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SENSORY CHARACTERIZATION OF PU-ERH TEA BEVERAGES

The aim of this study was to develop a sensory profile of pu-erh tea beverages. Additionally, sensory evaluation results were compared with the color of the beverages measured in the CIE L, a*, b*. The results showed that the color of infusions was a combination of black and brown with a high proportion of copper (15.00 – 63.75). The most fresh were Bio-Active and UNO-Foods. In turn, the strongest brew was prepared from Grande tea. All products were characterized by citrus flavor. Principal component analysis helped reduce the number of variables that describe presented tea, to just two. The first includes differentiators describing flavor infusion and infusion appearance, while the second cover the citrus flavor of beverages. Both groups represent 51% of the inputs.*

Keywords: *Pu-erh tea, profile sensory analysis, infusion color*

INTRODUTION

Pu-erh tea is a unique Chinese black tea and it is usually categorized as a post-fermented tea. In 2003 pu-erh tea was defined as "products fermented from green tea of big tea leaves picked within Yunnan province" [12]. Currently it is produced mostly from leaves of *Camelia sinensis*. Generally it has two forms: raw and ripe pu-erh. The first one is called as green pu-erh, because it includes sun fixation, rolling, and sun drying before compression. The ripend type is produced in the same way as raw, but after sun drying and before compressing there is the most important step of wet pilling (the process is called "wodui") [12, 13]. The fermentation process, similar to composting, takes several weeks to months. It is commonly believed, *Aspergillus niger* is main microorganism detected during the fermentation process. Haas and others [5] show, that next to *Aspergillus*, it can be found *Penicilium, Fusarium, Eurotium* and few other species of fungal. It is believed that the longer preservation period, the better the quality and taste. When tea is fermented to a suitable degree, the fermented tea is then sterilized and this is ripe tea. Both types undergo a natural postfermentation during storage before consumption [13].

Pu-erh tea has lower concentration of tea polyphenols than green or black tea, because during the fermentation process the chemical constituents have changed dramatically. Catechins are at the beginning oxidized to quinone, and then condensed to form bisflavanols, theaflavin, thearubigen, and other high molecular

components [8, 9, 14]. The major compounds of pu-erh tea are: flavan-3-ols and their derivatives, flavones and their derivatives (quercetin, kaempferol, myricetin), gallic acid and other simple phenolic acids, alkaloids and their derivatives (caffeine, theobromine, theophylline), few elements (fluoride, lead, copper, chromium, arsenic, cadmium), vitamin C and vitamin E and it is relatively rich in natural statins – both in lactone and hydroxyl acid forms [6, 9, 15]. The tannic compounds are primarily responsible for color and flavor of fermented tea. Theaflavins give the tea color from golden yellow to red, while thearubigins – from reddish-yellow to orange-brown. Thearubigins are also responsible for characteristic astringent flavor of infusion [4, 11]. Due to the complexity of the fermentation process, it can be assumed that pu-erh tea can have ingredients, that are still not identified. In 2011 it was announced, that in pu-erh tea was found a new catechin oxidation product [7].

In few last years, many investigations have been carried out to determine the biological effects on human health. Studies have confirmed that pu-erh tea has antioxidant, antimutagenic and antimicrobial activity [2]. It can also prevent cancer [2], lower blood sugar, blood cholesterol and blood pressure [4]. Pu-erh tea is known for its dramatically reduced weight gain and serum LDL-C accumulation. It can help to prevent hyperlipidemia. Further, it can also improve work of bacterial flora in the intestine [2].

The analysis was performed in this way, to identify and characterize the sensory attributes associated with pu-erh tea color and flavor, to generate a more comprehensive picture of this product. The aim of this study was to develop a sensory profile of Pu-erh tea beverages. Additionally, sensory evaluation results were compared with the color of the infusion of color parameter values measured in the CIE L*, a*, b* system.

1. MATERIAL AND RESEARCH METHODS

The research material consisted of 6 teas purchased in 2010 in stores in Gdynia: Oskar (OsL), Astra (AS), Bio-Active (BAL), K&K (KKL), UNO-Foods (UFL), Grande (GS) and 2 teas obtained at the Port of Gdynia: organic (OS) and fannings (FS). Specially for the research purposes, non-flavored teas were selected, both loose leaf and teabags. The research was carried out on 5-minute infusions.

