysis can be found in Siebert et al. (2018). Briefly, a generic descriptive analysis protocol was applied (Lawless & Heymann, 2010), with three two-hour attribute generation and discussion sessions completed, followed by a practice rating session. A series of samples were presented to encompass the range of sensory properties. The first session was used for attribute generation, with panellists generating individually sensory attributes that described the samples. In subsequent sessions panellists agreed on the list of attributes, their reference standards and written definitions (Table 2).

All seventeen wines were presented to panellists three times in a modified Williams Latin Square incomplete random block design generated by Fizz sensory acquisition software (version 2.51, Biosystemes, Couternon, France). The seventeen wines were split into six blocks: five blocks of three wines and one block of two wines. Panellists assessed five blocks per two-hour session. There was a forced rest of two minutes between each wine, with a minimum ten-minute break between blocks. Assessment took place over four sessions, with one session per day.

Panel performance was assessed using Fizz and R (version 3.3.2, Vienna, Austria) with the FactomineR (Lê, Josse, & Husson, 2008) package, and included analysis of variance for the effect of judge and presentation replicate and their interactions, degree of agreement with the panel mean and degree of discrimination across samples. All judges were found to be performing to an acceptable standard.

2.3. Data analysis

2.3.1. Pivot Profile

Results were transposed from paper to spreadsheet software, separated into 'more than' or 'less than' attributes × taster × wine. The most frequently used attributes were listed and then the original attributes used by each judge were assimilated into a master list of attributes, maintaining how they were used ie. 'more than' or 'less than'. Some interpretation was required during this analysis to reconcile terms that have similar meanings (for example: tannin, tannic, blocky tannin, tannins, soft tannin, hard tannin), to compile a data matrix of adjectives describing the wine sensory profiles. The approach as detailed previously (Thuillier et al., 2015) was followed, with the frequency of the 'less than' terms subtracted from the 'more than' terms for each attribute to obtain a value for each attribute for all wines. As some values were negative (some attributes were used in a 'less than' context more than in a 'more than' one), the data was adjusted to contain only positive values, with the most negative value from the matrix added to all the values in the set, making the most negative attribute zero and all other attribute's values positive. Once completed, the modified frequency data was then analysed using correspondence analysis (CA) (XLSTAT, Addinsoft, 2019) to produce a biplot of the wines and the attributes. Analysis was initially undertaken for appearance, aroma and palate terms individually, and then another CA was completed for all terms, excluding those attributes from the initial CA with loadings of less than 0.1 on either of the first two factors for each modality. For the final CA the original data was re-normalized to have the most negative score of all the attributes equal zero.

2.3.2. Descriptive analysis

Analysis of variance (ANOVA) was carried out using Minitab 18.1 (Minitab Inc., 2017). The effects of wine (W), judge (J), presentation replicate (R), and their two-way interactions were evaluated, treating judge as a random effect. Principal component analysis (PCA) was conducted on the mean values of the significant ($p < 0.05$) and nearly significant ($p < 0.1$) attributes averaged over panellists and replicates, using the correlation matrix. Multiple Factor Analysis (MFA) was used to compare the PP and DA data sets (XLSTAT, Addinsoft, 2019).

3. Results

3.1. Pivot profile with two different groups of expert panellists

The 49 international sommeliers characterized the wines using a total of 81 different attributes, which were aggregated into nine appearance, 36 aroma and 36 palate attributes. CA was first completed with only appearance attributes, then aroma, then palate data, to discern which attributes most differentiated the wines. Attributes from all three groups that were not effective at separating the wines were then removed from the analysis (data not shown), and a group CA was then completed with the remaining 33 attributes (Fig. 1a).

The total explained variance for the first two factors in the CA was 70.5%. Attributes that most differentiated the wines along Factor 1 in Fig. 1a were deep colour, body and tannin, characterising the wines plotted to the right of the figure, including MV1, MV2, BV, HC, FR1 and FR2, with attributes including fresh flavour, ruby red colour, spice, herbal, floral aroma, and red fruit aroma used for those wines to the left of Fig. 1a, including CB, YV1, YV2, AH, HV, GE, EV and GR, together with less specific attributes more related to hedonics such as balanced, drinkable and elegant. Tannin and body were also important along Factor 2, along with acid, Brett aroma and fruit flavour. The French and the New Zealand wines, as well as the BE wine, were characterized by the attributes tannin, Brett/medicinal aroma, acid and deep colour. The term 'Brett' refers to Brettanomyces/Dekkera yeast flavour, which is a relatively common wine flavour attribute world-wide (Goode, 2018).

