PREDICTING THE ORGANOLEPTIC QUALITY OF SOME ROMANIAN BEERS FROM PHYSICAL-CHEMICAL DATA USING MULTIVARIATE ANALYSIS

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Abstract: *Two categories of pale lager beer produced in Romania, of which twelve samples are common pale lager beer type and eight samples are superior pale lager beer type were studied to evaluate their quality through physical-chemical (apparent extract, original extract, alcohol concentration, pH, turbidity, viscosity, colour, acidity, bitterness value) and sensorial (appearance, colour, odour, taste, gas release, foam stability) characteristics. Beer characteristics measurements were examined by multivariate data analysis, using principal component analysis (PCA). The analysis of the principal components sheds light on the correlations between variables as well as on differences between the samples analyzed. The values of correlation coefficients indicate important direct statistical relations between the variables taste and alcohol concentration for all the 20 samples of beer analyzed. For the samples belonging to the category of common pale lager beer type, the values of correlation coefficients show that there are reverse statistical connections between the bitterness value and characteristics used in the sensorial analysis ($p \geq 0.05$). For this type of beer, Skol was mostly appreciated, while for the superior pale lager beer category Ursus Premium was considered the best, both types of beer being regarded as very good quality beers according to the sensorial evaluation methodology described by SR 13355-1:1997.*

Keywords: *Principal Component Analysis, physical-chemical parameters, sensory property, pale beer*

Introduction

The quality of beer depends mostly on the composition and quality of raw materials used [1]. Its chemical composition, brewing and technological process are highly determinative for the beer quality which embodies both its sensorial characteristics and physical chemical ones. Brewers focus primarily on chemical and physical properties as percentage of original wort, amount of alcohol, degree of fermentation, pH-level, degree of bitterness, colour, etc., to compare various sorts of beer. Chemical and physical methods of analysis can provide a great deal of information about beer quality but are unable to render it with the greatest precision.

This is mainly due to the fact that the consumer is not interested in the beer composition but in its sensorial characteristics as for they the Latin saying "*De gustibus non est disputandum"* works for the best in this situation. For this reason, most large-scale breweries used different sensory methods of quality between different types of beers to underline certain differences of quality between various types of beer. Most of the interest has shifted to factors affecting the changes in beer aroma and taste, as beer flavour is regarded as the most important quality parameter of the product [3]. Beer sensorial parameters are evaluated in many ways. In Romania the most important one is quality assessment using a 20-points system according to SR 13355-1:1997 where beer is appreciated on certain qualities with regards to its comparative

ranking and value.
Since a beer sample is characterized by many different chemical, physical and sensory parameters (variables) it is difficult to obtain a comprehensive overview of its quality. Therefore, it might be useful to reduce the number of variables to describe beer. Therefore, the main objective of this study is to use a multivariate statistical method, namely principal component analysis (PCA) [4], to analyze the relationships between physical, chemical and sensory properties of two types of beer (common pale lager beer and superior pale lager beer) both produced in Romania. The PCA method makes it possible to distinguish beer samples and also to identify the most important variables in a multivariate data matrix.

Materials and methods

Beers. Twenty beers from the Romanian market were chosen for this study. They represented beer samples easily available to consumers in the off-premise chain. They covered according to SR 4230: 2004 two categories of beer: common pale lager beer (twelve samples) and superior pale lager beer (eight samples). The commercially available beers included in the study are listed in Table 1. Sample abbreviations used in biplots, tables and text are also reported.

Table 1.
Identification of the 20 beers studied

Common pale lager beer	Abbreviated name	Superior pale lager beer	Abbreviated name
Skol	Skol	Bergenbier	Bergenbier
Bucegi	Bucegi	Azuga	Azuga
Ciucas	Ciucas	Ursus Premium	Ursus_P
Harghita	Harghita	Golden Brau	Golden_B
Noroc	Noroc	Timisoreana	Timisoreana
Senior	Senior	Ursus	Ursus
Coroana Moldovei	Coroana_M	Burger	Burger
Coroana Premium Pils	Coroana_PP	Bermas	Bermas
Zimbru Premium Pils	Zimbru_PP	-	-
Zimbru	Zimbru	-	-
Caimani	Caimani	-	-
Suceava	Suceava	-	-

