DISCRIMINATION BASED ON COMMERCIAL/CRAFT ORIGIN AND ON LAGER/ALE FERMENTATION OF UNDILUTED SPANISH BEER SAMPLES- FRONT-FACE EXCITATION-EMISSION MATRICES AND CHEMOMETRICS

Abstract: Spanish beer samples of different origin (craft and commercial) and with different type of fermentation (ale and lager) were analyzed employing molecular fluorescence. Excitation-emission matrices were obtained of the bulk samples, employing front-face mode. PARAFAC was performed on the data, obtaining a 6-components model that could be related to the fluorescent components of the beer. A statistical analysis of the scores was carried out, from which it was deduced that the commercial samples are more similar to each other than the craft ones. In addition, ale-fermented samples tend to differ more between them than lager-fermented samples. Finally, an attempt was made to relate the iso-α-acid component to the bitterness values of the samples. This study describes the fluorophores of Spanish beers, and has allowed its qualitative characterization on the basis of their origin, type of fermentation and degree of bitterness.

Keywords: beer; EEM; fluorescence; front-face; PARAFAC; chemometrics; ale; lager; craft; commercial

1. Introduction

Beer is the beverage resulting from the alcoholic fermentation (by means of selected yeasts) of a brewing wort, which transforms the sugars present into ethanol and carbon dioxide. This wort is obtained after aqueous extraction and enzymatic saccharification of ground malt or its extracts, and then, it is clarified and hops and/or derivatives are added, before following a boiling process. Other sources of starch may be used as long as the malt is at least 50% by weight of the raw material (Bamforth, 2005; Boletín Oficial del Estado, 2022; Grupo Mahou - San Miguel, 2021; Makwana & Hati, 2019). Thus, although the brewing process is a complex procedure with several phases, only the four main stages of it will be discussed, to allow the reader an overview of the procedure. These main stages are:

- Preparation of the malt by controlled germination and roasting of the cereal grains.
- Aqueous extraction of the malt, which results in obtaining the "sweet wort", rich in sugars and soluble nitrogen compounds.
- Addition of hops and/or derivatives and boiling of the wort, after clarification and filtration.
- Alcoholic fermentation of the wort, by means of which the yeasts transform the sugars present into ethanol and carbon dioxide. In the same way, parallel reactions will generate other compounds that will contribute to the aroma and flavour of the beer.

Beers are classified according to the type of fermentation they undergo. Although there are many different types of beers, the most basic classification divides beers into *lagers* and *ales*. *Lager* beers (also called bottom-fermented beers) are those that are fermented and matured at a low temperature (6 – 15ºC). The yeasts used for their production are usually *Saccharomyces* hybrids, which tend to precipitate at the bottom of the wort. *Lagers* are the most widely consumed beers in the world, accounting for 90% of global consumption during the last years (Callejo et al., 2020; Li et al., 2017; Radonjić et al., 2020). Their organoleptic characteristics preserve the flavour of the raw materials, offering a beverage with a sweet smell from the malt and a fresh taste from the hops. On the other hand, *Ale* beers, also called high-

fermented or top-fermented, owe their name to the fact that their fermentation takes place at higher temperatures than *lagers* (temperatures between 15 and 24°C, compared to temperatures of 6 – 15ºC aforementioned). This type of beer is also called "top-fermented" because the yeast most commonly used for its production (*Saccharomyces cerevisiae*), does not precipitate, but instead (due to its hydrophobicity) rise up to the surface of the wort with the carbon dioxide gas bubbles, generating, in addition, a surface layer of foam. The taste of these beers is fruitier than the *lagers*, due to the presence of more esters and other secondary flavour and aroma compounds. However, an excessive amount of these compounds would generate a solvent smell, so their concentration must be controlled. Furthermore, there are synergies between the different esters, so, although the detection threshold of each ester is low, they are all important in the final flavor (Callejo et al., 2020; Li et al., 2017; Radonjić et al., 2020; Tang & Li, 2017).

Spain is the third largest beer producer at European level (2020 and 2021 data), and the eighth country at European level in number of breweries (2020 data). With respect to consumption, Spain ranked third within Europe in 2020 and 2021 (Cerveceros de España y Ministerio de Agricultura Pesca y Alimentación, 2021; Statista, 2021; The Brewers of Europe, 2021). Due to this great socio-economic importance of beer in Spain, there are a large number of companies dedicated to its production. In addition, this importance has encouraged the creation of many small craft breweries.

The creation of these craft breweries brings with it a problem regarding the definition of "craft beer", since the conditions for being considered as such vary from one country to another. In Spain, the Official State Gazette defines craft beers as "those beers whose brewing process follows the quality standard, and are produced entirely in the same facility, under the direction of a master brewer or craftsman with demonstrable experience, and giving priority to the human factor over the mechanical, thus obtaining an individualized final result, not produced in large series and following the applicable legislation on craftsmanship" (Boletín Oficial del Estado, 2022). As this definition does not establish the total production that companies can obtain nor the independence of large brewing groups (as does the

legislation of other countries), in 2014 the AECAI (Spanish Association of Independent Craft Brewers) was founded. The objective of this association is to define and regulate the craft beer sector, as well as to promote the quality, culture and variety of craft beer, defending the common interests of the sector (AECAI, 2021).

On another note, and with respect to one of the techniques that has been used for the analysis of samples of beer, fluorescence spectroscopy is a non-destructive instrumental technique, with a high sensitivity and selectivity, that provides a lot of information about molecular structure. For these reasons, it has been widely employed for foodstuff characterization. In addition, this technique is fast and easy-to-use, and can be easily implemented in industry (Airado-Rodríguez et al., 2011; Azcarate et al., 2017; Callejón et al., 2012; Carbonaro et al., 2019; Ríos-Reina et al., 2019).