A smaller group of winemakers characterized the same wines using the PP method, using 53 different attributes in total, which were aggregated into six appearance, 22 aroma and 25 palate attributes. The correspondence analysis biplot for this data is shown in Fig. 1b. The total variance for the Factors 1 and 2 was 63.8%, somewhat smaller than for the sommeliers' CA. The order of the wines along Factor 1 was similar between the two groups of experts, with the MV1, MV2, BV, HC, BE, FR2 and FR1 wines again situated to the right of Fig. 1b, and GE, YV2, CB, EV, GR, CV, YV1 and HV to the left of Fig. 1b. The NZ wine was plotted close to the origin. The wines to the right of Fig. 1b were more frequently described as higher in body and opaque colour compared to the pivot, while those to the left were more associated with red colour, transparent, red fruit, green, acid, floral and vibrant attributes. The positioning of the wines along Factor 2 was somewhat different to that of the sommeliers' CA, notably for the wines AH and BE, which

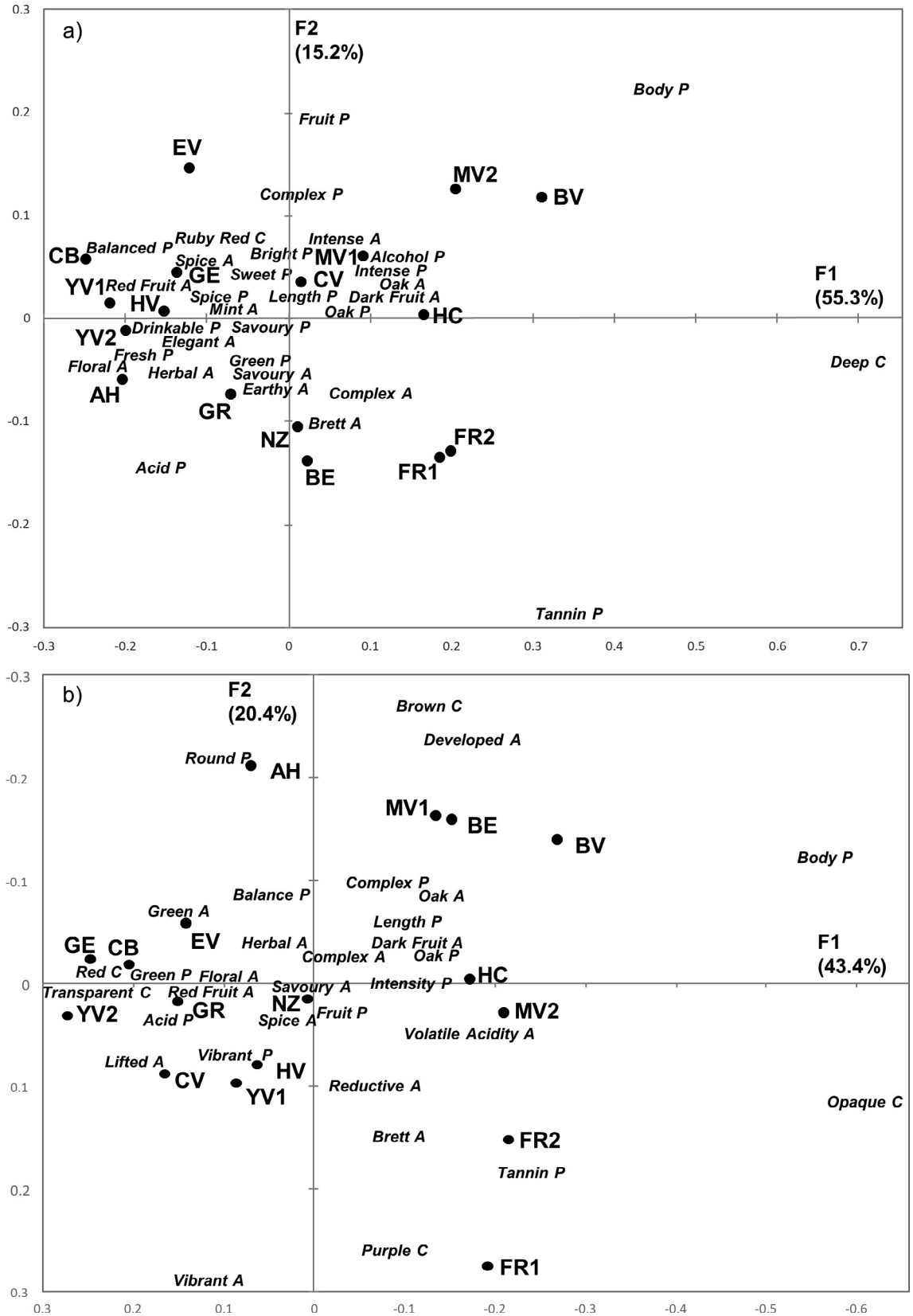

Fig. 1. Correspondence analysis biplot of the 17 Shiraz wines using Pivot© Profile from a) 49 international sommeliers and b) 11 Australian winemakers. C: colour attributes, A: aroma attributes, P: palate attributes.

