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1 **The influence of style and origin on mineral composition of beers retailing in the**
2 **UK**

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26 **ABSTRACT**

27 Beer has high nutritional values in terms of energy, and is also a dietary source of
28 antioxidants, carbohydrates and minerals among others. In Europe, 53 Mt of beer are
29 produced annually, and with an average supply of 68.2 kg *capita*⁻¹ year⁻¹ among adults.
30 In this study, the mineral composition of 125 commercial beer samples retailing in the
31 UK, but originating from 10 countries, was determined; such detailed information is
32 lacking in UK food composition tables. Beer composition data are reported for Al, As,
33 Ba, Ca, Cd, Co, Cr, Cs, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb, Se, Sr, U, V and Zn,
34 following analysis by inductively coupled plasma-mass spectrometry. ANOVA results
35 showed higher concentrations of Mo, Pb and Sr (0.160; 491.70×10⁻⁵; 0.38, mg L⁻¹
36 respectively) for stout/porter style and a significant higher amount of minerals such as
37 Al (3.835 mg L⁻¹), Cd (8.64×10⁻⁵ mg L⁻¹), Mn (1.02 mg L⁻¹) or Ni (0.312 mg L⁻¹) among
38 others for lambic beer. Regarding the country of origin, higher Se concentrations were
39 reported from beer brewed in the USA (0.110 mg L⁻¹). It is concluded that beer style
40 was determined to have a greater effect on beer mineral composition than origin or
41 container type.

42

43 *Keywords:*

44 Alcoholic beverage

45 Nutrients

46 Chemometrics

47 ICP-MS

48

49

50

51 **1. Introduction**

52 The last data recorded by FAO (2011) stated that Europe produced ~53 Mt of beer, with
53 an average reported supply of 68.2 kg *capita*⁻¹ year⁻¹ for adults. The Russian Federation
54 and Germany (9.9 Mt and 8.9 Mt, respectively) had the highest beer production,
55 followed by UK, Spain, Poland and Ukraine, each with production of 3-4.5 Mt. The
56 Russian Federation, Czech Republic and Ireland have the greatest *per capita* beer
57 supply in Europe, with >130 kg *capita*⁻¹ year⁻¹. According to the FAO¹ data, the UK and
58 Spain have an annual supply of 75–79 kg *capita*⁻¹ year⁻¹. All these figures highlight the
59 importance of beer in Europe, in both trade and food supply.

60

61 Beer contributes significantly to energy intake due to its ethanol content (7 kcal mL⁻¹
62 FW) but also due to protein (4 kcal mL⁻¹) and carbohydrate (3.75 kcal mL⁻¹) which
63 includes starch partially degraded in a non-fermentable form². Beer also contains a
64 range of antioxidants, polyphenols, phenolics, folates, carbohydrates, soluble fibre,
65 vitamins and minerals³⁻⁷. There is considerable ongoing debate about potential health
66 benefits arising from moderate alcohol consumption, such as reduced coronary heart
67 disease or ischemic stroke risk⁸ and improved immune response⁹. Moderate alcohol
68 consumption is defined as an alcohol intake of 10-12 mL d⁻¹ for women and 20-24 mL
69 d⁻¹ for men according to Díaz et al.¹⁰, which is equivalent to 1 - 3 drinks d⁻¹ for studies
70 carried out in the UK by Rimm et al.¹¹. Currently, there is limited information in the
71 literature regarding the influence of beer style or origin on beer mineral profiles⁷. In the
72 UK, the Food Standards Agency¹² periodically publishes Food Composition tables, with
73 information about beer among other foods and beverages. In these tables some entries
74 correspond to ale, stout or lager, the beer types most widely consumed in the UK. For
75 these entries, concentrations of Ca, Cl, Cu, Fe, I, K, Mg, Mn, Na, P, Se and Zn are

76 reported, but not all minerals are reported for all beer types. Therefore, the aim of this
77 study is to determine a wider mineral composition of a range of domestic and imported
78 beers currently retailing in the UK.

79

80 **2. Materials and methods**

81 *2.1. Beer samples*

82 Beers (n = 125) were purchased from UK-based stores or obtained directly from UK-
83 based breweries. Beers originated from 10 countries (Belgium, China, Czech Republic,
84 Germany, Holland, Ireland, Italy, Mexico, UK and USA), according to the label.
85 Alcohol contents given in the label ranging between 2.8 and 10.1%. Ale style was
86 represented by 67 samples, lager style by 58 samples including 4 specifically classified
87 as pilsner. Within ale style, 7 beers were specifically classified as bitter, 6 as India pale
88 ale (IPA), 4 as lambic and 10 as stout/porter. More information about the samples can
89 be found in Rodrigo et al.¹³. Sample containers were bottles (n=104), aluminium cans
90 (n=16) or brewery barrels of varying capacities (n=5).