Fluorescence spectroscopy can be used in different ways (i.e.: by obtaining spectra or by using it as a detector for other analytical techniques), but one of the most useful ways is the obtention of excitation-emission matrices (EMMs), as they allow a large amount of information to be gathered from the system under study, which can be then analysed using chemometric logarithms. Parallel Factor Analysis (PARAFAC) is the most commonly used second-order logarithm for the decomposition of EMMs, and has been used for several types of food matrices (Airado-Rodríguez et al., 2011; Azcarate et al., 2017; Callejón et al., 2012).

The fluorescence of beer has been studied previously and it has been found that it is mainly due to the presence of iso-α-acids (compounds from hops which are responsible for the typical bitterness of beer), different vitamins (mainly group B), aromatic amino acids (in particular tyrosine, tryptophan and phenylalanine) and phenolic compounds (Dramićanin et al., 2019; Fang et al., 2021; Pale et al., 2021; Sikorska et al., 2008).

Various authors have used beer fluorescence together with chemometric tools for the characterization and/or classification of different beers. Thus, Sikorska et al. (2004) employed total luminescence and scanning synchronous fluorescence spectra to characterize and differentiate 8 different

beer samples. On the other hand, the use of this same method together with the application of Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA) and kNN (Nearest Neighbour Method) allowed the clustering of different beer samples based on different storage conditions (Sikorska et al., 2006). Finally, this same group also achieved the simultaneous analysis of riboflavin and aromatic amino acids in beer by means of front-face fluorescence coupled to different PLS (Partial Least Squares) algorithms (Sikorska et al., 2009). Besides that, Gordon et al. (2017) studied different samples of Australian beer by synchronous fluorescence spectroscopy and EEMs, achieving the classification of the samples based on the brand; while Braga et al. (2021) compared the possible classification of malted and unmalted beer samples using different spectroscopic techniques (i.e.: infrared, UV-VIS and fluorescence), differentiating both types of beer by means of fluorescence spectroscopy associated to Self-Organizing Maps (SOM). Fang et al. (2021), used EEMs and different chemometric algorithms to classify different brands of Chinese *lagers* beers, using three- and four-way data, comparing the results obtained employing each data set. Finally, Pale et al. (2021) used EEMs and scanning synchronous fluorescence together with PARAFAC, PCA and LDA to differentiate a set of 49 samples, and monitor the effects of their storage at different temperatures and with different exposures to sunlight.

However, to the best of our knowledge, no one has studied the front-face EEMs of Spanish beers, and, neither beers from different origins and with different fermentation styles have been studied simultaneously. For this reason, the aim of this research has been to analyse and compare the EEMs obtained from Spanish beers belonging to different classes (craft and commercial) and with different types of fermentation (*ale* and *lager*), in order to be able to describe their fluorescent components, as well as classify them into these categories based on their fluorescent profile.

2. Materials and Methods

2.1 Beer samples

Beer samples employed in this study were purchased from different local shops and stored at room temperature, protected from direct light, until their analysis. A total of 45 samples were analysed, of which 23 were craft beers and 22, commercial beers. On the other hand, 22 samples were *ale*-fermented, while the other 23 samples were *lager*-type. Table 1 lists the samples used, together with their respective information. Before the analysis, the bottles/cans were opened and approximately 10 mL of beer were placed in a beaker. Degassing of the samples was carried out by applying ultrasounds for 5 minutes.

2.2 Instrumentation and software

An Ultrasons bath (reference 3000683) purchased from J. P. Selecta (Spain) was used for degassing beer samples before the EEMs obtention.

EEMs were obtained in a Cary Eclipse Varian spectrofluorometer (Agilent Technologies Inc., USA) connected to a PC by means of a GPIB488 card. The instrument was equipped with two Czerny-Turner monochromators, a constant xenon light source and a photomultiplier tube as detector. Equipment control and data acquisition were carried out employing Cary Eclipse's own software.

Data was processed employing MatLab R2016B (The MathWorks Inc., USA). The correction of the Rayleigh dispersion was made employing the EEM_corr routine (Chiappini et al., 2019), freely downloaded from https://fbcb.web1.unl.edu.ar/laboratorios/ladaq/download/. PARAFAC was carried out using the graphical interface MVC2 (Olivieri et al., 2009), available at www.iquir-conicet.gov.ar/descargas/mvc2.rar. Statistical analysis of the PARAFAC scores obtained was carried out using XLSTAT software (Addinsoft, France).

2.3 Excitation-emission matrices obtention

The EEMs were obtained from the degassed undiluted beer samples. Measurements were made in a 1.0 cm quartz cell, at room temperature. The excitation wavelength ranged between 250 and 500 nm, with steps of 5 nm; while the emission spectra was registered every 2 nm, between 300 and 600 nm.

The excitation and emission slits were set at 5 nm, and the voltage of the lamp was stablished at 600 V. The scan rate employed was 1200 nm·min^{-1}, so each EEM took less than 14 minutes to be completely registered.

3. Results and discussion

3.1 Optimization of the measurement's conditions and data treatment

Before the measurement of the beer samples, some experiments were made to optimize the instrumental conditions, employing a commercial, *lager* beer. First, an EEM was recorded over a wide range of excitation (200 – 500 nm, each 5 nm) and emission wavelengths (250 – 700 nm, each 1 nm) to find out where the fluorescence of the corresponding beer fluorophores appeared. Slits, acquisition speed and voltage were left at their default values.