The method of quantitative descriptive analysis is a tool used for qualitative and quantitative characteristics of the food product. Its main objective is to conclude that tastiness consists of many basic taste and smell characteristics. The sensory profiling involved 8 judges. They were selected from a group of over 30 students of Gdynia Maritime University who graduated with positive results in the same semester the subject of "sensory analysis". Selected individuals stood out among the entire group of students adequate sensitivity, accuracy, and interest in these techniques. According to the accepted rules, they were informed only about

the object of the study. Therefore, during the analysis, their knowledge of the product was scarce [1]. After preparing a final list of characteristics, each research participant received a dictionary of all the terms used in the study. Prepared attempts have been given codes. The scale used in the descriptive analysis indicates the intensity of each sensory attribute. They were evaluated on a structured 10 cm line scale that provided a zero to one hundred score range. 0 meant that there were no given attribute, 50 – neither weak nor strong, and 100 – the strongest (imaginable).

The color parameters of the infusions were determined with a Konica Minolta CR-400 colorimeter. All teas should have the same form; therefore, leaf teas were ground in a mortar. The determination was performed in the CIE system, which is based on measuring the three trichromatic components (L*, a*, b*).

Statistical analysis of the results included the calculation of basic measures such as the average and standard deviation. The Principal Component Analysis was determined using STATISTICA^{TM}10. It was performed for pu-erh tea's attributes grouping. Graphical presentation of the results is shown at the end of the analysis as dendrogram. 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.

2. RESULTS AND DISCUSSION

The first part of the research entailed a sensory analysis of the 5-minute infusions. The analysis focused on flavour and appearance of the infusion. In their forms, the participants put adjectives which they deemed relevant: citrus, lemony and fishy. Ultimately, the evaluation form included following adjectives: infusion flavor (earthy, astringent, ordinary, metallic, fresh, strong, musty, fishy, citrus, lemony), infusion appearance (milky, golden, brown, black, coppery, deep).

The obtained averages are provided in the table below [Tab. 1].

Table 1

The results of sensory analysis on the flavor and appearance of the beverages

BRAND	OsL	AS	BAL	KKL	UFL	GS	OS	FS
Infusion flavor:								
earthy	53,8 ^{a}	56,3 ^{a}	46,3 ^{a}	42,5 ^{a}	48,8 ^{a}	52,5 ^{a}	50,0 ^{a}	55,0 ^{a}
astringent	58,8 ^{a}	58,8 ^{a}	51,3 ^{a}	33,8 ^{a}	40,0 ^{a}	58,8 ^{a}	63,8 ^{a}	65,0 ^{a}
ordinary	25,0 ^{a}	27,5 ^{a}	25,0 ^{a}	18,8 ^{a}	23,8 ^{a}	26,3 ^{a}	23,8 ^{a}	32,5 ^{a}
metallic	11,3 ^{a}	11,3 ^{a}	17,5 ^{a}	8,8 ^{a}	11,3 ^{a}	18,8 ^{a}	13,8 ^{a}	41,3 ^{a}
fresh	21,3 ^{a}	15,0 ^{a}	32,5 ^{a}	28,8 ^{a}	30,0 ^{a}	17,5 ^{a}	21,3 ^{a}	18,8 ^{a}
strong	48,8 ^{a}	67,5 ^{a,b}	63,8 ^{a,b}	33,8 ^{a}	55,0 ^{a,b}	70,0 ^{a,b}	67,5 ^{a,b}	80,0 ^{b}
musty	10,0 ^{a,b}	10,0 ^{a,b}	5,0 ^{a,b}	1,3 ^{a}	5,0 ^{a,b}	13,8 ^{b}	7,5 ^{a,b}	12,5 ^{b}
fishy	10,0 ^{b}	5,0 ^{a}	2,5 ^{a}	5,0 ^{a}	17,5 ^{b}	11,3 ^{b}	3,8 ^{a}	31,3 ^{c}
citrus	1,3 ^{a}	5,0 ^{a,b}	8,8 ^{a,b}	2,5 ^{a}	8,8 ^{a,b}	2,5 ^{a}	12,5 ^{b}	1,3 ^{a}
lemony	0,0 ^{a}	60,3 ^{c}	18,8 ^{b}	3,8 ^{a}	8,8 ^{a,b}	2,5 ^{a}	10,0 ^{b}	0,0 ^{a}