Physical and chemical analysis. The physico -chemical parameters of beer were determined according to the Romanian standard methods at S.C. Bermas S.A. Suceava: apparent extract (SR 13355-5:2005), original extract (SR 13355-5:2005), alcohol concentration (SR 13355-3:2005), pH (STAS 6182/72), colour (SR 13355-7:2005), acidity (SR 13355-6:2000) bitterness value (SR 13355-9:2003), turbidity (EBC method) and viscosity (EBC method). All analytical determinations were performed at least in triplicate. The values of different parameters were expressed as the mean.
Sensory analysis. Sensory testing has been carried out, in conformity with the method described by SR 13355-1:1997 which evaluates the organoleptic properties of beer, using a 20-points scale system. A panel of 15 judges consisting of students and staff from "Stefan cel Mare" University, Faculty of Food Engineering were selected on the basis of interest and availability. The judges evaluated the 20 commercial beers in duplicate in 14 sessions over a two-week period. At each session, three beers chosen from the two categories of beers were presented in coded according to SR ISO 6658:2007, standard, tulip-shaped, clear 330 mL beer glasses. All beers were evaluated at 12-14^{0}C in the sensory laboratory of Food Engineering Faculty, Suceava. A 50 ml of each beer sample was poured in glasses, covered with a watch glass

to preserve volatile compounds and presented with nearly the same level of foam. Panelists received distilled water for palate cleansing between samples and dry unsalted breadsticks to avoid cross-contamination among samples. Appearance, colour, smell, taste, gas release, foam stability and overall impression were tested. Each organoleptic property was evaluated using a 5-point scale. Based on their evaluation and on the weight factor (appearance - 0.6; colour - 0.8; smell - 0.2; taste - 1.4; gas release - 0.6; foam stability - 0.4) we have obtained the total score of beer which placed beer on different levels of quality as follwos: 18.1 ÷ 20 – very good beer; 15.1 ÷ 18 - good beer; 12.1 ÷ 15 - ordinary beer; 7.1 ÷ 12 - poor beer but commercially acceptable; 0 ÷ 7 unacceptable.

Data analysis. All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS). Principal component analysis (PCA) was carried out for the physical and chemical data for the set of 20 beers and a PCA was also made on the combined sensory and instrumental data.

Results and discussion

Physical and chemical analysis. To illustrate the physical-chemical characteristics of the sample set, the mean, range, and variation coefficient are given in Table 2 and Table 3 respectively. The quality of beer samples complied with the Romanian standard for pale lager beer products of common and superior type. All values given are means of three determinations.

Table 2
Physico-chemical characteristics of common pale lager beer samples

Physical-chemical parameters	Abbreviated name	Mean	Range		CV %
			min	max	
Apparent extract, °P	AE	1.7	0.1	2.3	33.37
Original extract, °P	OE	9.91	6.67	10.67	10.82
Alcohol concentration, % (v/v)	AlC	4.15	3.3	4.6	10.70
pH	pH	4.36	3.88	4.57	4.70
Turbidity, EBC units	TU	0.53	0.3	0.75	27.71
Viscosity, MPa·s	VI	1.37	1.18	1.5	6.12
Color, EBC	CO	6.58	5.0	9.6	21.70
Acidity, ml NaOH 1n/100 ml beer	AC	1.79	1.5	2.5	19.54
Bitterness value, BE	BV	19	16.5	23	9.38

Table 3
Physico-chemical characteristics of superior pale lager beer samples

Physical-chemical parameters	Abbreviated name	Mean	Range		CV %
			min	max	
Apparent extract, °P	AE	1.8	1.5	2.1	11.50
Original extract, °P	OE	10.87	10.42	11.52	3.45
Alcohol concentration, % (v/v)	AlC	4.68	4.3	5.2	6.97
pH	pH	4.40	4.21	4.6	3.27
Turbidity, unit. EBC	TU	0.45	0.2	0.63	30.98
Viscosity, MPa·s	VI	1.37	1.3	1.42	2.97
Colour, EBC	CO	7.28	4.2	8.7	21.42
Acidity, ml NaOH 1n/100 ml beer	AC	1.82	1.4	2.7	21.86
Bitterness value, BE	BV	21.5	18	23.5	9.04

Different quantities of alcohol for various sorts of beer analyzed result from the chemical reaction of transforming sugar into alcohol, carbon dioxide and water.