Once the matrix was obtained, the area with relevant information was checked and the corresponding excitation (250 – 500 nm, each 5 nm) and emission (300 – 600 nm; each 2 nm) wavelength ranges were chosen. The slits and voltage were left at their default values (5 nm for both excitation and emission slits, and 600 V, respectively). The acquisition speed was set to 1200 nm·min^{-1}.

After obtaining the EEMs, and although Rayleigh scattering did not directly affect any of the areas of interest in the matrices, the EEM_corr routine was applied to eliminate its presence in order to perform a better analysis of the EEMs. Correction of the first level Rayleigh scattering (Ry1) was done by removing 10 nm, while removal of the second (Ry2) required a width of 13 nm. The interpolation option was used to try to alter the matrix as little as possible.

3.2 Beer samples fluorescence

Under the optimised conditions, the excitation-emission matrices of the 45 beer samples were recorded without any pre-treatment. Figure 1 shows as examples the EEMs obtained from two types of beer (A: craft beer with *ale* fermentation; B: commercial beer with *lager* fermentation). As can be seen,

their shape is very similar, although the intensity of each zone depends on the type of beer analysed. In any case, there are two distinct zones: a very intense zone between 300 - 600 nm of emission, with a maximum excitation between 400 - 450 nm; and a second, much less intense zone in the range of 350 - 400 nm of emission, with a maximum excitation of approximately 275 nm. This shape is similar to those obtained by other authors in previous works (Fang et al., 2021).

After visual analysis of the 45 matrices, it was found that the fluorescence intensity of samples 5, 18 and 40 was very low (Figure 2). As can be seen in the Figure, the fluorescence intensity of sample 5 is 25% of the intensity of the EEMs shown in Figure 1, while the intensity of samples 18 and 40 barely exceed 10% of the fluorescence intensity of the other samples. This great difference with the rest of the samples influenced the chemometric and statistical analyses, making it difficult to differentiate the rest of the samples between them. Therefore, they were removed and the chemometric and statistical analysis performed was applied to a set of 42 samples.

The low fluorescence intensity of these samples may be due to their specific characteristics. Sample 5 was a craft beer with *lager*-type fermentation, which, at the end of fermentation, was mixed with Pedro Ximénez wine, thus altering its composition and, therefore, its fluorescent fingerprint. Sample 18, on the other hand, was a commercial *ale*-type beer, but of a special type (*stout*), which generates darker and more complex beers. Finally, sample 40 was a craft *ale*-beer that used acorns together with barley for the preparation of the malt, which explains the difference in the fluorescent component profile compared to the other samples.

3.3 PARAFAC analysis of the samples

PARAFAC was performed on the matrices to obtain the main components causing the fluorescence of the beer samples. Taking into account that neither the concentration of the possible fluorophores nor the fluorescence spectra can take negative values, the non-negativity constraint was applied in all modes.

The selection of the optimal value of components was made bearing in mind the core consistency diagnosis (CORCONDIA), residual analysis (S_{fit}) and the physiognomy of the loadings. The CORCONDIA criterion takes as optimal value the value prior to the number of components that generate a drop in core consistency below 50% (Bro, 1997), while S_{fit} criterion optimize the number of components as the one at which the value of S_{fit} becomes approximately constant (Bro y Kiers, 2003). Taking into account both criterions, and the shape of the loadings, six was selected as the optimal number of components. The contour maps of these components are shown in Figure 3.

Taking into account the excitation-emission maxima, the first component can be associated with the iso-α-acid group. These compounds are derived from hops and are responsible for the bitter taste of beer. The second, third and fourth components possess fluorescent characteristics similar to those of the different forms of vitamin B. In particular, these compounds can be related to riboflavin (vitamin B2), niacin (vitamin B3) and pyridoxine (vitamin B6), respectively. On the other hand, sixth component shares excitation-emission wavelengths with the fluorescent amino acids present in beer (i.e.: tyrosine, tryptophan and phenylalanine, represented by the first of them). Finally, the fifth component is the one with the least clear fluorescent characteristics, but could be related to the different phenolic compounds and other fluorescent forms of B vitamins. These components are in agreement with the literature (Dramićanin et al., 2019; Fang et al., 2021; Sikorska et al., 2008).

3.4 Statistical study of the PARAFAC scores

3.4.1 Principal Component Analysis

Once the different components were obtained, the scores were statistically analysed. First, a PCA was performed, in order to further reduce the information and obtain the most important fluorophores. Two principal components explained 90% of the variance of the data. Within these, the first Principal Component was mainly influenced by the positive contribution of riboflavin (40.9%), phenolic compounds (18.9%) and iso-α-acids (18.0%) concentration. On the other hand, the second Principal

Component was mainly influenced by the positive contribution of the concentration of iso-α-acids (44.8%) and niacin (31.9%). Under these conditions, the resulting score plot can be seen in Figure 4.

Although samples were not fully separated into groups based on their class (craft - commercial) or their fermentation type (*ale* - *lager*), some information can be obtained from the PCA. On the one hand, *ale* samples are mainly clustered in the right half of the plot, i.e., positive contribution of Principal Component 1; while *lager* samples appear in the left half of the plot (lower contribution of Principal Component 1). Therefore, it could be said that *ale* fermented beer samples generate a richer profile in riboflavin, phenolic compounds and iso-α-acids than *lager* ones. Also, *ale* samples are more distributed along the plot, indicating a greater difference between them. The *lager* samples, on the opposite, are slightly more clustered.

On the other hand, it can also be noted that the commercial samples are more similar between them than the craft samples (blue dots are more grouped than orange ones). This can be explained taking into account one of the characteristics of craft beers, which are sold as more special beers with a greater number of nuances than the commercial ones, due to the specific blends created by each brewmaster.