Infusion appearance:								
milky	7,5 [a]	5,0 [a]	5,0 [a]	10,0 [a]	7,5 [a]	15,0 [a]	12,5 [a]	20,0 [a]
golden	16,3 [a]	16,3 [a]	15,0 [a]	26,3 [a]	15,0 [a]	12,5 [a]	7,5 [a]	8,8 [a]
brown	47,5 [a]	70,0 [a]	67,5 [a]	31,3 [a]	56,3 [a]	61,3 [a]	58,8 [a]	56,3 [a]
black	22,5 [a,b]	18,8 [a,b]	23,8 [a,b]	3,8 [a]	25,0 [a,b]	56,3 [a,b]	68,8 [b]	45,0 [a,b]
coppery	50,0 [a,b]	25,0 [a,b]	30,0 [a,b]	63,8 [b]	36,3 [a,b]	17,5 [a,b]	15,0 [a]	28,8 [a,b]
deep (vivid)	52,5 [a]	46,3 [a]	53,8 [a]	45,0 [a]	53,8 [a]	43,8 [a]	45,0 [a]	50,0 [a]

Values are expressed as mean
a-c – different letters in the same row indicate statistically differences between means at $p < 0.05$.

All samples of tea were characterized by a strong, astringent infusion, but at the same time it was considered as fresh. Each of the infusions had a citrus or lemony flavor (1.25 – 18.75), even though none of the teas was flavored. Unflavored pu-erh tea obtained in a traditional way may have a citrus flavor; however, this was not the tea investigated by the research. This product, obtained through the wo-dui process, has a specific smell and taste. Most literary sources describe it as "earthy." This group of panelists had a different association, more similar to flavor of fish. Possible infusion defects included a metallic or musty flavor. Again, the panelists indicated these characteristics for each infusion, although the teas were certainly of good quality and free from any of the mentioned defects.

The color of infusions was a combination of black and brown with a high proportion of copper (15.00 – 63.75), but also with a tinge of golden (7.50 – 26.25).

The below graphs are provided for easier interpretation and direct comparison of the sensory profiling results. They also include the distribution of the research material into loose leaf teas [Fig. 1] and bagged teas [Fig. 2].

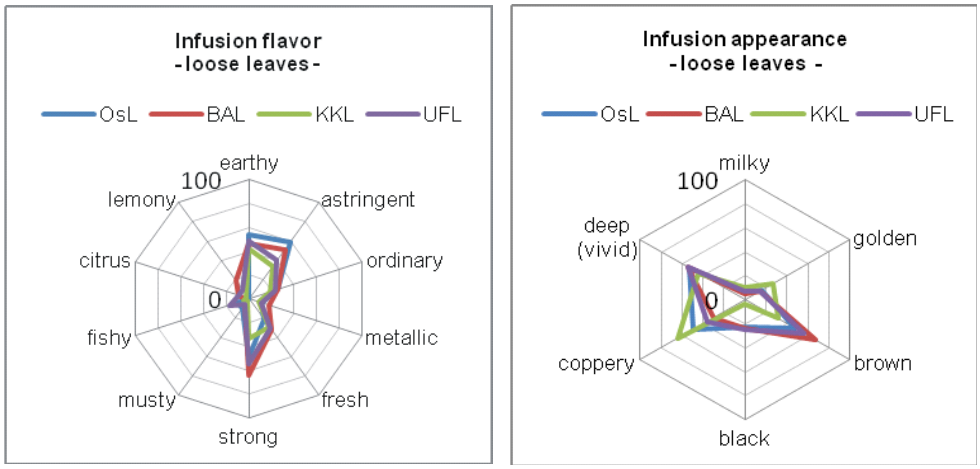

Fig. 1. Profiling results: flavor and appearance of the 5-minute infusions of loose leaf teas

