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SENSORY CHARACTERIZATION AND THE ANTIOXIDANT ACTIVITY OF ROOIBOS TEA

Abstract: Rooibos tea is a herbal tea which comes from the endemic South African fynbos plant, *Aspalathus linearis* and it has a lot of medicinal properties. The most important characteristics of rooibos are its antioxidant as well as antimutagenic/antitumoral properties. In spite of the growing popularity of rooibos as a herbal tea in Poland, general tools to ensure effective quality assessment and the control of its sensory properties do not currently exist. This study was thus conducted to characterize and identify the sensory attributes associated with the rooibos flavour; colour and mouth feel to generate a more comprehensive picture of what is frequently referred to the Polish consumer of rooibos tea as "typical" or "characteristic". The aim of this study was to find the sensory attributes of rooibos tea offered for retail sales on the Tri-city market and next to compare them with the total phenolic content, determined with the Folin-Ciocalteu reagent and antioxidant activity determined by using the DPPH reagent. The sensory quality (i.e. the colour, flavour, taste and mouth feel of the infusion) of 10 samples was evaluated by experts. The most frequently occurring descriptors were selected to compile a rooibos sensory lexicon of 15 flavour, taste, colour and mouth feel attributes. Rooibos samples contained a total amount of polyphenols from 34.38 mg GAE/100 ml to 145.23 mg GAE/100 ml. Antioxidant properties also were very different and varied from 64.82% to 96.54%. There was a substantial correlation between the phenolic content versus antioxidant activity ($r = 0.857$, $p = 0.0015$). The sensory analysis showed significant differences in rooibos tea in colour, flavour, taste and mouth feel attributes. Using the PCA analysis the products currently offered on the Tri-city market have been classified into two main quality groups. Most low-quality samples were associated with negative sensory attributes such as a hay/dried grass taste, and an astringent and bitter mouth feel, while higher-grade samples were

generally associated with the "characteristic" rooibos attributes, i.e. honey, fruit and herbal-floral flavours, a sweet, caramel taste, clear colour and soft/smooth mouth feel. The statistically significant linear correlation between the results of the sensory analysis and total phenolic content was found.

Keywords: rooibos, profile sensory analysis, antioxidant activity, phenolic content.

JEL classification: D18, O13, P46.

CHARAKTERYSTYKA SENSORYCZNA I AKTYWNOŚĆ ANTYOKSYDACYJNA NAPARÓW ROOIBOS

Streszczenie: Rooibos stanowią łodygi i pocięte liście krzewu *Aspalathus linearis* endemicznie porastającego zachodnią część Republiki Południowej Afryki. Napary przygotowane z liści tego krzewu wykazują szereg właściwości prozdrowotnych, w tym przede wszystkim właściwości antyoksydacyjne oraz antymutagenne. Pomimo stale rosnącej w naszym kraju popularności naparu rooibos nie opracowano jednolitego standardu jakości sensorycznej tych naparów. Obowiązujące określenia są nieprecyzyjne i bardzo często niejednoznaczne, tym samym utrudniają klasyfikację jakościową tych naparów. Przeprowadzone badania dotyczyły zidentyfikowania i scharakteryzowania wyróżników jakości sensorycznej, związanych z barwą, zapachem, smakiem naparów rooibos, tak aby wygenerować bardziej kompleksowy obraz tego, co jest często określane przez polskiego konsumenta tych naparów jako "typowe" lub "charakterystyczne". Celem badania było opracowanie wyróżników sensorycznych naparów rooibos dostępnych w na rynku Trójmiasta i porównanie uzyskanych wyników z ogólną zawartością polifenoli, oznaczoną metodą Folin-Ciocalteu oraz z aktywnością antyoksydacyjną, oznaczoną przy użyciem rodnika DPPH, badanych naparów. Oceny sensorycznej (barwa, zapach, smak, posmak) dziesięciu naparów rooibos dokonał dziewięcioosobowy zespół o sprawdzonej wrażliwości sensorycznej. Z uzyskanych w pierwszej części badania wyróżników wyselekcjonowano łącznie piętnaście, które posłużyły do dalszej oceny jakości sensorycznej badanych naparów. Ogólną zawartość polfenoli w badanych naparach oznaczono w zakresie od 34.38 mg GAE/100 ml do 145.23 mg GAE/100 ml. Aktywność antyoksydacyjna również oznaczono w szerokim zakresie od 64.82% do 96.54%. Stwierdzono statystycznie istotną korelację pomiędzy ogólną zawartością polifenoli a aktywnością antyoksydacyjną (r = 0,857, p = 0,0015). Analiza sensoryczna wykazała istotne zróżnicowanie naparów w zakresie wyróżników barwy, zapachu, smak i posmaku. Przeprowadzona analiza PCA pozwoliła na zakwalifikowanie badanych produktów dostępnych na trójmiejskim rynku do dwóch głównych grup. Napary o niskiej jakości były powiązane z negatywnymi atrybutami jakości sensorycznej, do których należały takie określenia, jak smak siana czy ściągające, gorzkie wrażenie pozostające po spożyciu naparów ro-