3.4.2 Discriminant analysis

In addition to PCA, a Discriminant Analysis (DA) was performed on the PARAFAC scores. First, two analyses were performed on all data, trying to differentiate the samples based on their class (craft/commercial) and fermentation type (*ale*/*lager*), respectively. In both cases a single factor was necessary for the classification of the samples, consisting of the positive contribution of the concentrations of riboflavin, niacin and phenolic compounds. The main difference between the differentiating factor in both analyses was that, for the differentiation based on class, the concentration of the other components (iso-α-acids, pyridoxine and amino acids) did not affect; whereas in the

differentiation based on fermentation type, these components contributed negatively to the differentiating factor.

As can be seen in Table 2, in both cases a good classification rate was obtained in the estimation samples (76.19 - 83.33%), which was reduced when cross-validation was performed (64.29%). It is important to note that, in the differentiation based on class, the commercial samples were better assigned than the craft samples, where there was more confusion. This is in line with what was seen in the PCA, where commercial samples were found to be more similar to each other than craft ones. On the other hand, in the differentiation based on fermentation type, there was not much difference between the assignment of the two types.

DA were carried out within each of the categories, too. Thus, in the DA of the samples with *lager*-type fermentation, a 100% correct classification was obtained (both of the estimation sample and after cross-validation) of the samples based on their craft or commercial origin. Similarly, in the DA of the samples of craft origin, samples were fully differentiated on the basis of their fermentation type, with a 100% correctness both before and after cross-validation. These results confirm that craft samples are more different from each other than commercial ones, as seen previously in section 3.4.1. Furthermore, greater differences are also observed in the samples with *lager* fermentation, as the *ale* samples could not be differentiated on the basis of their class. This may be due to the fact that the craft yeasts used in *ale* fermentation are very similar to those used in the industry (mainly *Saccharomyces cerevisiae)*, whereas there seems to be more variety in the *lager* yeasts (*Saccharomyces* hybrids).

3.5 Correlation between EEMs and beer bitterness

After PARAFAC, and taking into account that Principal Component 1 seemed to represent the iso-α-acid group, it was tried to correlate these data with the IBU values of the different samples (Table 1).

IBU (International Bitterness Units) are the unit of measurement for the degree of bitterness of a beer, which corresponds to the milligrams of iso-α-acids per litre. Commonly, IBU are measured by

spectrophotometric analysis of the iso-octane acidified extract of the beer, measuring the absorbance at 275 nm (Jaskula et al., 2007). In our case, the IBU values of the samples were obtained directly from the brewing companies and/or from websites specialised in compiling information on this type of products.

Thus, the values of the Principal Component 1 scores were plotted against the IBU values (Figure 5). As can be seen in the Figure, there is not a good correlation between the values, but certain areas can be differentiated. The red circle in the upper area separates craft samples with IPA (Indian Pale Ale) fermentation (average IBU of 70), while the blue circle slightly lower down separates the commercial samples with the same type of fermentation (average IBU of 40.5). As can be seen, the samples with IPA-type fermentation produce much more bitter beers. On the other hand, the average bitterness values of the other beer types are quite similar: the rest of the craft beers with *ale* fermentation (orange circle) have an average IBU of 20, the craft beers with *lager* fermentation (yellow circle) have an average IBU of 22 and the commercial samples with *lager* fermentation (green circle) have an average IBU value of 22.5. Although due to this resemblance these samples appear quite mixed in the graph, a slight grouping of samples of the same style can be observed.

4. Conclusions

EEMs have been obtained from 45 undiluted beer samples (craft and commercial, *ale* and *lager* fermented), without applying any type of pre-treatment, employing front-face fluorescence technique. All the samples analyzed are from Spain and, to the best of our knowledge, this is the first time that the fluorescence of beers with variation in their fermentation type and class has been studied simultaneously.

Due to the low fluorescence intensity of three beers, PARAFAC was performed on the remaining 42 samples. A 6-components model was obtained, which could be related with the different fluorescent components of the beer, based on the excitation and emission maxima obtained.

The PARAFAC scores obtained were statistically analyzed. Firstly, a PCA was carried out, in which, although a total differentiation of the samples was not achieved, it could be concluded that

commercial samples are more similar to each other than craft samples, and that samples with *ale* fermentation tend to be more different from each other than those with *lager* fermentation.

Then, different DA were carried out. Using the total number of samples, differentiation based on fermentation type and type of fermentation generated a 64.29% success rate after cross-validation. On the other hand, within each category, it was found that samples with *lager* fermentation can be fully classified into craft and commercial. Similarly, craft samples can be fully classified on the basis of their fermentation type. These results confirmed the information obtained by PCA.

Finally, taking into account that Principal Component 1 corresponded to iso-α-acids (responsible for bitterness), an attempt was made to correlate its scores with the IBU values of the analyzed samples. Although a good correlation was not achieved, the higher bitterness of the samples with IPA-type fermentation was confirmed, as well as a slight grouping of the samples based on these values.

The study of the samples allowed the description of the fluorophores responsible for the fluorescence in Spanish beers, as well as the qualitative differentiation of the samples based on their class, type of fermentation or degree of bitterness.

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FIGURE CAPTIONS

Figure 1. Contour maps of two example beers. A) Craft beer with ale-type fermentation. B) Commercial beer with lager-type fermentation.