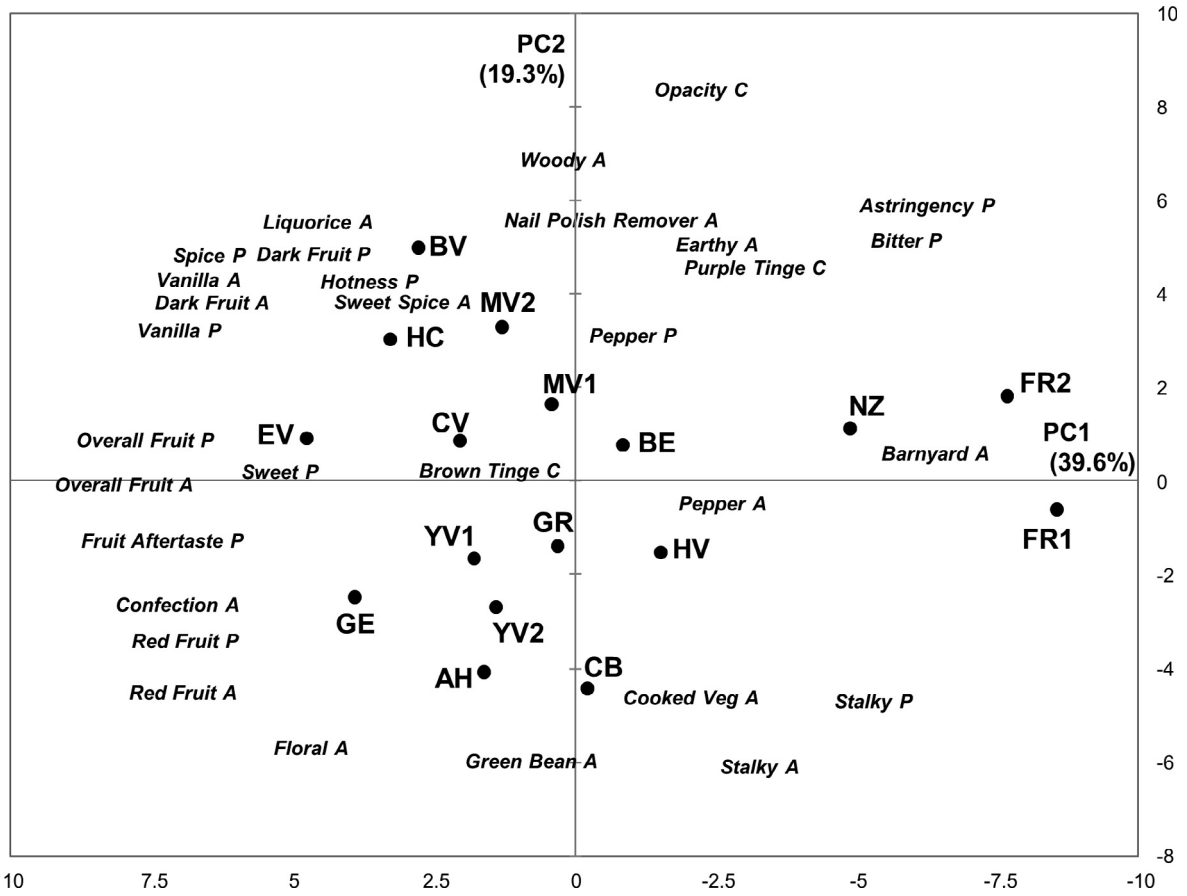

Fig. 2. PCA scores and loadings biplot from the mean values of the descriptive analysis of the 17 Shiraz wines for the first two PCs. C: colour attributes, A: aroma attributes, P: palate attributes.

were linked to brown colour, developed aroma and round palate terms, and less associated with purple colour. The descriptive attributes used by the two groups were overall similar, however a major difference was that the winemakers used the appearance attributes brown and purple, highly loaded on Factor 2, which were not used by the sommeliers. The winemakers used a more technical lexicon, with terms such as volatile acidity, reductive and developed, which were not used by the sommeliers. The winemakers also used a smaller number of attributes to characterize the wines.

A Multiple Factor Analysis (MFA) was completed on the two data sets, returning an RV coefficient value of 0.79 ($p < 0.001$), indicating a moderate to high level of similarity between the sample spaces obtained from the two groups of experts.

3.2. Descriptive analysis

A panel of trained panellists completed a descriptive analysis on the same set of wines. From the results of the ANOVA, 28 of the 34 attributes differed significantly ($p < 0.05$) among the wines, with three showing a trend ($p < 0.1$).

Fig. 2 shows that the first two PCs explained 58.9% of the variance, with PC1 (39.6% of the explained variance) separating the wines according to differences in ratings of fruit, confection and vanilla attributes, as opposed to barnyard aroma, astringency, bitterness and stalky, with the FR1, FR2 and NZ wines rated highly in these attributes. PC2 (19.3% of the variance) shows that the wines BV, MV1, MV2 and HC were rated higher in opacity, woody, pungent, nail polish remover, dark fruit aroma and flavour, hotness, liquorice, spice and vanilla, with the wines situated in the lower part of Fig. 2 rated lower in these attributes and higher in cooked veg, stalky and green bean. The wines EV, GE, AH, YV1 and YV2 had higher ratings for red fruit, floral and confection attributes.