The higher the quantity of fermented wort, the higher the quantity of alcohol is. Therefore, there is a direct correlation between the alcohol content, apparent extract and original extract of the samples analyzed. Thus, the correlation factors r = 0.791 (for common pale lager beer) and r = 0.946 (for superior pale lager beer), significant for p = 0.01 between alcohol and the original extract, show a very strong association. A significant correlation factor between the original and apparent extract was obtained r = 0.786 at a level p = 0.01, for all 20 beer samples analyzed. For the first type of beer analyzed (common pale lager beer), the variation limits of original extract content, apparent extract and alcohol content are shown in Table 2, while for the second type of beer analyzed (superior pale beer), in Table 3.

There is a direct connection between beer acidity and pH. These variables depend on respecting a proper hygiene throughout the technologic process, starting from brewing and ending with bottling. The variation limits of acidity and pH of the samples of common pale lager beer and those of superior pale lager beer are shown in Tables 2 and 3 respectively.

Beer colour has values varying between 5 and 9.6 EBC for common pale lager beer and between 4.2 and 8.7 EBC for superior pale lager beer. Its value depends on various factors such as: raw material quality (barley used for making malt), the quality of malt produced, brewing process, pasteurizing process etc.

Bitterness value depends on the quality of the hops used and quantity of its α-acids. For the analyzed types, there are variations in values probably due to the fact that different types of hops are used. The samples analyzed have shown bitterness values that vary between 16.5 and 23.5 units BE.

Sensory characteristics. The variation limits of the organoleptic characteristics obtained in the analysis of common pale lager beer samples are given in Table 4 and those for superior pale lager beer samples in Table 5.

Table 4
The sensorial characteristics for common pale lager beer samples

Sensorial characteristics	Abbreviated name	Range	
		min	max
Appearance	A_P	3	5
Colour	C_O	3	4.9
Odour	O_D	3.8	5
Taste	T_A	2.8	4.9
Gas release	G_R	3.8	5
Foam stability	F_S	3.2	5

Table 5
Sensorial characteristics for superior pale lager beer samples

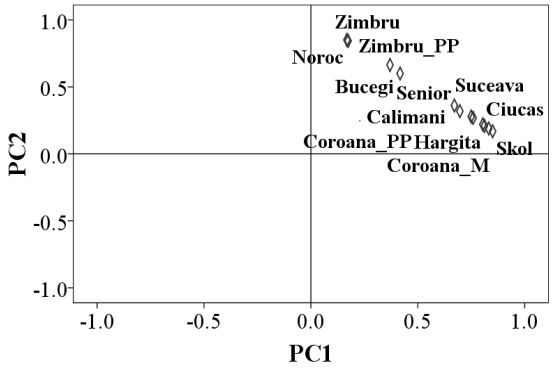
Sensorial characteristics	Abbreviated name	Range	
		min	max
Appearance	A_P	3.3	4.8
Colour	C_O	3.4	4.8
Odour	O_D	3.7	5
Taste	T_A	2.8	4.8
Gas release	G_R	4.1	5
Foam stability	F_S	3.9	5

For the first category of beer analyzed (common pale lager beer), the largest score was registered in Skol beer (19.7 points), followed by Ciucas, Calimani (beers 18.6 points) and Harghita (18.3 points). These types of beer have been regarded as very

good. At a lower level (the good beer category) the analysis has placed Suceava, Coroana Premium Pils, Coroana Moldovei, Zimbru Premium Pils, Coroana Moldovei, and Zimbru Premium Pils. The rest of the sorts of beer analyzed have been placed in the category of ordinary beer (12.1 ÷ 15 points).