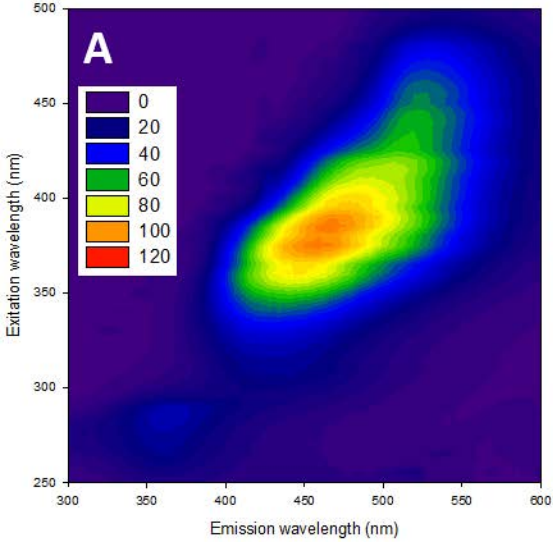
Figure 2. Contour maps of the three samples (5, 18 and 40) removed from the study due to their low fluorescence intensity.

Figure 3. Contours maps of the six components obtained by PARAFAC. Legend is common to all of them (arbitrary units of fluorescence intensity).

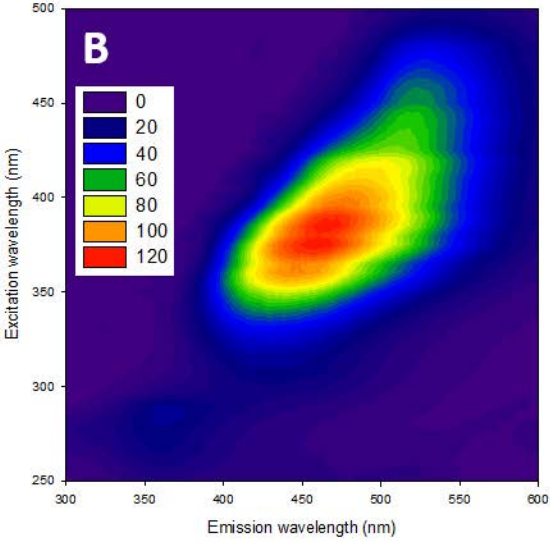
Figure 4. PCA scores plot obtained. Craft samples are marked in orange and commercial samples in blue. Samples with the filled marker are ale fermentation samples, while those with the unfilled marker are lager fermentation samples.

Figure 5. Principal Component 1 versus IBU plot. Craft samples are marked in orange and commercial samples in blue. Samples with the filled marker are ale fermentation samples, while those with the unfilled marker are lager fermentation samples.

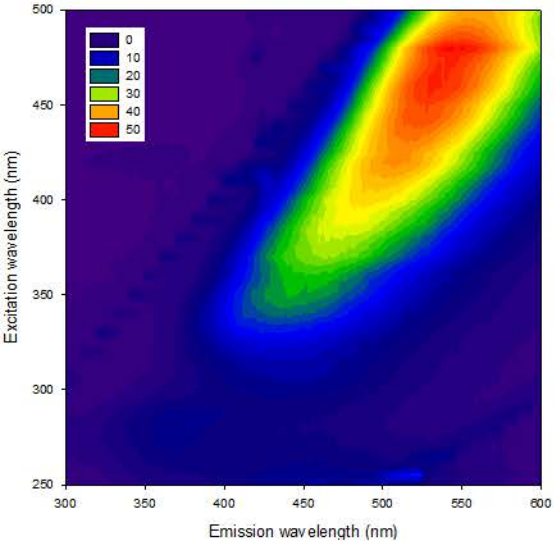
T20


A
0
20
40
60
80
100
120
Exitation wavelength (nm)
Emission wavelength (nm)
500
450
400
350
300
250
300
350
400
450
500
550
600

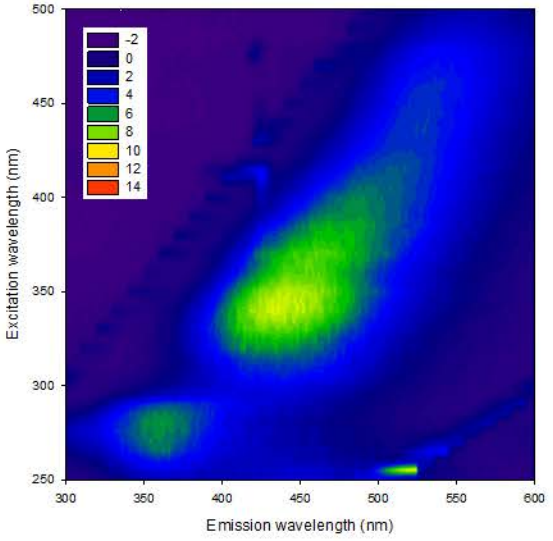
T41


B
0
20
40
60
80
100
120
Excitation wavelength (nm)
Emission wavelength (nm)
500
450
400
350
300
250
300
350
400
450
500
550
600