oibos, natomiast w próbkach o wyższych parametrach jakości dominowały określenia powiązane z charakterystycznymi atrybutami naparów rooibos, jak ziołowy zapach, słodki, karmelowy smak, klarowny kolor oraz gładki posmak. Stwierdzono również statystycznie istotną korelację pomiędzy wynikami oceny sensorycznej a ogólną zawartością polifenoli.

Słowa kluczowe: rooibos, profilowanie sensoryczne, aktywność antyoksydacyjna, polifenole.

Introduction

Rooibos tea is a herbal tea product coming from the endemic South African fynbos plant, *Aspalathus linearis* and production is mainly concentrated in the Clanwilliam area, Western Cape, South Africa. The genus *Aspalathus* (*Fabaceae, Tribe Crotalarieae*) is comprised of more than 270 types of which most are endemic to the Cape Floristic Region. Rooibos tea, produced from *A. linearis* (Burm.f.) Dahlg., had no commercial value at the beginning of the 20th century, but today it is a well-known herbal tea, enjoyed in more than 37 countries, including Poland [Joubert and de Beer 2011].

Rooibos tea is not only consumed for the enjoyment of its taste and aroma, but also for its medicinal properties. Rooibos tea has been found to provide relief for allergies, dermatological problems, asthma, infantile colic and other gastrointestinal complaints, such as nausea and heartburn. It has also been reported that rooibos tea can improve appetite, reduce tension and improve sleep. Rooibos tea is not well-known by the general public for its antimicrobial activity, but there have been studies confirming the inhibitory effects of rooibos against certain microorganisms, such as *Escherichia coli, Staphylococcus aureus, Bacillus cereus, Listeria monocytogenes, Streptococcus mutans* and *Candida albicans* [Joubert et al. 2008; Hübsch, Van Vuuren, and Van Zyl 2014].

Rooibos is a rich source of polyphenols and is used to make a mild-tasting tea containing no caffeine. It is low in tannins compared to green or black teas. There are two types of rooibos tea: unfermented and fermented. The unfermented product remains green in colour and is referred to as green rooibos. During fermentation, the colour changes from green to red, with oxidation of the constituent polyphenols, so the final product is often referred to as red tea or red bush tea. The most important characteristics of rooibos are its antioxidant and antimutagenic properties [Morton 1982; Van der Merwe et al. 2006; Villaño et al. 2010; Joubert and de Beer 2011; Kotina et al. 2012].

A recent report by the Swiss Business Hub South Africa stated that 'Rooibos appears to become the second most commonly consumed beverage tea ingredient in the world after ordinary tea' (*Camellia sinensis*). In spite of the growing popularity of rooibos as a herbal tea, general tools to ensure effective quality assessment and the control of its sensory properties, such as a flavour wheel and lexicon, do not currently exist. Sensory lexicons or sensory wheels offer a collection of descriptive terms which describe the attributes of a certain product. Such tools can facilitate and improve communication between different role players in the industry by standardizing the terminology that is used when discussing certain product characteristics. This lack of a proper 'communication' tool is especially relevant with the introduction of rooibos to markets not familiar with its use. Furthermore, since the international tea market is becoming cluttered with numerous new herbal teas, fruit infusions and blends, effective product differentiation has become an increasingly important issue. According to an official South African regulation outlining the quality standards of rooibos it is simply stated that "all rooibos shall have the clean, characteristic taste and aroma of rooibos". However, for a lot of consumers from other countries, including Polish consumers, the concept of "characteristic" rooibos flavour, could be difficult to understand. Furthermore, the variation in the sensory attributes of different batches of rooibos has not been established yet. A grading system is currently attributed to major rooibos marketing companies which distinguish high and low quality tea for commercial purposes [Koch et al. 2012].