91

92 *2.2. Elemental analysis*

93 Concentrations of Al, As, Ba, Ca, Cd, Co, Cr, Cs, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, Pb,
94 Se, Sr, U, V and Zn in the beers were determined by ICP-MS (X-Series^{II}, Thermo
95 Fisher Scientific Inc., Waltham, MA, USA), using a H₂ reaction cell to enhance
96 resolution of Se, and diluting the samples 1-in-6 with 1% Trace Analysis Grade (TAG)
97 HNO₃. Samples in duplicate were introduced from an autosampler (Celtac ASX-520,
98 Omaha, ME, USA) at 1 mL min⁻¹ through a concentric glass venturi nebuliser and
99 Peltier-cooled (3 °C) spray chamber (Thermo Fisher Scientific Inc.). The instrument
100 (Thermo XSeries(II)) has a hexapole with 'kinetic energy discrimination in order to

101 reduce polyatomic interferences. The XSeries(II) uses a 7% hydrogen in helium gas as
102 the 'collision-reaction' gas in the hexapole chamber. Internal standards were introduced
103 to the sample stream via a T-piece and included Sc (50 ng mL⁻¹), Rh (10 ng mL⁻¹) and Ir
104 (5 ng mL⁻¹) in 2% TAG HNO₃. An acid-digested wheat flour standard (NIST 1567a;
105 National Institute of Standards and Technology, Gaithersburg, MD, USA) was used as
106 reference material. Two sets of multi-element standards were used: 0, 10, 20, 30 ppm
107 (mg/L) for Ca, Mg, Na and Mg (PlasmaCAL, SCP Science, France) 0, 20, 40, 100 ppb
108 for all other elements (Claritas-PPT grade CLMS-2 from Certiprep/Fisher, UK). The
109 limit of detection (LOD) for the analysis was calculated by substituting three times the
110 standard deviation of the blank into the equation operational blank samples (ten
111 replicates).

112

113 *2.3. Statistical analysis*

114 Mineral element concentrations and alcohol content were subjected to two 1-way
115 analysis of variance (ANOVA) including beer style (ale, bitter, India pale ale, lager,
116 lambic, pilsner and stout/porter) and country of origin (Belgium, China, Czech
117 Republic, Germany, Holland, Ireland, Italy, Mexico, UK and USA) in the models.
118 Moreover, the influence of the container type (barrel, bottle and can) on mineral
119 elements concentration was also assessed using a 1-way ANOVA. When significant
120 differences were found in ANOVA, means were compared using Fisher's protected
121 least significant difference (LSD) test at $p \leq 0.05$. Pearson correlation tests were
122 performed between the different parameters. Principal component analysis (PCA) and
123 discriminant analysis (DA) were conducted on the 22 elemental composition traits for
124 each beer style and country of origin with the aim of determining the most explanatory

125 variables in the method. All these analyses were performed with the XLStat (Addissoft,
126 USA) 'add-on' for Microsoft Excel.

127

128 **3. Results and discussion**

129 *3.1. Beer mineral content*

130 The elements present at highest concentrations in beers were K, Mg, Ca and Na (means
131 of 451, 78, 52 and 41 mg L⁻¹ respectively) (Table 1), fact that perfectly agrees with the
132 results given by Montari et al.¹⁴. Most elemental concentrations in the current survey are
133 similar to data reported in the literature, except K and Mg, whose values are lower than
134 those reported by Rubio et al.¹⁵ and Alcázar et al.¹⁶, in their surveys with 28 and 32 beer
135 samples respectively. In the UK food composition tables, Ca, Cu, Fe, Mn, Na and Zn
136 concentrations are smaller than those in our survey¹², that could be explained by the
137 higher number of entries of the survey here presented with reference to the one done by
138 the Food Standard Agency (FSA). Moreover, FSA survey does not reflect any
139 classification by beer styles or origin, while this paper presents all the complete data for
140 describing any beer including in the study. These two reasons could explain the
141 differences found between the FSA data and the presented data.

142

143 Alcázar et al.¹⁶ also found lower Zn values in Portuguese beers than the values obtained
144 from our survey. As expected, toxic elements were present at the lowest concentrations;
145 the average concentrations of Cd, Cs, Pb and U were <0.1 mg L⁻¹.