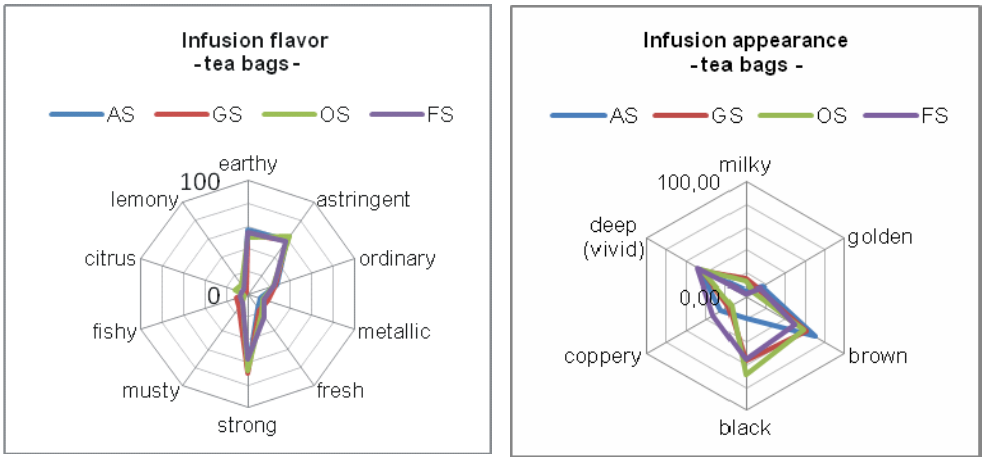

Fig. 2. Profiling results: flavor and appearance of the 5-minute infusions of bagged teas

This method of result presentation clearly shows that the results obtained for infusion flavor (both for loose leaf and bagged teas) are very similar. The graphs almost coincide with each other. More differences occur for infusion appearance. There are several significant differences. The infusions obtained from loose leaf teas are more fresh than those obtained from teabags. Bagged teas give infusions with varying degrees of astringent, while the astringent of loose leaf teas is very similar. Loose leaf tea infusions had stronger citrus, lemony, and fish-foody flavors.

The appearance of beverages brewed from loose leaf teas was marked by a greater amount of copper color compared to teabag infusions. The latter were more black. For both loose leaf and bagged teas, the participants described the color as deep (vivid).

The first part of the analysis is complemented by the analysis of the color of the 5-minute beverages. For this purpose, a colorimeter was used. The measurement was done twice, and the results were averaged [Tab. 2].

Table 2

Color parameters of pu-erh tea beverages [mean ± standard deviation]

Parameters		L	a*	b*
Brand of pu-erh tea	OsL	26,11 ± 0,18	11,5 ± 0,27	11 ± 0,32
	AS	35,25 ± 0,45	7,23 ± 0,01	21,4 ± 0,61
	BAL	28,62 ± 0,33	9,96 ± 0,36	14,1 ± 0,58
	KKL	30,55 ± 0,54	8,26 ± 0,38	16,6 ± 0,86
	UFL	25,95 ± 0,04	9,37 ± 0,07	9,71 ± 0,06
	GS	21,42 ± 0,01	4,56 ± 0,01	2,07 ± 0,01
	OsL	22,17 ± 0,00	6,91 ± 0,01	4,11 ± 0,04
	FS	21,25 ± 0,00	4,84 ± 0,08	2,45 ± 0,03

The results were presented on the CIELAB diagram with two axes: axis a* and axis b*, which are perpendicular to each other. On axis a*, there are values between red (+a*) and green (-a*), while axis b* presents values from yellow (+b*)

to blue (-b*). At the point where the two axes intersect, there is axis L, perpendicular to the ab system. The L parameter denotes brightness (color intensity) and obtains values from white to black [10].

It was noted that the infusion of AS tea had the biggest amount of yellow. The value of the b* parameter has a big impact on the infusion brightness. Therefore, this particular infusion was brighter than the rest (L = 35.25, with the average of all infusions being 26.41). Two samples (GS and FS) marked in the diagram were almost identical in color and, together with organic tea, had the darkest infusions of all.

The level of correlation was checked for all the results obtained in both the first and second part of the study. Several correlations are particularly noteworthy. The strongest correlation (r = 0.99, p = 0.000) was demonstrated between the brightness of infusion (L) and the parameter b* (values from yellow to blue). It is not the black color of infusion so strongly associated with the astringent flavor of the infusion (r = 0.69, p = 0.057), but the brown color (r = 0.91, p = 0.002). The alleged relationship is interesting discovery, which may be related to the extraction of tannin compounds (mainly tannins). These substances are responsible for the astringent flavor and color of tea infusion. Shortly brewed tea contains higher amounts of caffeine, which is more easily extracted. The longer brewed tea, the more tannin in the infusion [3].