This study was thus conducted to characterize and identify the sensory attributes associated with rooibos flavour; colour and mouth feel to generate a more comprehensive picture of what is frequently referred for the Polish consumer of rooibos tea as "typical" or "characteristic". The aim of this study was to find the sensory attributes of rooibos tea offered for retail sales on the Tri-city market and compare them with the total phenolic content and antioxidant activity.

1. Experimental

1.1. Materials and research methods

The samples of rooibos tea originated from 10 producers (MAR, CnH, MŁK, TfY, LEB, HON, KAW, ROB, EcoS, SON) and were obtained from the Tri-city market. Tea infusions were prepared with water. 100 ml of deionised water (95°C) was added to 2.0 g of rooibos tea and brewed for 5 minutes without additional heating. All samples were filtered through Whatman No. 4 filter paper.

Total phenolic content was measured using the Folin-Ciocalteu colorimetric method according to ISO 14502–1 *Determination of substances characteristic of green and black tea. Part 1* [ISO 14502–1:2005]. The prepared samples were incubated in the dark for 60 min. at room temperature. Distilled water was used as a reference. Absorbance was measured at 760 nm against the blank and results expressed as mg of gallic acid equivalent per 100 ml of the water extract of rooibos tea (mg GAE / 100 ml). The determinations were carried out in duplicate.

The total antioxidant potential of samples was determined by using the procedure described by Brand-Williams, Cuvelier, and Berset [1995] and Büyükbalci and El [2008]. 1 ml of extract was added to 2 ml of DPPH (7.78 mg/100 ml methanol) followed by vigorous stirring. The DPPH solution was then allowed to stand for 30 minutes before absorbance was measured at 517 nm by using a Varian Spektra 250 plus spectrophotometer. Spectrophotometric measurements were made using methanol as a blank value. The reaction was allowed to take place in a dark space at room temperature to reach a plateau. The ability of extracts to scavenge DPPH free radicals was calculated according to the following equation:

$$AA[\%] = \frac{Abs_{\text{contr}} - Abs_{\text{sample}}}{Abs_{\text{contr}}} \cdot 100,$$

where:
Abs_{contr} – absorbance of the control incubation,
Abs_{sample} – absorbance of the tested sample.
All tests were done in duplicate and the results were presented as means ± SD.

Sensory properties were evaluated by the QDA method on the basis of certain quality markers of colour, taste and aroma [PN-ISO 6658:1998; PN-ISO 11035:1999; PN-ISO 6564:1999; PN-EN ISO 13299:2010]. The profile sensory of rooibos tea was measured using the method described by Koch et al. [2012]. The profile was conducted in order to highlight the advantages and disadvantages of the sensory attributes of the water extracts of rooibos tea. A panel of 9 people experienced in profile sensory analysis analysed 10 samples of each rooibos extract [PN-EN ISO 8586–1:1996; PN-EN ISO 8586–2:2008]. The sensory properties were evaluated by the QDA method on the basis of certain quality markers of colour, taste and aroma [Baryłko-Pikielna and Matuszewska 2014]. A descriptive sensory analysis is still regarded as the most comprehensive and useful sensory method to obtain detailed information regarding the perceived sensory attributes of sample products. However, there

are problems associated with these descriptive sensory analyses. For example, it is time consuming and expensive to screen and train panellists involved in the studies. Additionally, the unanimous consensus of trained panellists could induce a subjective bias caused by the characteristics of the panel group or the opinions held by the leader of the panel. Finally, the different perception of the same attributes when the sample is at different temperatures during evaluation, has been overlooked, especially for food that is usually consumed when hot (e.g. coffee, tea, and rooibos tea). To address such problems, we used a modified descriptive analysis, *Time Scanning Descriptive Analysis* (TSDA) according to Seo et al. [2009] and Dmowski and Szczygieł [2014]. A total of 2 g of rooibos tea leaves were then brewed with 100 ml of water. The temperature of the freshly brewed rooibos tea was around 95°C. A total of 50 ml of each of the beverages of rooibos tea were presented in a paper cup coded with a random 3-digit number. The samples were served at a temperature range from 70 to 60°C. Because the temperature of the freshly brewed rooibos was around 95°C, the samples were cooled at room temperature to (19–20°C) until served.