When comparing the descriptive analysis PCA map to that from the PP characterizations, the Factor 1 scores from the PP biplots relate most closely to PC2 from the descriptive analysis. Overall, the pattern of the samples from the DA resembles the PP characterization with a 90-degree rotation. However, the samples FR1 and FR2 fall outside of this resemblance, as they are strongly characterized along PC1, and appear to have been characterized by the DA panellists in a different way than the PP panellists. Therefore, care should be taken when interpreting PP results.

PC3 (10.3%, not shown) described pepper aroma and flavour attribute differences among the samples, with the NZ wine rated highest in the latter attributes, while PC4 (7.7%, not shown) describes further differences among the wines in 'green' flavours: green bean aroma, cooked vegetable aroma, stalky aroma and flavour.

The terms used by the sensory panel included some attributes describing important sensory properties that were not used by the experts, notably bitterness, sweet and astringency, as well as vanilla, confection, woody, stalky, green bean, cooked veg and pepper.

The RV coefficient between the descriptive analysis and the winemakers PP was 0.69 ($p < 0.001$), and between the descriptive analysis and the sommeliers PP was 0.67 ($p < 0.001$).

4. Discussion

The PP and DA results aligned moderately well. The sample space configuration was similar between DA and PP, with the French wines well separated in both methods from a group of Australian wines with similarly deep colour but with different aroma and flavour attributes.