It should also be stressed that there was a negative correlation between the coppery appearance of the infusion and a strong infusion flavor (r = –0.97, p = 0.000). This means that the more copper-colored infusion, the weaker its flavor. As a result, it is important to consider the results between the gold color of the infusion and its strong flavor. From a statistical point of view, these relationships are quite significant, because the more golden the infusion, the weaker its flavor (correlation at r = –0.83, p = 0.010). These relationships have their justification in the presence of compounds responsible for the color and taste of tea infusions [Tab. 3].

Table 3

The correlation coefficient between the results of sensory analysis and the results obtained by the colorimetric method

VARIABLES	COLOR: COLORIMETER			APPEARANCE (COLOR): SENSORY ANALYSIS					
	L	a*	b*	milky	golden	brown	black	coppery	deep (vivid)
L	1,00								
a*	0,42	1,00							
b*	0,99	0,52	1,00						
milky	-0,35	-0,24	-0,36	1,00					
golden	0,60	0,31	0,63	-0,17	1,00				
brown	0,11	-0,11	0,05	-0,09	-0,64	1,00			
black	-0,82	-0,65	-0,86	0,34	-0,86	0,29	1,00		
coppery	0,35	0,53	0,43	-0,22	0,88	-0,82	-0,76	1,00	
deep (vivid)	0,07	0,73	0,15	-0,58	0,00	0,13	-0,34	0,24	1,00

At the beginning of the Principal Component Analysis, the number of factors was automatically reduced to 7 items. First, it is necessary to consider the eigenvalues, which reflect the hierarchy of principal components as the carriers of information provided by the input variables. The important information is that the first principal component carries more than 35% of the information about pu-erh teas contained in the input variables. In order to select the final number of principal components on which further analysis should be based, it should be used the criterion of eigenvalue or the criterion of landslide. However, the two methods give two different results. Using the former, special attention should be paid to the first two principal components, which carry more than 57% of the information. With the latter, we should focus even on four principal components. A detailed analysis requires trying out both solutions and seeing which one provides the best interpretation of the results. Further, during the analysis, the first two principal components were used. Making such a reduction entails losing about 42% of the information carried by the input variables. However, this enables the graphical representation of the remaining larger part of the information. Selected components were used to create the axis of the system with points representing pu-erh teas. The graph below [Fig. 3] shows that by classifying the teas using two selected factors, organic tea and fannings are the most similar to each other (they are the closest to each other). Teas which are similar to them include GS and AS. The teas OsL, KKL, UFL, and BAL are definitely more varied.

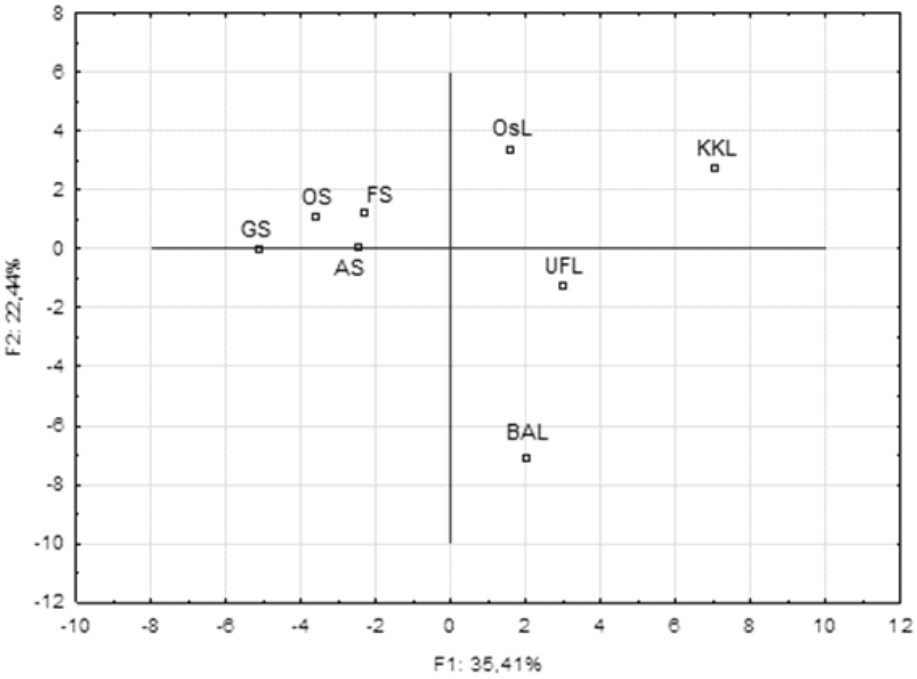

Fig. 3. Diagram of the configuration of points representing pu-erh teas in the system of the first two factor axes

The first principal component represents the variables related to the appearance of infusion flavor (astringent, strong, musty) and infusion appearance (golden, black, coppery). The second principal component is the carrier of information regarding the citrus flavor of the infusion.