A total of 10 rooibos tea samples were evaluated in two sessions on different days and all of the samples were rated twice. The samples were randomly presented to the trained panellists. During the first part of the training, panellists were exposed to a number of rooibos samples to become familiar with the product and the analysis protocol. In each session, the time interval between the sample presentations was 5 minutes, and after the evaluation of the first three samples a 10 minute break was made prior to the presentation of the other three samples. All attributes were evaluated on a structured 10 cm line scale that provided a zero to ten score range. The time required for the evaluation of each attribute, the order of evaluation, and the time of break were then determined and based on the results of the preliminary analyses. Ten seconds were allowed to evaluate each attribute, and an additional 10 seconds were provided for a rest at the end of each sensory category. Moreover, to reduce fatigue, an additional 10 second break was allowed in the middle of the evaluation of the odour and flavour-by-mouth/taste tests. During the evaluation, the staff checked the time and instructed panellists to evaluate the sensory attribute in accordance with the list of sensory attributes.

1.2. Statistical analysis

The statistical analysis of the results included the calculation of basic measures such as the average and standard deviation. The significance of the different brands of rooibos tea and their antioxidant potential was determined using

STATISTICA^{TM}12. A one-way analysis of variance (ANOVA) was performed for testing significant group differences followed by a post hoc Tukey's Studentised range test, to determine which groups differed significantly. Differences were considered statistically significant when $p \leq 0.05$. The principal compound analysis (PCA) was used to discriminate between varieties. PCA using the correlation matrix was conducted using STATISTICA^{TM}12 to visualize and elucidate the relationships between the samples.

2. Results and discussion

2.1. Antioxidant capacity

The total phenolic content and antioxidant activity of the rooibos tea extracts are shown in Table 1. The average concentration of total phenolic compounds in all types of aqueous rooibos extracts, as evaluated by the Folin-Ciocalteu assay, were determined at 120.5 mg GAE/100 ml of the total polyphenols. The Folin-Ciocalteu reagent is nonspecific for any phenolics, and the colour yielded depends on hydroxyl groups and their place in molecules. Despite the fact that phenolic reagents are unspecific, in certain circumstances, we may get only relative results for phenolics [Iswaldi et al. 2011].

Table 1. Total phenolic content and antioxidant activity of different rooibos tea extracts

Parameters		TP [mg GAE / 100 ml]	AA [%]
Brand of rooibos tea	MAR	125.00 ± 1.77 ^{a}	91.95 ± 0.05 ^{a,c}
	CnH	145.23 ± 1.22 ^{d}	90.26 ± 0.05 ^{b}
	MŁK	140.16 ± 9.72 ^{b,c,d}	93.86 ± 2.76 ^{d,e}
	TfY	137.66 ± 1.55 ^{a,b,c,d}	96.54 ± 0.10 ^{g}
	LEB	92.66 ± 4.42 ^{f}	94.34 ± 0.21 ^{e}
	HON	34.38 ± 0.22 ^{e}	64.82 ± 0.57 ^{f}
	KAW	129.77 ± 3.87 ^{a,b,c}	92.87 ± 0.31 ^{c,d}
	ROB	131.95 ± 0.99 ^{a,b,c,d}	91.32 ± 0.10 ^{a,b}
	EcoS	126.56 ± 1.10 ^{a,b}	91.29 ± 0.16 ^{a,b}
	SON	141.64 ± 0.99 ^{c,d}	91.73 ± 0.05 ^{a}

Values are expressed as the mean ± SD.
a–g – different letters in the same column indicate statistical differences between mean values at $p < 0.05$.