The RV coefficients between the DA sample configuration and the two PP data sets were moderate and significant (0.69 and 0.67), indicating agreement between the results of the two methodologies. However, these are not as high RV coefficients as found for other evaluations for descriptive methods with similarly complex samples, such as for free choice profiling and flash profiling with a red wine sample set (Liu, Bredie, Sherman, Harbertson, & Heymann, 2018), where RV coefficients for several comparisons to DA were from 0.86 to 0.92, or comparing RATA with consumers to DA for a set of wines (Danner et al., 2018, RV values found of 0.92 and 0.97).

The DA results, when visualised using PCA, showed that the highest variation in attribute ratings among the wines along PC1 related to the astringency, bitter and barnyard attributes, separating the French and New Zealand wines from those Australian wines with higher fruit attributes. For the PP for both groups of experts, the main separation of the wines along Factor 1 related to overall colour intensity and body. This difference is likely to be related to the evaluation approaches encouraged in the two methods, with the cognitive strategies elicited by PP more related to a similarity-based approach (Lelièvre-Desmas et al., 2017). Therefore, the major, most obvious sensory differences between each wine and the pivot wine are most strongly considered and allow for individual differences in expression. The cognitive strategy used by the experts in PP was also evidenced in the terms used, with the DA results showing that the wines differed significantly in heat and bitterness, while neither these terms nor any equivalents were applied by either group of experts. The DA attributes gave an arguably more detailed, nuanced profile compared to that provided by the PP, with for example the attributes liquorice, pepper and confection not used by the PP experts. Other attributes used in PP were quite broad, and related to terms used in a more specific manner by the DA panel, with 'green' used in the PP while stalky and green bean were applied in the DA, and similarly oak used in PP, with vanilla and woody used in DA.

As expected, experts used technical terms to describe some sensory characteristics, such as volatile acidity, Brett and reductive, while the DA panel used the more specific equivalent, namely nail polish remover, barnyard and cooked vegetal. It is possible that PP does not highlight more subtle differences between samples, or that when tasked with making a comparison assessment using the pivot, assessors only focus on the most salient of attributes, where a DA assessment allows for subtle or less prominent attributes to be characterized more effectively. The attribute bitterness highlights this, as this was not an attribute used by either set of judges using PP, but yet was an important attribute in the DA assessment. As bitterness has been found to be of importance to consumer liking responses for wines (Francis & Williamson, 2015) it is important to consider this when deciding on the use of PP.

The PP results showed that some interesting insights can be obtained that are not available with conventional DA, namely descriptions related to overall judgements such as 'drinkable', 'complex', 'round', 'balance', 'fresh' or 'vibrant', which can provide a richer and more powerful overview of the sample set. From the PP results the association of these complex terms with the more specific terms can be used to interpret the complex terms. Both the sommeliers and the winemakers used the terms drinkable and balanced to refer to wines with less intense colour and body, and greater red fruit and floral sensory properties.

When comparing the two different PP sessions completed with experts from different professional backgrounds, and with different numbers of experts, the results show that the sensory characterization was similar, with comparable sample patterns found. This could infer that the number of experts used as assessors is not critically important, and a larger number was potentially not necessary to the overall sensory characterization of the wines, although this may not be the case when using non-experts or consumers. However, this result would need to be confirmed in an assessment specifically designed to test this. In considering the attributes used by the winemakers and the sommeliers, the winemakers used the appearance terms brown, purple and developed to describe the wines in the PP exercise, as well as depth of colour terms like opaque and transparent, whereas the sommeliers used only depth of colour terms. As noted above for attributes such as bitterness and heat, this is a potential issue with PP that the degree of attention due to the background and prior experience of the panellists can mean some important but relatively subtle sensory information is missed. Winemakers are trained to note and describe small differences in wine colour, which may have been the cause for this difference between the groups. The larger number of attributes used by the sommeliers could have also been affected by the number of judges, as there were more than four times as many judges for the sommeliers tasting as the winemakers tasting, so it is reasonable that there could be more terms used overall.

The background of the expert judges appears to have little influence on the overall characterization of the products. While the two groups of judges used slightly different lexicons to describe the products, the locations of the wines on the biplots were very similar.