Starting on the left side of the graph [Fig. 4], each object is its own class. They were combined with each other in more and more items and aggregated in ever increasing focus elements increasingly different from each other. In the end, the final stage, all objects are linked together. Completed analysis gives the ability to detect clusters (branches) and their interpretation.

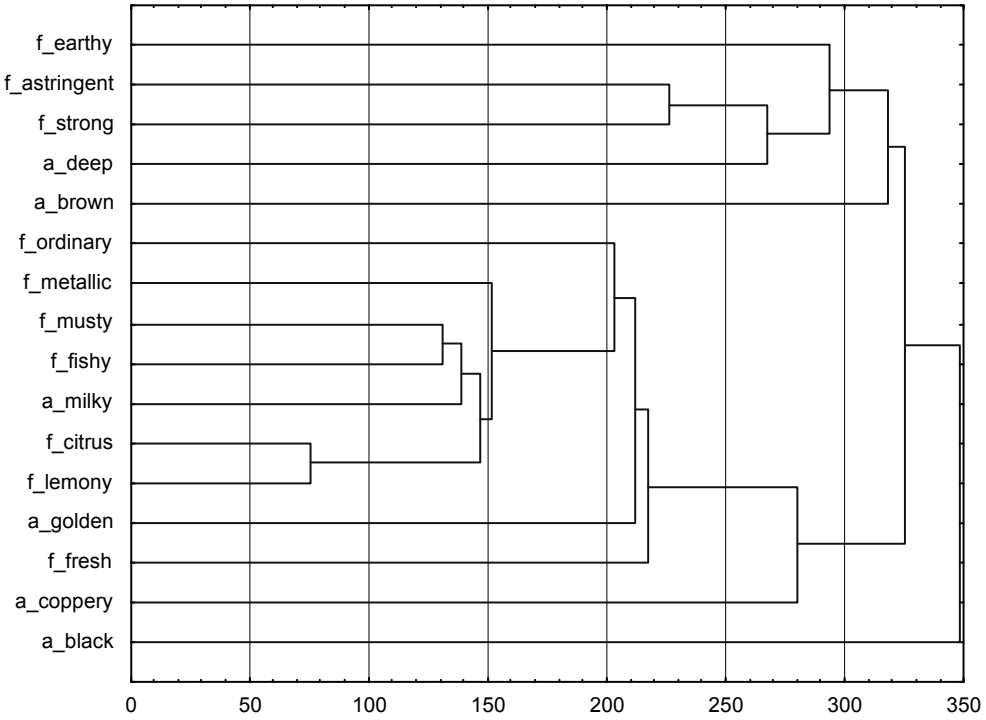

Fig. 4. Dendrogram grouping presented attributes by hierarchical method

Prepared dendrogram shows that the sensory profile of pu-erh tea describes the 7 groups of features. They are: black appearance, brown appearance, coppery appearance, deep appearance, earthy flavor, strong and astringent flavor, and the last group – fresh, ordinary, metallic, musty, fishy, citrus and lemony flavor and milky and golden appearance.

CONCLUSIONS

1) On the basis of dendrogram it can be seen that the sensory profile of pu-erh tea beverages describes the 7 groups of features: first – black appearance, second – brown appearance, third – coppery appearance, fourth – deep appearance, fifth – earthy flavor, sixth – strong and astringent flavor, and the last one – fresh, ordinary, metallic, musty, fishy, citrus and lemony flavor and milky and gold appearance.
2) Pu-erh teas beverages have a unique taste and smell (even referred to as resembling fish or fish food). Obtained in the process of artificial aging, they are similar in terms of sensory qualities.
3) Infusions with brown color have a stronger taste. On the other hand infusions of large amounts of gold and copper are weaker. The alleged relationship may be related to the extraction of tannin compounds.
4) Among the variables selected for analysis, there are only two which are the carrier of 51% of the information about the product. However, 4 variables represent almost 80% of the information.

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