Therefore, by the Folin-Ciocalteu test, we could observe that the total polyphenolic content in CnH (145.23 mg GAE/100 ml), MŁK (140.16 mg GAE/100 ml)

and SON (141.64 mg GAE/100 ml) rooibos tea extracts is much higher than in the LEB (92.66 mg GAE/100 ml) and HON (34.38 mg GAE/100 ml) rooibos teas. The antioxidant activity values for the rooibos tea that was extracted varied from 64.82% to 96.54%. The best values were obtained for TfY rooibos tea (96.54%), while the HON rooibos tea (64.82%) was the weakest of all. These results indicate that the CnH, MŁK and SON rooibos teas are a richer source of phenolic than the TFY and HON rooibos tea, which are twice as cheap. The extraction efficiency of these compounds and thereby the antiradical activity is highly dependent on the brand of rooibos tea. The results of ANOVA indicated that the brand of rooibos, as well as the price of the product had a significant effect on the total phenolic content and antioxidant properties (Table 1).

According to these results, the antioxidant activity increased proportionally with the phenolic content. The correlations between phenolic content and antioxidant activity were investigated. There was a substantial correlation between the phenolic content versus antioxidant activity ($r = 0.857$, $p = 0.0015$). Thus it can be noted that strong antioxidant properties may be attributed to the phenolic components in the rooibos tea extracts. The fact that phenolic compounds possess a high potential to scavenge radicals can be explained by their ability to donate a hydrogen atom from their phenolic hydroxyl groups [Thitilertdecha, Teerawutgulrag, and Rakariyatham 2008]. The results of the antioxidant activity of tea presented by many authors in a lot of papers are very different; therefore their comparison is quite complicated. These results are in line with the findings obtained from previous studies [Marnewick et al. 2011]. They studied the total phenols content and antioxidant activity of the fermented/traditional rooibos herbal tea that has its origins directly from South Africa plantations and found 63.7 ± 5.2 mg that corresponded with our results. Significantly higher total polyphenols content was reported by Jourber et al. [2011] with an average of 27% in a hot water extract of unrefined fermented rooibos. Furthermore, their study did not show a significant correlation between total polyphenols and antioxidant capacity ($r = 0.024$, $p = 0.055$).

2.2. Profile sensory analysis

In the first step, the panellists were informed about the background and objectives of the study and instructed on the sample analysis procedure. During the first part of being trained, panellists were exposed to a number of rooibos samples to become familiar with the product and the analysis protocol. During the next few sessions the 10 samples were analysed and compared to one another, and the panel generated flavour, taste, aroma, and mouth feel terminol-

ogy. Descriptive terms were suggested and deliberated by the panel members, and each new term was recorded. Relationships and redundancies among the terms were discussed, and definitions and actual reference standards for the most recurring sensory descriptors were obtained. During the training sessions 24 aroma, 18 colour, 26 taste and mouth feel descriptors were generated for the 10 samples. The reduced list of 15 attributes of rooibos tea extracts is shown in Table 2. For efficient sensory profiling the number of attributes was further reduced to a set of 15 mutually exclusive terms – 2 colour descriptors (clear, amber colour), 3 aroma descriptors (honey, fruit, herbal/floral), 7 taste descriptors (sweet/caramel, honey, creamy, fruity, herbal, medicinal, hay/dried grass) and 3 mouth feel descriptor (soft/smooth, astringent, bitter) – based on their frequency of quotation during the training phase (Table 2). This data correlates with the results obtained by Koch et al. [2012].