In common with some other rapid methods, it should be noted that compared to DA, PP has limited applicability for relating sensory data to chemical or other compositional data, and there are challenges to model consumer preference with outcomes from PP. Another negative aspect to the use of the PP method is the amount of time required for data entry, as well as the complex nature of the textual analysis required. In the present study the paper ballot data for each panellist was required to be entered into a spreadsheet manually, and then categorised, sorted and analysed. The method has been applied using data acquisition software (Fonseca et al., 2016), but most current commercial sensory software packages do not have a specific pivot profile test included.

5. Conclusions

This study has shown that PP is a method that is sufficiently robust to produce similar and valuable results with different groups of expert panellists, even when the background, descriptive language and number of panellists differed. As previously pointed out by other researchers, PP was shown to be valuable way to assess cross-cultural differences in responses between groups of panellists. The method was found to give useful data on the sensory properties of wines, with relatively similar outcomes to that of descriptive analysis, and would be a suitable replacement in situations where time and cost are factors that preclude the use of DA, and where information on the largest, most discriminating aspects of the sample set are required.

PP may be less useful if information on attributes responsible for small differences among samples are needed. Obtaining expert viewpoints without the need to achieve consensus, and allowing insight into more complex attributes, is an advantage of the method. The use of PP with a fairly small number of technical experts with an established vocabulary allows meaningful sensory differences among samples to be ascertained, even with a relatively large sample set, and overall the method was found to be suitable for rapid assessment of a complex product such as red wine.

CRediT authorship contribution statement

Wes Pearson: Conceptualization, Investigation, Formal analysis, Writing - original draft. **Leigh Schmidtke:** Writing - review & editing, Funding acquisition, Supervision. **I. Leigh Francis:** Conceptualization, Writing - review & editing, Supervision. **John W. Blackman:** Conceptualization, Investigation, Writing - review & editing, Supervision.

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Appendix A

The Pivot Profile assessment ballot used.

Sample	The sample is ***less*** _____ than the control	The sample is ***more*** _____ than the control
Appearance		
Aroma		
Palate		

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2019.103858.

References

Addinsoft (2019). XLSTAT statistical and data analysis solutions. Long Island, NY, USA. https://www.xlstat.com.

Ares, G., & Varela, P. (2014). *Novel Techniques in Sensory Characterization and Consumer Profiling.* Bosa Roca: CRC Press.

Ares, G., Barreiro, C., Deliza, R., Giménez, A., & Gámbaro, A. (2010). Application of a check-all-that-apply question to the development of chocolate milk desserts. *Journal of Sensory Studies, 25*, 67–86.

Ares, G., Bruzzone, F., Vidal, L., Cadena, R. S., Giménez, A., Pineau, B., et al. (2014). Evaluation of a rating-based variant of check-all-that-apply questions: Rate-all-that-apply (RATA). *Food Quality and Preference, 36*, 87–95.

Brandt, M. A., Skinner, E. Z., & Coleman, J. A. (1963). Texture profile method. *Journal of Food Science, 28*, 404–409.

Bredie, W. L. P., Liu, J., Dehlholm, C., & Heymann, H. (2018). *Flash Profile Method. Descriptive Analysis in Sensory Evaluation.* John Wiley Sons Ltd.

Cairncross, S. E., & Sjöstrom, L. B. (1963). Flavor profiles: A new approach to flavor problems. *Food Technology, 4*, 308–311.

Dairou, V., & Sieffermann, J. M. (2002). A comparison of 14 jams characterised by conventional profile and a quick original method, flash profile. *Journal of Food Science, 67*, 826–834.

Danner, L., Crump, A. M., Croker, A., Gambetta, J. M., Johnson, T. E., & Bastian, S. E. P. (2018). Comparison of rate-all-that-apply and descriptive analysis for the sensory profiling of wine. *American Journal of Enology and Viticulture, 69*(1), 12–21.

Deneulin, P., Reverdy, C., Rébénaque, P., Danthe, E., & Mulhauser, B. (2018). Evaluation of Pivot Profile©, a new method to characterize a large variety of a single product: Case study on honeys from around the world. *Food Research International, 106*, 29–37.