146

147 The Food and Nutrition Board of the Institute of Medicine has established the TUL
148 (Tolerable Upper Intake Level) for Cu, Fe, Mn, Mo, Se and Zn, as 10, 45, 11, 2, 0.4 and
149 40 mg day⁻¹, respectively and the RDA (Recommended Dietary Allowance) for Cu, Fe,

150 Mo and Se as 0.9, 18, 0.045, 0.055 respectively and for Zn, 11 and 8 mg day⁻¹ for males
151 and females, respectively. The AI (Adequate Intake) for Cr is 0.025 and 0.035 mg day⁻¹
152 for males and females respectively, while the NOAEL (No-Observed Adverse Effect
153 Level) is 1.468 mg kg⁻¹ day⁻¹. Meanwhile, AI is established for Mn in 2.3 mg day⁻¹. If
154 we compare literature values with our results, drinking 1 L day⁻¹ of beer (all styles
155 excluding lambics), could cover between 10% - 50% and 20% - 50% of the RDA for Fe
156 and Zn respectively, while 100% of the RDA for Mn, Se and Cr would be
157 accommodated. The Cu RDA could be achieved from consumption of just 100 mL day⁻¹
158 of beer. In the case of lambic beers, Fe intake could exceed the TUL when drinking 1 L
159 day⁻¹.

160

161 *3.2. Effect of beer style and place of origin on mineral and alcohol contents*

162 There was a significant effect of beer style on mineral composition for all elements
163 except Na, Cu, Se and Cs ($p \leq 0.05$; Table 1). The IPA beers had the highest, and lager
164 beers the lowest, concentrations of Ca, K and Mg (Table 1). One hypothesis that could
165 explain this fact could be the use of various yeasts to brew the varied beer styles; thus,
166 as explained previously in another matrixes¹⁷ different fungal strains could behave
167 completely different regarding to the same raw material having contrary tendencies in
168 the uptake of the minerals contained in the matrix. Lambic beers had the highest Al, Cd,
169 Co, Cr, Fe, Mn, Ni and Zn concentrations; stout/porter beers had the highest Sr and Mo
170 concentrations. Bacteria (i.e. lactic acid bacteria) growth in lambic beer worts produce
171 higher concentrations of amine derivate compounds¹⁸, which probably increases the
172 amine-based ligands and accordingly heavy metal concentration¹⁹ in lambic beer. It
173 should be noted that all the lambic beers analyzed in this study were brewed in
174 Belgium, so the higher concentration of heavy metals could be not completely defined

175 by beer style but also by the mineral profile of the raw material. Ale, IPA and
176 stout/porter beers typically had higher alcohol contents than bitter, lager, pilsner and
177 lambic beers, which confirms the influence of beer style in beer alcohol content stated
178 previously by Willaert and Nedovic²⁰.

179

180 There was a significant effect of geographical origin on beer mineral concentration for
181 half of the elements, except Ba, Ca, Cd, Co, Fe, Mn, Mo, Ni, Pb and V ($p \leq 0.05$; Table
182 2). Beers from USA typically had higher Mg and K concentrations, while Mexican
183 beers had lower concentrations of these elements. Arsenic concentrations were higher in
184 beers from Mexico and the USA, while USA beers had the highest concentrations of Se
185 (Table 2). Previous studies have reported the relationship between Se availability in soil
186 and Se content of cereal grains^{13, 21-23} which could explain the higher Se concentration
187 in beers coming from the USA. Regarding to the alcohol content, significant differences
188 were only detected between beers originated in Czech Republic, Mexico and UK,
189 showing the beer originated in the two first countries a lower alcohol content than the
190 one registered from beers brewed in UK (Table 2).

191

192 *3.3. Influence of container type on beer mineral contents*

193 There was relatively little effect of container type on beer mineral composition for most
194 elements. Only the concentrations of As ($p \leq 0.001$), Mg ($p \leq 0.01$), Na ($p \leq 0.01$) and V
195 ($p \leq 0.01$) in beer were significantly affected by container type (Table 3). Concentrations
196 of As and Na were highest for beers stored in metal barrels and V concentrations were
197 lowest when stored in cans. It is known that metallic elements can be extracted from the
198 container surface due to complex formation between metal ions and chelating agents.
199 Thus, Al²⁴ and Sb²⁵ were reported to be transferred from cooking or storage container

200 surfaces into food. However, the common use of inox containers, except in the case of
201 lambic beers, where other materials are used, reduces considerably the possibility of
202 transferring constituents from the container to the beer²⁶. This suggests that the trends
203 seen in our work could reflect ingredients, mainly water, characteristics and quality
204 (every barrel is from the same area) rather than the use of different containers.

205

206 *3.4. Principal Component Analysis (PCA)*

207 PCA was applied to evaluate trends in the data taking into account both the beer style
208 and its origin. Only elements significantly affected by beer style or beer origin were
209 included in PCA studies.