Table 2. Average attribute intensities for each quality grade

Type of attributes/ attributes		Brand of rooibos tea									
		MAR	**CnH**	**MŁK**	**TfY**	**LEB**	**HON**	**KAW**	**ROB**	**EcoS**	**SON**
Aroma/ Flavour	honey	6.28^{a}	6.22^{a}	6.72^{a}	6.39^{a}	5.61^{a}	6.33^{a}	6.61^{a}	6.67^{a}	6.50^{a}	6.17^{a}
	fruit	4.44^{a}	4.61^{a}	4.78^{a}	4.78^{a}	3.89^{a}	6.00^{a}	5.06^{a}	4.06^{a}	5.33^{a}	4.22^{a}
	herbal--floral	4.78^{a}	5.22^{a}	4.50^{a}	4.83^{a}	5.56^{a}	5.78^{a}	4.06^{a}	4.33^{a}	3.94^{a}	4.11^{a}
Colour	clear	5.94^{a,b}	4.78^{a}	6.94^{a,b}	7.11^{a,b}	6.61^{a,b}	7.61^{b}	5.50^{a,b}	5.11^{a,b}	5.94^{a,b}	4.94^{a}
	amber	6.06^{a}	5.28^{a}	4.84^{a}	4.89^{a}	4.50^{a}	4.56^{a}	4.22^{a}	5.39^{a}	4.67^{a}	5.17^{a}
Taste	sweet	4.00^{a}	3.94^{a}	5.28^{a}	3.83^{a}	3.78^{a}	5.00^{a}	4.56^{a}	4.22^{a}	5.67^{a}	4.00^{a}
	honey	4.28^{a}	3.56^{a}	4.67^{a}	3.61^{a}	3.28^{a}	4.56^{a}	4.17^{a}	4.06^{a}	4.06^{a}	3.83^{a}
	caramel	3.33^{a}	3.50	4.44^{a}	3.17^{a}	2.67^{a}	4.06^{a}	3.67^{a}	3.06^{a}	3.39^{a}	2.78^{a}
	friut	3.22^{a}	2.72^{a}	3.22^{a}	2.50^{a}	3.06^{a}	4.44^{a}	3.11^{a}	2.61^{a}	4.11^{a}	2.44^{a}
	herbal	4.83^{a,b}	4.44^{a,b}	4.17^{a,b}	3.78^{a}	4.56^{a,b}	6.00^{b}	4.22^{a,b}	3.67^{a}	3.94^{a,b}	3.78^{a}
	medici-nal	3.61^{a}	3.56^{a}	3.50^{a}	3.72^{a}	3.17^{a}	4.50^{a}	3.06^{a}	2.56^{a}	2.78^{a}	2.67^{a}
	hay/dried grass	4.17^{a}	3.83^{a}	3.78^{a}	4.89^{a}	4.22^{a}	3.78^{a}	4.00^{a}	3.33^{a}	3.78^{a}	4.39^{a}
Mouth feel	soft/ smooth	5.22^{a}	5.33^{a}	6.33^{a,b}	5.28^{a}	6.00^{a,b}	7.89^{b}	5.89^{a,b}	6.33^{a,b}	5.89^{a,b}	4.83^{a}
	astrin-gent	3.94^{a,b}	4.72^{a}	3.61^{a,b}	4.17^{a,b}	3.72^{a,b}	2.17^{b}	4.00^{a,b}	3.17^{a,b}	4.22^{a,b}	4.56^{a,b}
	bitter	3.83^{a,b}	4.28^{a}	2.67^{a,b}	3.28^{a,b}	3.22^{a,b}	1.83^{b}	3.72^{a,b}	3.06^{a,b}	2.83^{a,b}	4.17^{a}

Values are expressed as mean ± SD

a–b – different letters in the same row indicate statistical differences between the means at $p < 0.05$.

According to Table 2, the attribute "honey" aroma and "clear" colour had the highest average score, followed by "soft/smooth" mouth feel, "amber" colour, "fruit" and "herbal" aroma. These attributes were perceived in all of the 10 rooibos samples. "Honey" aroma and "clear" colour were demonstrated to be the most important attributes since they were as at the highest level of all attributes in the all of the rooibos samples. Other attributes, as "caramel", "fruit", "medicinal" taste, "astringent" and "bitter" mouth feel occurred also frequently in the rooibos samples, but their average intensity scores were fairly low with maximum scores of less than 4.00.

Moreover, based on the results obtained and the dependencies existing between them, we can group the different brands of rooibos tea (Figure 1 and 2).