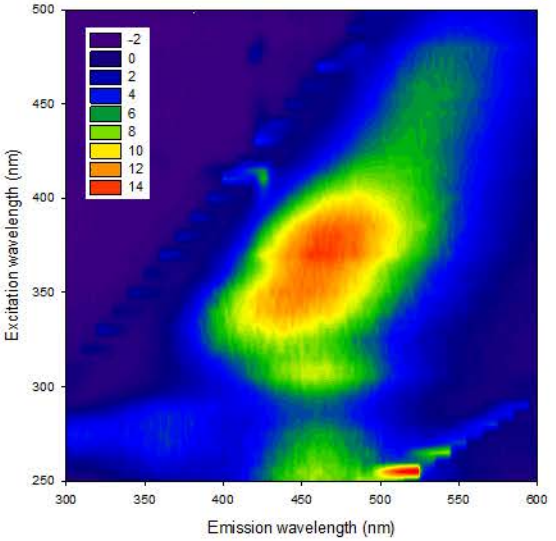
T5

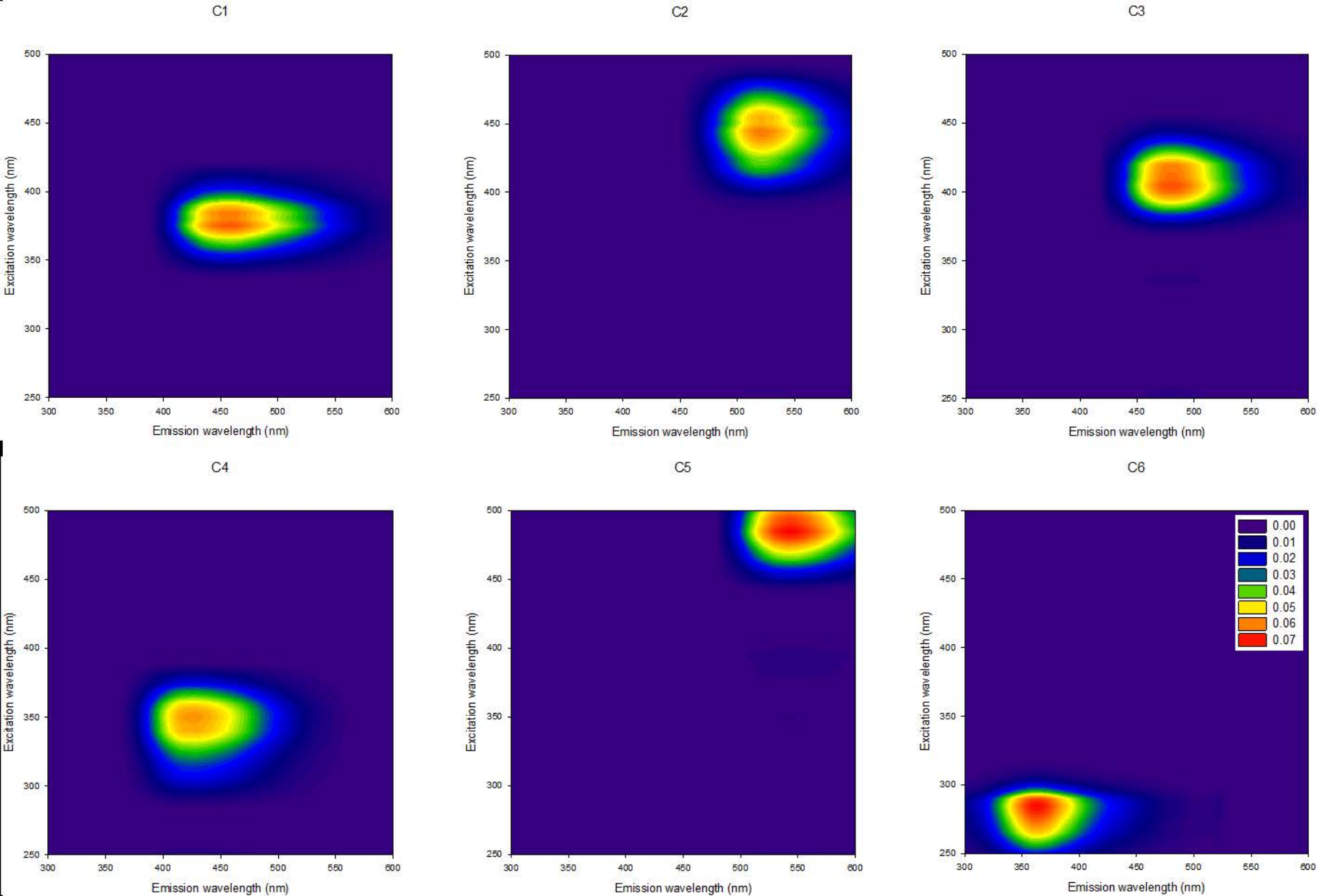

0
10
20
30
40
50
Excitation wavelength (nm)
Emission wavelength (nm)