210

211 In the first application of PCA (style), two principal components (PCs) explained 75%
212 of the total variance; PC1 explained up to 54% and PC2 up to 21% (Fig. 1). In Fig. 1 it
213 can be seen that Al, Ba, Cd, Co, Cr, Fe, Mn, Ni and Zn and, are located at positive
214 values of PC1, and Mo, Pb and Sr, at positive values of PC2; these elements had the
215 highest loadings (> 0.85; data not shown). Elements in the first group (+ve PC1) are
216 clustered very tightly suggesting that they provide similar information, reflecting a
217 similar underlying cause, such as similar water characteristics²⁷, meanwhile V appeared
218 opposite this first group (in -ve PC1), which was expected due to the opposite relation
219 between Mn and Ni with V reported by Fargašová and Beinrohr²⁸ in metal accumulation
220 in plants. Manganese, Mg and K were identified by Alcázar et al.²⁹ as the most
221 important variables for beer classification purposes but only Mn shows a strong
222 underlying trend in the present study. There is greater variability in Mg and K values in
223 our survey because of the inclusion of different beer styles, whereas in Alcázar et al.²⁹
224 most of analyzed beers were lager.

225

226 At the bottom-left in the observations plot (Fig. 1), a group of four out of the seven beer
227 styles appear together, suggesting some similar characteristics, due to the slight
228 separation between observations. Lambic and stout/porter beers appear in the bottom-
229 right side and the upper-left part of the figure respectively, showing a clear separation
230 from the other beer styles. Differences between beers arise from different methods of
231 processing raw material³⁰ (i.e. fermentation). This could explain the differences found
232 between beer styles in this study regarding the mineral profile, due to the different
233 behavior of the mineral elements during brewing process showed by Kayodé et al.³¹ for
234 Zn and Fe.

235

236 In the second PCA (origin), variables are more poorly explained than in the first PCA
237 (style); there was a lower two principal components (PCs) explanation of the total
238 variance (56%). PC1 explained up to 35% and PC2 explained 21% of the variance (Fig.
239 1). Chromium, Mn, Fe, Co and Cd, with loadings higher than 0.83 (data not shown) and
240 at positive values in PC1, seem to be the most dominant variables, together with U and
241 Cs, at positive values of PC2 (Fig. 1) and loadings higher than 0.84, respectively (data
242 not shown).

243

244 Belgium, USA and Italy, appear clearly separated in the observations plot (Fig. 1), a
245 group of seven out of the ten places of origin studied are clustered together, showing
246 some kind of consistent trend, due to the slight separation between observations.
247 Recognition of Belgian beers based on multivariate analysis was previously described
248 by Cajka et al.³²; this arose due mainly to unusual traditional brewing practices such as

249 Trappist and lambic monastic brewing recipes and spontaneous fermentation
250 respectively.

251

252 *3.5. Supervised learning methods: Discriminant Analysis (DA)*

253 Discriminant analysis (DA) to identify differences between beers was undertaken both
254 for beer style and beer origin. DA regarding beer style (Fig. 2) showed a prediction
255 ability higher than 81%, while DA for beer origin place showed a lower prediction
256 ability (76%) which means that only 76% of the beers are placed by the method in the
257 correct style group (Fig. 2). For the first DA (beer style) five out of the seven beer styles
258 were predicted with a success rate higher than 70% (ale 78%, lager 90%, lambic 100%,
259 pilsner 75% and stout/porter 70%) while bitter and India pale ale showed success rates
260 of 57% and 50% respectively. IPA beers re-categorized by the analysis were placed in
261 the Ale group. Lambic beers, with a 100% of the success rate (every lambic beer was
262 included by the method in the correct beer group), reveal special characteristics of this
263 beer style in terms of its mineral profile, probably due to its unique fermentation using
264 wild yeast and uncontrolled amounts of bacteria³³. Unlike our results, significant
265 differences were not found by Blanco et al.³⁴ when analyzing AI in different beer types.
266

267 The second DA (beer origin) produced prediction success rates for the origin place,
268 higher than 63%, except beers brewed in Belgium (42%), whose characteristics made
269 the analysis place them in Germany or Holland groups, among others. Alcázar et al.¹⁶
270 found in their study about beer chemical descriptors higher predictions success rate
271 (99%), although only three countries were studied in their work.

272

273 As expected by the multivariate analysis results presented in sections above, average
274 data for each beer style and mineral element (Table 1), showed the highest Mg, Mo, Pb
275 and Sr in stout/porter and Al, Ba, Cd, Co, Fe, Mn, Ni and Zn values in lambic beers,
276 which was expected due to the correlation ($r > 0.60$ in the first group and $r > 0.64$, in the
277 second group respectively) between the element except for Fe with Ba, Cd, Mn, Ni and
278 Zn. Regarding stout/porter beers, their higher Mg content could be explained by the
279 correlation existing between Mg and polyphenols described by Vitali et al.³⁵, where
280 polyphenols decrease the mineral binding to fermentable compounds and thus the
281 yeast's mineral consumption. This leads to an increase in the Mg concentration in beer
282 after fermentation³⁶. The higher amount of polyphenols in stout/porter beer can be
283 inferred by the fact of including in the brewing process a slightly higher amount of
284 hops³⁷, which contains important concentration of polyphenols according to Nagasako-
285 Akazome et al.³⁷ study.