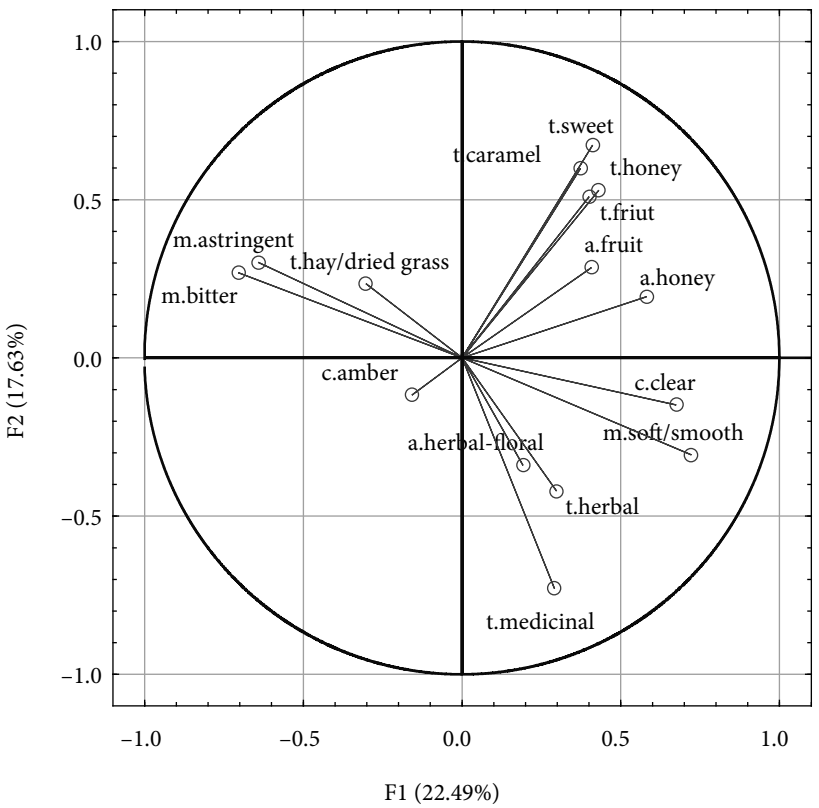

Figure 1. PCA loading plots showing the positioning the fifteen sensory attributes

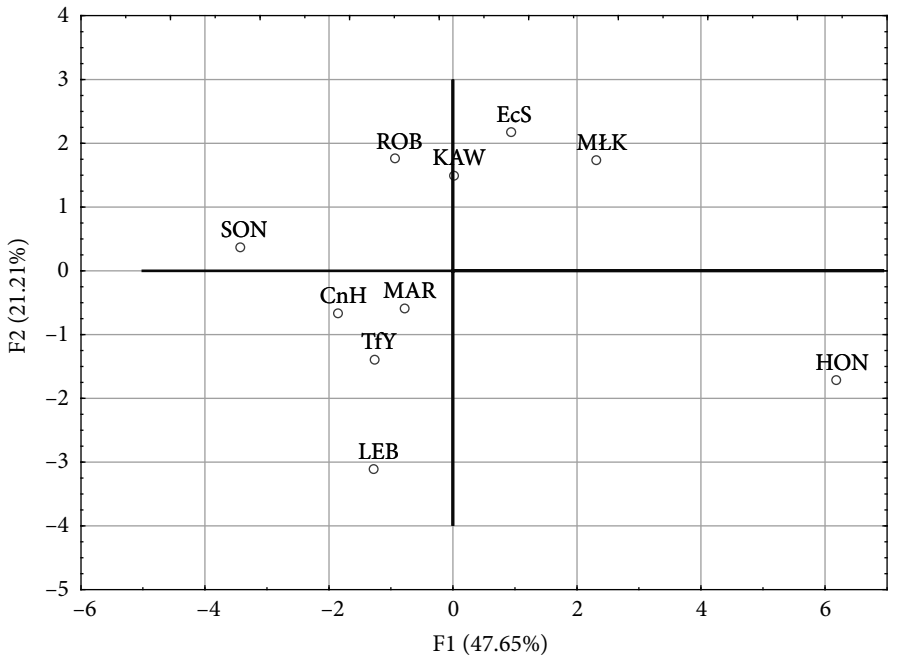

Figure 2. PCA score plots showing the positioning the ten rooibos samples

By means of the principal component analysis (PCA) two factors were identified: PC1 and PC2. For Figure 1: PC1 accounted for 22.49% of the total variance and PC2 for 17.63%, while for figure 2: PC1 accounts for 47.65% and F2 for 21.21%. Together, PC1 and PC2 account for respectively 40.12% and 68.86% of total variance which is considered to be low. Thus, it was not possible to provide good clustering as well as meaningful relationships between samples and variables. The PCA loadings plot (Figure 1) displays the positioning of, and association between the rooibos attributes. This plot shows the separation between negative attributes ("astringent", "bitter" mouth feel and "hay/dried grass" taste) and positive sensory characteristics. One attribute that deserves a special mention is the mouth feel attribute, namely astringency. In Figure 1 astringency lies on the left side of the plot, and, therefore, is associated to some extent with the negative attributes such as "hay/dried grass" taste and "bitter" mouth feel. However, astringency is not necessarily a negative characteristic. On the contrary, it is one of the most essential and defining attributes of black tea (*Camellia sinensis*), and also plays an important role in the sensory profile

of rooibos tea. The data stays in good correlation with the results obtained by Koch et al. [2012].