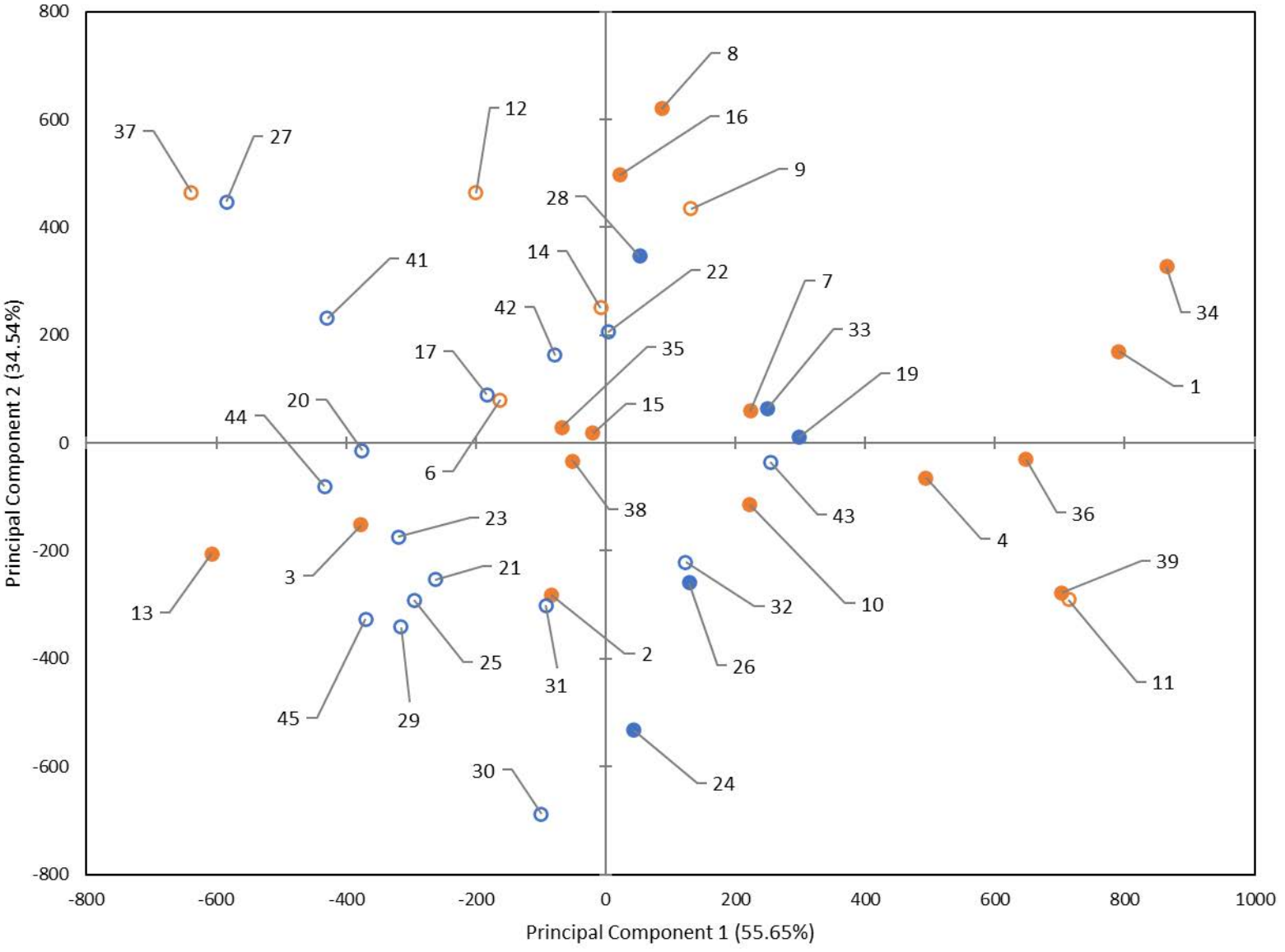
T18


-2
0
2
4
6
8
10
12
14
Excitation wavelength (nm)
Emission wavelength (nm)

T40


-2
0
2
4
6
8
10
12
14
Excitation wavelength (nm)
Emission wavelength (nm)


C1
C2
C3
C4
C5
C6
Excitation wavelength (nm)
Emission wavelength (nm)
250
300
350
400
450
500
550
600
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07


800
600
400
200
0
-200
-400
-600
-800
-800
-600
-400
-200
0
200
400
600
800
1000
Principal Component 2 (34.54%)
Principal Component 1 (55.65%)
8
16
12
37
27
9
28
41
14
22
7
34
42
33
17
35
19
1
20
15
44
6
38
43
4
36
23
3
21
39
13
32
10
25
2
26
31
11
45
29
24
30