286

287 The most important result to highlight regarding the DA with respect to the country of
288 origin is found in the relationship between Se and beers brewed in the USA. USA beers
289 showed the highest Se values in the whole survey. Moreover, high Ni and Fe
290 concentration were detected for Belgian beers, and high Cs concentration in beers
291 manufactured in Italy (Table 1). Several elements such as U and Cs are well explained
292 by factor 1 (data not shown) with loadings of -0.72 for U and -0.89 for Cs. Selenium, on
293 the other hand is very well explained by factor 2 with loading of 0.92. Aluminium, Cd,
294 Co, Mn, Ni and Zn are correlated ($r^2 > 0.50$) to each other, but their loadings are lower
295 than 0.18 in both factor 1 and 2. However, Al, Cd, Co, Mn, Ni and Zn loadings are
296 higher than 0.5 in factor 6 (data not shown), even when the program did not chose this
297 factor as one of the most important ones.

298

299 **4. Conclusions**

300 The mineral concentration of beer can be differentiated by style and place of origin
301 place using a chemometric approach. Beer style had a greater effect on beer mineral
302 composition than place of origin; higher Mg, Sr, Mo and Pb concentrations classified
303 stout/porter beer while higher Al, Mn, Fe, Co, Ni, Zn, Cd and Ba clearly described
304 lambics. The Se concentration of beers from the USA highlights the likely higher
305 concentration of this element in USA cereal grains due to prevailing soil geochemical
306 characteristics.

307

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312

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431 **Figure captions**

432 **Fig. 1.** Correlation between loadings and factors (up-left) and observations plot (up-

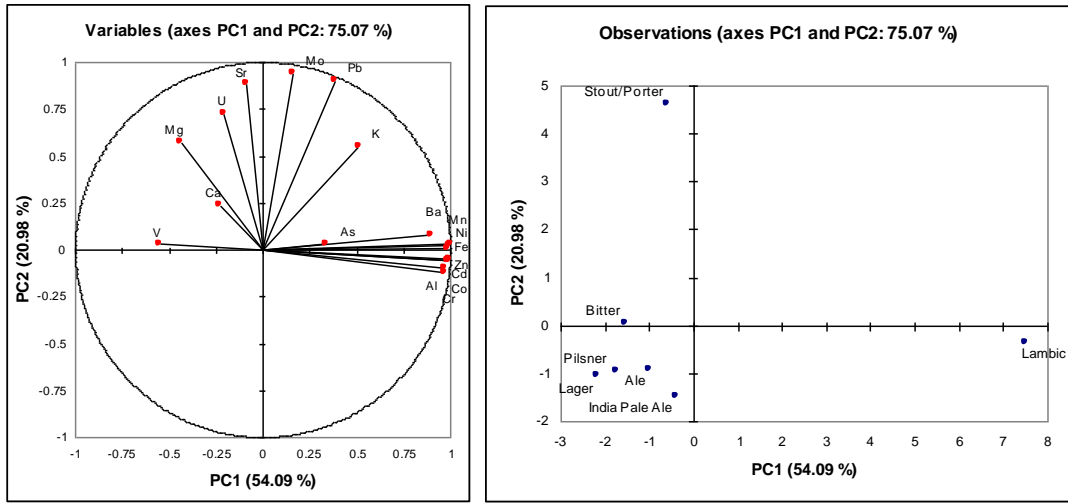
433 right) regarding the effect of style on beer mineral composition in the Principal

434 Components Analysis (PCA), and correlation between loadings and factors (down-left)

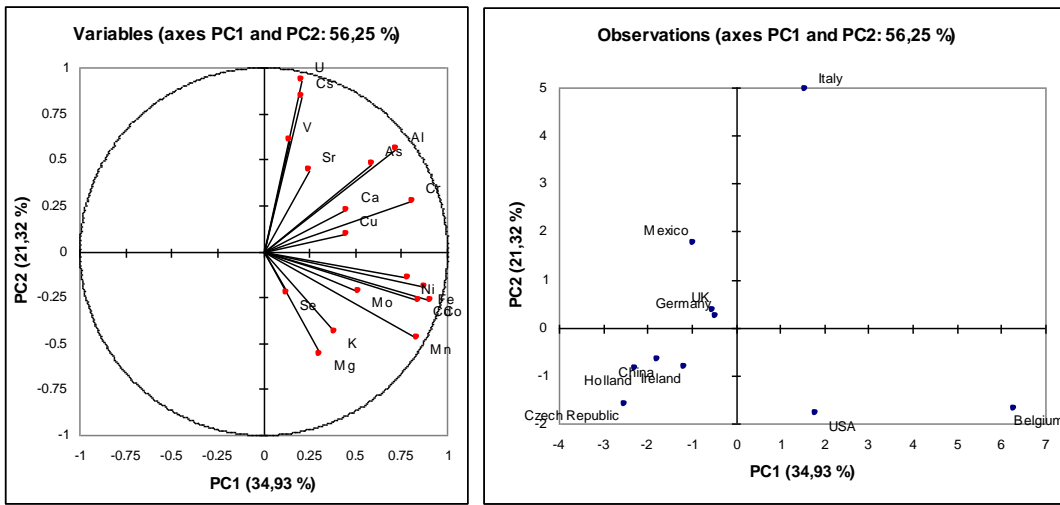
435 and observations plot (down-right) regarding the effect of place of origin on beer

436 mineral composition in the Principal Components Analysis (PCA).