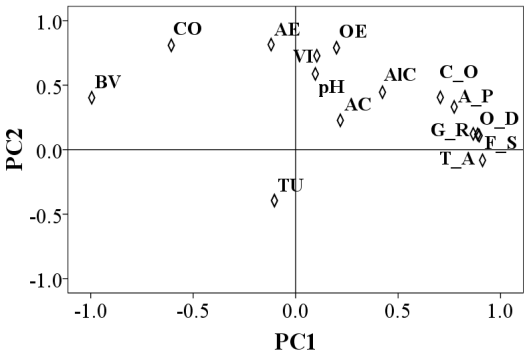
For the second category of beer analyzed (superior pale lager beer), the highest score was registered by Ursus Premium (19.3 points), which was the only one to be placed in the category of a very good beer. Timisoreana, Bergenbier, Bermas, Golden Brau, Ursus have been placed in the category of good beer, while Burger and Azuga were regarded as ordinary beers.

Sensory attributes combined with physical and chemical parameters. The correlation between the results of sensory testing and physico-chemical parameters obtained for common pale lager beer samples are represented in Figure 1a. The first two principal components explain 99.41% of the total variance (PC1 = 97.87% and PC2 = 1.54%). In respect to the first principal component PC1, one can notice that there is a very good correlation between the beers Skol, Coroana_M, Harghita, Coroana_PP, Calimani, Senior, Ciucas and Suceava. These beers are strongly associated with the first component PC1. The second principal component, PC2 is strongly correlated to the quality of Zimbru beer which is characterized by high value of the original extract (OE). PCA loadings of the physico-chemical parameters and variables used in sensorial quality evaluation are represented in Figure 1b. The two plots represented here have 51.92% and 26.17% of the total variance.



(a)

Figure 1a. Principal component analysis of the combined physico-chemical and sensory parameters from common pale lager beer samples; the 12 common pale lager beers, with their commercial names being plotted on the first two principal components.



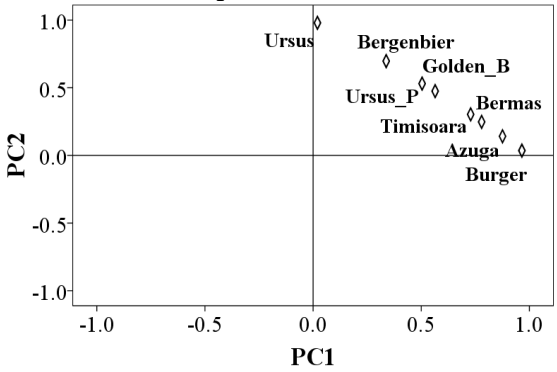
(b)

Figure 1b. Principal component analysis of the combined chemical and sensory data from superior pale lager beer samples: the 9 chemical and 6 sensorial parameters and panel score range are plotted on the first two principal components

The first component PC1 underlines the difference between bitterness value (BV) and appearance (A_P). The closeness of the acidity variable to the centre of PC shows that it is not useful to describe the differences between the 12 samples from the category of common pale lager beer. The second component PC2 distinguishes the variables apparent extract (AE) and turbidity (TU), which are opposed. Weighted heavily on the second PC was apparent extract (AE). As regards the second main component PC2, the parameters bitterness value (BV), colour (CO), apparent extract (AE) and turbidity (TU) are placed at the left of graph showing that these contribute to a larger extent in the evaluation of beers in comparison with the variables at the right.

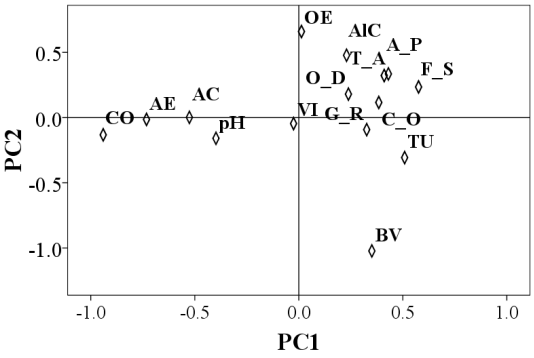
The plot of PC1 vs. PC2 loadings

shows, alongside with the PC1 component, a close association between gas release (G_R), foam stability (F_S), odour (O_D), appearance (A_P), colour (C_O) and taste (T_A) which reflect highly significant correlation coefficients. The variables mentioned indicate a strong correlation with this component, which can be characterized as a function of the organoleptic characteristics. These characteristics have an essential role in the appreciation of common pale lager beer samples - Skol, Coroana_M, Harghita, Coroana_PP, Calimani, Senior, Ciucas and Suceava, Figure 2a.