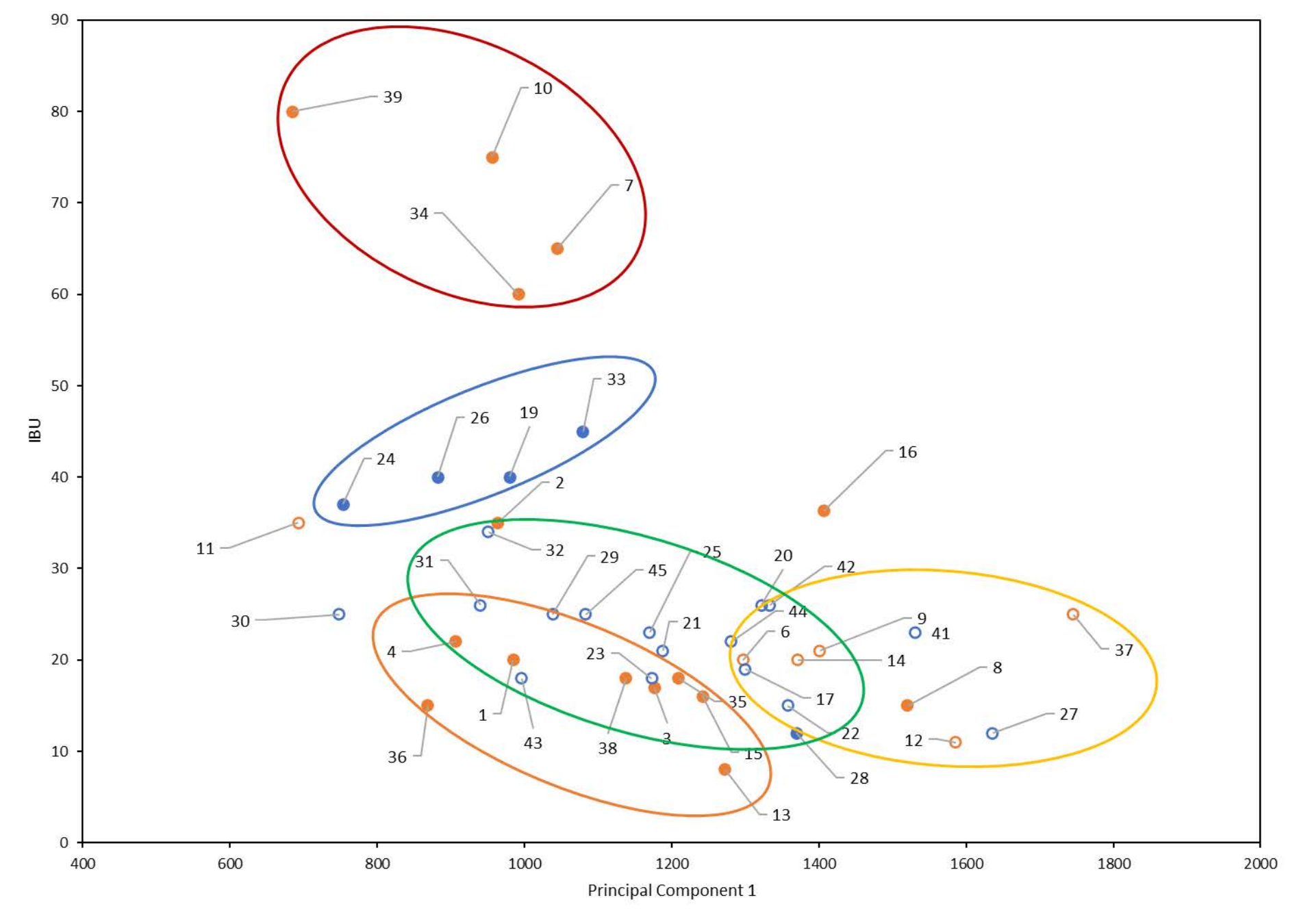

IBU
Principal Component 1
90
80
70
60
50
40
30
20
10
0
400
600
800
1000
1200
1400
1600
1800
2000
39
10
7
34
33
26
19
24
2
16
11
32
31
29
45
25
20
42
30
44
21
9
41
6
4
23
14
37
8
17
1
35
27
43
38
3
22
12
36
15
28
13

Table 1. *Beer samples analysed during the research. IBU (International Bitterness Units) represent the unit of measurement for the degree of bitterness of a beer (mg iso-α-acids per litre).*

	Sample	Name	Fermentation	IBU		Sample	Name	Fermentation	IBU
CRAFT BEERS	1	La Virgen Jamonera	Ale *(amber)*	20	COMMERCIAL BEERS	17	Heineken	Lager *(pilsen)*	19
	2	La Virgen 360	Ale *(pale)*	35		18	Guinness Draught	Ale *(stout)*	45
	3	Califa Rubia	Ale *(blonde)*	17		19	Cruzcampo Andalusian IPA	Ale *(IPA, oat)*	40
	4	Califa Morena	Ale *(amber)*	22		20	Cruzcampo Especial	Lager	26
	5	Dawat Pedro Ximenez	Lager *(sweet)*	17		21	Amstel Original	Lager	21
	6	Dawat Dry Lager	Lager	20		22	El Águila sin filtrar	Lager *(corn)*	15
	7	Dawat IPA Citrix	Ale *(IPA)*	65		23	San Miguel Especial	Lager *(pale)*	18
	8	Dawat 2 Sunset Ale	Ale	15		24	San Miguel Yakima Valley	IPA *(rye)*	37
	9	Pergara	Lager *(blonde)*	21		25	Alhambra Lager Singular	Lager *(pale)*	23
	10	Albero IPA	Ale *(IPA)*	75		26	Mahou IPA	Ale *(IPA, oat)*	40
	11	Albero Doble Malta	Lager *(pilsen)*	35		27	Budweiser	Lager	12
	12	La Sagra Bohemia	Lager	11		28	Franziskaner Weissbier	Ale *(wheat)*	12
	13	La Sagra Radler	Ale	8		29	Estrella Galicia Especial	Lager *(pilsen)*	25
	14	Blanca y Verde Coraje	Lager *(pilsen)*	20		30	1906 Reserva Especial	Lager *(pilsen)*	25
	15	Guadalquibeer Sevilla	Ale *(cream)*	16		31	Turia	Lager *(Märzen)*	26

	16	Río Azul Flora	Ale	36.3		32	Voll Damm	Lager *(Märzen)*	34
	34	Arriaca IPA	Ale *(IPA)*	60		33	Ambar IPA	Ale *(IPA)*	45
	35	Ballut	Ale *(blonde)*	18		41	Clásica El Corte Inglés	Lager	23
	36	Azarías	Ale *(pale)*	15		42	Daura	Lager	26
	37	Rabiosa Pilsen	Lager *(pilsen)*	25		43	Daura Märzen	Lager *(Märzen)*	18
	38	Tyris Original	Ale *(blonde)*	18		44	Cruz del Sur	Lager	22
	39	Sevebrau	Ale *(IPA)*	80		45	Victoria Málaga	Lager *(pilsen, rice)*	25
	40	Cerex	Ale	28					

Table 2. *Confusion matrices obtained for the estimation sample and after cross-validation in the DA performed on the scores obtained by PARAFAC.*

CLASS DIFFERENCIATION	**ESTIMATION SAMPLE**				
		Craft	***Commercial***	***Total***	***%Correct***
	Craft	12	9	21	57.14
	Commercial	1	20	21	95.24
	Total	13	29	42	76.19
	CROSS-VALIDATION				
		Craft	***Commercial***	***Total***	***%Correct***
	Craft	12	9	21	57.14
	Commercial	6	15	21	71.43
	Total	18	24	42	64.29
FERMENTATION TYPE DIFFERENCIATION	**ESTIMATION SAMPLE**				
		Ale	***Lager***	***Total***	***%Correct***
	Ale	17	3	20	85.00
	Lager	4	18	22	81.82
	Total	21	21	42	83.33
	CROSS-VALIDATION				
		Ale	***Lager***	***Total***	***%Correct***
	Ale	13	7	20	65.00
	Lager	8	14	22	63.64
	Total	21	21	42	64.29