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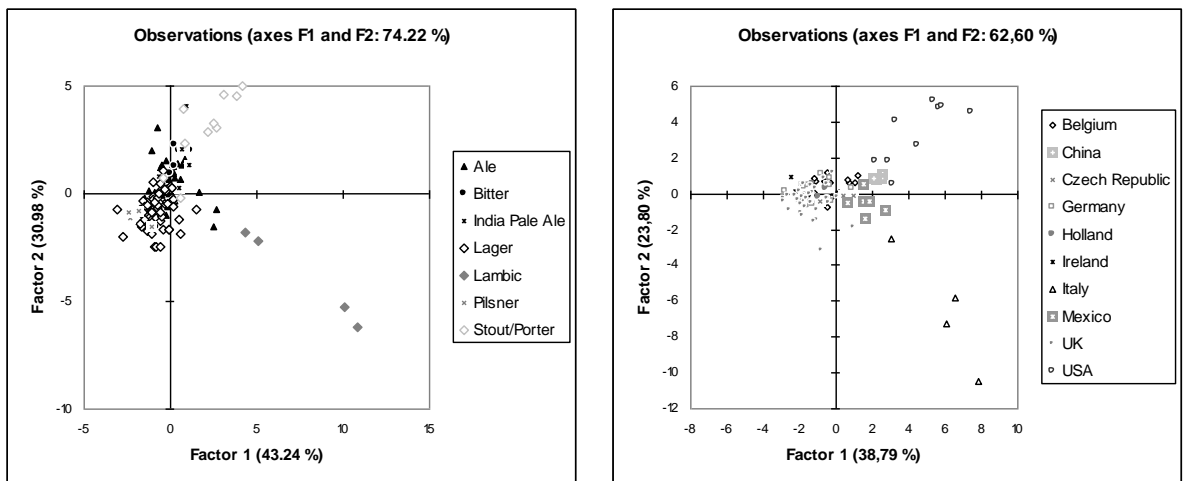
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444 **Fig. 2.** Discriminant Analyses (DA) of beer mineral composition data for 22 elements,



445 regarding the style (left) and the place of origin (right)

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460 **Table 1.** Mean mineral content (mg L⁻¹) and alcohol content (%) of beer samples as affected by beer style. Different letters mean significant
 461 differences (p ≤ 0.05).