Esmerino, E. A., Tavares Filho, E. R., Carr, B. T., Ferraz, J. P., Silva, H. L. A., Pinot, L. P. F., et al. (2017). Consumer-based product characterization using Pivot Profile, Projective Mapping and Check-all-that-apply (CATA): A comparative case with Greek yogurt samples. *Food Research International, 99*, 375–384.

Fonseca, F. G. A., Esmerino, E. A., Tavares Filho, E. R., Ferraz, J. P., da Cruz, A. G., & Bolini, H. M. A. (2016). Novel and successful free comments method for sensory characterization of chocolate ice cream: A comparative study between pivot profile and comment analysis. *Journal of Dairy Science, 99*, 3408–3420.

Francis, I. L., & Williamson, P. O. (2015). Application of consumer sensory science in wine research. *Australian Journal of Grape and Wine Research, 21*, 554–567.

Goode, J. (2018). *Flawless: Understanding faults in wine.* Oakland, California: University of California Press.

Kelly, G. A. (1955). The psychology of personal constructs. Vol. 1. A theory of personality. Vol. 2. Clinical diagnosis and psychotherapy. Oxford, England: W. W. Norton.

Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food. Principles and practices* (2nd ed.). New York: Springer.

Lawless, H. T., Sheng, N., & Knoops, S. S. C. P. (1995). Multidimensional scaling of sorting data applied to cheese perception. *Food Quality and Preference, 6*, 91–98.

Lê, S., Josse, J., & Husson, F. (2008). FactoMineR: An R package for multivariate analysis. *Journal of Statistical Software, 25*, 1–18.

Lelièvre-Desmas, M., Valentin, D., & Chollet, S. (2017). Pivot profile method: What is the influence of the pivot and product space. *Food Quality and Preference, 61*, 6–14.

Liu, J., Bredie, W. L. P., Sherman, E., Harbertson, J. F., & Heymann, H. (2018). Comparison of rapid descriptive sensory methodologies: Free-choice profiling, flash profile and modified flash profile. *Food Research International, 106*, 892–900.

Meilgard, M. C., Civille, G. V., & Carr, B. T. (1991). *Sensory evaluation techniques* (2nd ed.). Boca Raton, Fl: CRC Press.

Pagès, J. (2005). Collection and analysis of perceived product inter-distances using multiple factor analysis: Application to the study of 10 white wines from the Loire Valley. *Food Quality and Preference, 16*, 642–649.

Risvik, E., McEvan, J. A., Colwill, J. S., Rogers, R., & Lyon, D. (1994). Projective mapping: A tool for sensory analysis and consumer research. *Food Quality and Preference, 5*, 263–269.

Robinson, J., Harding, J., & Vouillamoz, J. (2012). *Wine grapes: A complete guide to 1,368 vine varieties, including their origins and flavours.* New York: Ecco/HarperCollins.

Siebert, T. E., Barker, A., Pearson, W., Barter, S. R., de Barros Lopes, M. A., Darriet, P., et al. (2018). Volatile compounds related to 'stone fruit' aroma attributes in Viognier and Chardonnay wines. *Journal of Agricultural and Food Chemistry, 66*, 2838–2850.

Stone, H., Sidel, J., Oliver, S., Woolsey, A., & Singleton, R. C. (1974). Sensory evaluation by quantitative descriptive analysis. *Food Technology, 8*, 24–32.

Teillet, E., Schlich, P., Urbano, C., Cordelle, S., & Guichard, E. (2010). Sensory methodologies and the taste of water. *Food Quality and Preference, 21*, 967–976.

Thuillier, B., Valentin, D., Marchal, R., & Dacremont, C. (2015). Pivot© Profile: A new descriptive method based on free description. *Food Quality and Preference, 42*, 66–77.

Varela, P., & Ares, G. (2012). Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterisation. *Food Research International, 48*, 893–908.

Williams, A. A., & Arnold, G. M. (1985). A comparison of the aroma of six coffees characterised by conventional profiling, free-choice profiling and similarity scaling methods. *Journal of the Science of Food and Agriculture, 36*, 204–214.

Williams, A. A., & Langron, S. P. (1984). The use of free-choice profiling for the evaluation of commercial ports. *Journal of Agricultural and Food Chemistry, 35*, 558–568.