(a)

Figure 2a. Principal component analysis of the combined physico-chemical and sensory parameters from superior pale lager beer samples; the 8 superior blonde beer, with their commercial names are plotted on the first two principal components



(b)

Figure 2b. Principal component analysis of the combined chemical and sensory data from superior pale lager beer samples: the 9 chemical and 6 sensorial parameter and panel score range are plotted on the first two principal components

There is a significant correlation between the original extract variable (OE) and viscosity (VI) (r = 0.790), (r = 0.769), alcohol concentration (AlC) (r = 0.791), which are important coefficients for a level p = 0.01. These variables have a major role in the evaluation of beers such as Zimbru, Zimbru_PP, Noroc and Bucegi. The placement of Zimbru, Zimbru_PP, and Noroc in the space of principal components shows that these beers have a high level of original extract (O_E). For all the samples in the category of common pale lager beer, significant reverse correlations have been obtained between bitterness value and taste (r = - 0.660), odour (r = - 0.697), gas release (r = - 0.620) and foam stability (r = -0.671), for a level of 0.05. The correlation between the results of sensory testing and physico-chemical parameters obtained for the 8 beer samples from the first category are represented in Figure 2a. The first two principal components explain 99.48% of the total variance (PC1 = 97.16% and PC2=2.32%). As regards the principal component PC1, very good correlation between the beers Burger, Azuga, Timişoara and Bermas can be noticed. These brands are closely associated with the first principal component. The second principal component is strongly correlated to Ursus beer, which is characterized by high value of variable original extract (OE). PCA loadings of the physico-chemical parameters and variables used in the sensorial evaluation are represented in Figure 2b. The two plots represented here 49.69% and 34.10% of the total variance. The first component PC1 underlines the opposition between turbidity (TU) and colour (CO). Closeness of viscosity (VI) to the centre of PC shows that this variable is not useful to describe the differences between beers. As for the second component PC2, the original extract parameter (OE) is placed the highest while

the parameter bitterness value (BV) is placed the lowest. The position of original extract in the space of main components is associated with a high level of original extract (OE) for Ursus beer. The characteristics that contribute to a large extent in the evaluation of beers are the following parameters: alcohol concentration (AIC), turbidity (TU), appearance (A_P), foam stability (F_S) and taste (T_A).

Conclusions

Principal component analysis of the physico-chemical and sensorial data revealed the first PC to be a function of sensorial data and the second PC was a function of physico - chemical parameters. All the beers clustered together by those physico-chemical analyses have been identified as being related to sensorial attributes. When principal component analysis was performed on the combined sensory and physico-chemical data, the clustering of 20 beers irrespective of the beer type was also seen in the PC space. The sensorial characteristics used in the organoleptic analysis - appearance, colour, odour, taste, gas release and foam stability have a decisive role in identifying samples from the category of common pale lager beer. To identify samples of the superior pale lager beer category, the following characteristics such as appearance, foam stability and taste had a major contribution. Regarding the correlations between physico-chemical parameters and sensorial characteristics for all the samples analyzed, irrespective of the category they belong to, a direct significant correlation was obtained between alcohol concentration and taste. For all the samples in the category of common ale beer, significant reverse correlations were obtained between bitterness value and almost all the sensorial characteristics used: taste, odour, gas release and foam stability.

Sensory evaluation of the tested types of beer could reveal that physico-chemical parameters are responsible for sensorial attributes and important interaction occuring among these parameters.

Acknowledgements

The authors thank S.C. Bermas S.A. for technical support.

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