Style	Al ^{***}	As [*]	Ba ^{***}	Ca ^{***}	Cd ^{***}	Co ^{***}	Cr ^{***}	Cs	Cu	Fe ^{***}	K ^{***}	
Ale(n=35)	0.492 ^b	0.076 ^a	0.321 ^b	56.1 ^b	2.83×10 ^{-5b}	23.81×10 ^{-5b}	0.044 ^b	26.58×10 ⁻⁵	0.512	0.884 ^b	474.3 ^b	
Bitter(n=7)	0.655 ^b	0.092 ^a	0.364 ^b	86.0 ^a	1.40×10 ^{-5b}	22.76×10 ^{-5b}	0.038 ^b	28.71×10 ⁻⁵	0.289	0.467 ^b	455.5 ^{bc}	
IPA(n=6)	0.455 ^b	0.082 ^a	0.478 ^{ab}	76.1 ^{ab}	2.87×10 ^{-5b}	32.02×10 ^{-5b}	0.044 ^b	35.93×10 ⁻⁵	0.395	0.264 ^b	647.8 ^a	
Lager(n=59)	0.598×10 ^{-3b}	0.063 ^a	0.192 ^c	41.7 ^c	2.40×10 ^{-5b}	18.95×10 ^{-5b}	0.048 ^b	135.06×10 ⁻⁵	0.428	0.461 ^b	379.9 ^c	
Lambic(n=4)	3.835 ^a	0.042 ^a	0.674 ^a	39.3 ^c	8.64×10 ^{-5a}	279.85×10 ^{-5a}	0.141 ^a	98.35×10 ⁻⁵	0.482	1.3 ^a	677.4 ^a	
Pilsner(n=4)	0.395 ^b	0.007 ^b	0.230 ^{bc}	25.4 ^c	1.93×10 ^{-5b}	12.30×10 ^{-5b}	0.046 ^b	78.60×10 ⁻⁵	0.576	0.208 ^b	462.6 ^{bc}	
Stout/Porter (n=10)	0.411 ^b	0.064 ^a	0.380 ^b	74.2 ^{ab}	3.66×10 ^{-5b}	26.49×10 ^{-5b}	0.040 ^b	21.75×10 ⁻⁵	0.432	0.15 ^b	592.6 ^a	
Mean	0.977	0.061	0.501	56.9	3.39×10 ⁻⁵	59.45×10 ⁻⁵	0.057	60.71×10 ⁻⁵	0.445	0.329	527.2	
Style	Mg ^{***}	Mn ^{***}	Mo ^{***}	Na	Ni ^{***}	Pb ^{**}	Se	Sr ^{**}	U [*]	V [*]	Zn ^{***}	Alcohol content ^{***}
Ale	84.8 ^{bc}	0.18 ^b	0.053 ^b	44.9	0.061 ^b	41.90×10 ^{-5b}	0.039	0.15 ^c	4.06×10 ^{-5b}	0.174 ^b	0.443 ^b	5.35 ^a
Bitter	73.7 ^{cd}	0.17 ^b	0.040 ^b	52.7	0.041 ^b	48.19×10 ^{-5b}	0.013	0.23 ^b	11.87×10 ^{-5a}	0.209 ^{ab}	0.200 ^b	7.06 ^{bc}
IPA	95.3 ^{ab}	0.28 ^b	0.022 ^b	51.2	0.067 ^b	41.30×10 ^{-5b}	0.049	0.19 ^c	1.88×10 ^{-5b}	0.105 ^b	0.464 ^b	7.55 ^{ab}
Lager	67.9 ^d	0.10 ^b	0.055 ^b	33.0	0.045 ^b	36.99×10 ^{-5b}	0.022	0.14 ^c	10.24×10 ^{-5a}	0.386 ^a	0.178 ^b	5.11 ^{bc}
Lambic	63.6 ^d	1.02 ^a	0.074 ^b	53.3	0.312 ^a	263.73×10 ^{-5ab}	0.014	0.15 ^c	5.45×10 ^{-5ab}	0.109 ^b	3.545 ^a	4.25 ^c
Pilsner	92.7 ^{abc}	0.10 ^b	0.039 ^b	32.4	0.059 ^b	55.73×10 ^{-5b}	0.011	0.09 ^c	3.75×10 ^{-5b}	0.199 ^{ab}	0.251 ^b	5.05 ^{bc}
Stout/Porter	103.5 ^a	0.27 ^b	0.160 ^a	51.9	0.084 ^b	491.71×10 ^{-5a}	0.029	0.38 ^a	13.90×10 ^{-5a}	0.208 ^{ab}	0.428 ^b	4.93 ^{ab}
Mean	83.1	0.30	0.063	45.6	0.096	139.94×10 ⁻⁵	0.025 ^b	0.19	7.31×10 ⁻⁵	0.199	0.787	5.65

462 *, ** and *** significance at p ≤ 0.05, 0.01 and 0.001 respectively following one-way ANOVA.

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469 **Table 2.** Mean mineral composition (mg L⁻¹) and alcohol content (%) in the analyzed beer samples as affected by beer origin place. Different

470 letters mean significant differences ($p \leq 0.05$)