Moreover, a cluster analysis was carried out for the significantly different descriptors, which resulted in identifying 4 clusters. The points of the rooibos tea samples distributed in space make 4 clusters. The positioning of the 10 rooibos samples relative to each other is reflected by the corresponding scores plot (Figure 2). The first cluster is made up of MŁK, EcS, KAW rooibos tea, the second cluster of SON, ROB, the third CnH, MAR, TfY, LEB and the fourth of HON. In the first group the "sweet", "caramel", "honey", "fruit" taste and "honey", "fruit" aroma are dominant and the other attributes are less intensive. In the second group ROB and SON rooibos are characterized by negatives attributes, as "hay/dried grass" taste and "astringent", "bitter" mouth feel. The third group has an intensive "amber" colour. The fourth group is characterized by an intensive attribute of the "clear" colour, and "soft/smooth" mouth feel. The intensity of the other attributes ("medicinal" taste and "herbal" aroma) was lower. As it can be seen, PCA plots can also be used to indicate whether certain attributes are redundant and may be reduced to a simplified set of terms to prevent different attributes from being used to describe the identical sensory characteristic.

The correlation between total sensory scores and total phenolic content was determined. There was a statistically significant linear correlation between the analysed parameters ($r = -0.634$, $p = 0.049$). The HON rooibos tea, which obtained the highest sensory scores (especially for the honey aroma, clear colour, sweet and herbal taste and smooth mouth feel) was characterized by the lowest antioxidant activity. This beverage was also characterized by the lowest sensory scores, especially for astringent and bitter mouth feel.

However, there were also positive significant correlations between selected sensory attributes of rooibos and total phenolic content. The rooibos tea samples, which obtained the highest sensory scores, especially for bitter and astringent mouth feel (CnH, SON), was characterized by the highest content of total polyphenols. Recent data revealed strong correlations between total polyphenols content and bitter mouth feel ($r = 0.70$; $p = 0.023$) and also between total polyphenols content and astringent mouth feel ($r = 0.81$; $p = 0.004$). The fermentation conditions (time and temperature) of rooibos leaves are the reason for the correlation between the selected sensory attributes of rooibos and total phenolic content. The fermentation of rooibos plant material to produce traditional herbal tea (oxidised form) causes substantial quantitative changes in its phenolic composition, that influenced the sensory qualities of the rooibos infusions. One of the major changes is oxidation of aspalathin via

its flavanone analogues to isoorientin and orientin. Furthermore, an aspalathin dimer, partly responsible for browning as a result of aspalathin oxidation, has also been identified [Joubert and de Beer 2011]. Moreover, rooibos (*Aspalathus linearis*) is a rich source of polyphenols and used to make a mild-tasting tea containing no caffeine, and is low in tannins compared to green or black teas. Approximately 30% of the total polyphenols content and 4.34% of the hot water soluble solids of fermented rooibos, is tannin, which could the specific aroma and taste of these beverages [Joubert et al. 2008].

Conclusions

Most low-quality samples (SON, ROB) were associated with negative sensory attributes such as hay/dried grass taste, and an astringent and bitter mouth feel, while higher-grade samples (HON, MŁK, EsC) were generally associated with the "characteristic" rooibos attributes, i.e. honey, fruit and herbal-floral flavours, a sweet, caramel taste and soft/smooth mouth feel. The results of this study confirm that the antioxidant activity of rooibos tea extracts and its polyphenol contents may vary widely. Rooibos samples originating from the Tri-city market contained total polyphenols from 34.38 mg GAE/100 ml to 145.23 mg GAE/100 ml. Antioxidant properties were also very different and varied from 64.82% to 96.54%. Both the total phenolic content and antioxidant activity of rooibos tea extracts depends on the type of rooibos. Finally, there was a substantial correlation between the phenolic content versus antioxidant activity and also a statistically significant linear correlation between total phenolic content and sensory evaluation was observed.

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