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Country of origin	Al*	As*	Ba	Ca	Cd	Co	Cr*	Cs***	Cu*	Fe	K***	
Belgium(n=19)	0.13 ^a	0.080 ^{ab}	0.423	54.8	20.63×10 ⁻⁵	79.77×10 ⁻⁵	0.070 ^a	46.41×10 ^{-5b}	0.633 ^a	4.073	504.2 ^b	
China(n=4)	0.04 ^b	0.039 ^{bc}	0.93	35.1	1.23×10 ⁻⁵	13.30×10 ⁻⁵	0.038 ^{ab}	20.58×10 ^{-5b}	0.365 ^{bc}	0.252	298.9 ^{cd}	
Czech Republic (n=4)	0.03 ^b	0.024 ^c 0.074 ^{ab}	0.155	2.4.1	1.05×10 ⁻⁵	9.95×10 ⁻⁵	0.042 ^{ab}	80.80×10 ^{-5b}	0.532 ^{abc}	0.198	416.8 ^{bc}	
Germany(n=13)	0.05 ^b	0.055 ^{bc}	0.219	41.7	2.11×10 ⁻⁵	18.02×10 ⁻⁵	0.051 ^{ab}	35.68×10 ^{-5b}	0.400 ^{bc}	0.579	450.2 ^b	
Holland(n=4)	0.04 ^b	0.061 ^{abc}	0.089	29.7	1.95×10 ⁻⁵	19.83×10 ⁻⁵	0.033 ^{ab}	24.30×10 ^{-5b}	0.476 ^{abc}	0.487	506.0 ^{ab}	
Ireland(n=3)	0.03 ^b	0.091 ^a	0.240	55.2	2.63×10 ⁻⁵	18.95×10 ⁻⁵	0.027 ^b	17.20×10 ^{-5b}	0.232 ^c	0.850	475.3 ^b	
Italy(n=4)	0.17 ^a	0.093 ^a	0.304	44.0	1.50×10 ⁻⁵	20.82×10 ⁻⁵	0.071 ^a	1616.62×10 ^{-5a}	0.521 ^{abc}	0.843	412.8 ^{bc}	
Mexico(n=7)	0.04 ^b	0.060 ^{bc}	0.262	50.4	5.57×10 ⁻⁵	22.29×10 ⁻⁵	0.032 ^b	68.30×10 ^{-5b}	0.677 ^a	0.332	239.8 ^d	
UK(n=53)	0.05 ^b	0.088 ^a	0.268	61.5	2.36×10 ⁻⁵	22.29×10 ⁻⁵	0.043 ^{ab}	21.36×10 ^{-5b}	3.49×10 ^{-3c}	0.554	436.5 ^b	
USA(n=14)	0.05 ^b		0.307	38.7	3.66×10 ⁻⁵	28.60×10 ⁻⁵	0.059 ^{ab}	39.22×10 ^{-5b}	5.85×10 ^{-3ab}	0.489	626.2 ^a	
Country of origin	Mg**	Mn	Mo	Na**	Ni	Pb	Se***	Sr*	U***	V	Zn	Alcohol content
Belgium	83.3 ^b	0.35	0.070	49.7 ^a	0.111	94.03×10 ⁻⁵	0.017 ^d	0.14 ^{ab}	4.28×10 ^{-5c}	0.200	0.987	4.99 ^{ab}
China	76.4 ^b	0.14	0.023	53.2 ^a	0.779	51.75×10 ⁻⁵	0.058 ^b	0.23 ^a	1.73×10 ^{-5c}	0.093	0.145	4.82 ^{ab}
Czech Republic	89.1 ^{ab}	0.10	0.019	20.8 ^{ab}	0.547	53.92×10 ⁻⁵	0.012 ^d	0.07 ^b	1.70×10 ^{-5c}	0.069	0.234	4.00 ^b
Germany	79.5 ^b	0.13	0.082	19.1 ^b	0.445	33.61×10 ⁻⁵	0.009 ^d	0.09 ^b	6.30×10 ^{-5bc}	0.487	0.162	5.34 ^{ab}
Holland	68.5 ^{bc}	0.09	0.032	20.5 ^{ab}	0.345	25.00×10 ⁻⁵	0.014 ^d	0.05 ^b	2.22×10 ^{-5c}	0.160	1.073	5.58 ^{ab}
Ireland	76.4 ^b	0.20	0.070	21.2 ^{ab}	0.330	31.57×10 ⁻⁵	0.014 ^d	0.12 ^{ab}	7.27×10 ^{-5bc}	0.246	0.357	5.10 ^{ab}
Italy	72.6 ^{bc}	0.11	0.036	15.7 ^b	0.667	76.98×10 ⁻⁵	0.019 ^{cd}	0.23 ^a	42.30×10 ^{-5a}	0.365	0.159	4.95 ^{ab}
Mexico	57.3 ^c	0.10	0.038	53.1 ^a	0.431	31.03×10 ⁻⁵	0.042 ^{bc}	0.22 ^a	11.76×10 ^{-5b}	0.294	0.189	4.53 ^b
UK	73.6 ^d	0.14	0.060	48.3 ^a	0.504	120.48×10 ⁻⁵	0.016 ^d	0.18 ^a	9.26×10 ^{-5b}	0.312	0.194	5.72 ^a
USA	99.8 ^a	0.25	0.080 ³	26.8 ^{ab}	0.673	33.05×10 ⁻⁵	0.110 ^a	0.22 ^a	3.47×10 ^{-5c}	0.153	0.853	5.61 ^{ab}

472 *, ** and *** significance at $p \leq 0.05$, 0.01 and 0.001 respectively

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476 **Table 3.** As, Mg, Na and V concentration as affected by container. Different lower case
 477 letters in the same column mean significant differences ($p \leq 0.05$)

Container	As (mg L ⁻¹) ^{***}	Mg (mg L ⁻¹) ^{**}	Na (mg L ⁻¹) ^{**}	V (mg L ⁻¹) ^{**}
Barrel	0.006 ^b	7.8.1 ^{ab}	82.7 ^a	0.014 ^b
Bottle	0.079 ^a	80.1 ^a	38.9 ^b	0.264 ^b
Can	0.071 ^a	605 ^b	3670 ^b	0.441 ^a

478 ^{**} and ^{***} significance at $p \leq 0.01$ and 0.001 respectively

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