

A SNAPSHOT MAPPING OF THE DANISH BEER MARKET



DAVIDE GIACALONE, E-MAIL: DGI@LIFE.KU.DK; HELENE CHRISTINE REINBACH, E-MAIL: HCRE@LIFE.KU.DK AND MICHAEL BOM FRØST, E-MAIL: MBF@LIFE.KU.DK. DEPARTMENT OF FOOD SCIENCE, FACULTY OF LIFE SCIENCES, UNIVERSITY OF COPENHAGEN

This article, written by scientists and researchers at KU LIFE, the new partner of the Scandinavian School of Brewing, takes a fascinating, inspiring and innovative look at the myriad of Danish beers, and, through multivariate statistics, successfully finds very interesting relations between them.

WANT TO KNOW MORE ABOUT MULTIVARIATE STATISTICS?

The research group of Quality and Technology at KU LIFE is our leading unit in developing and applying multivariate analytical models to solve food-related problems. If you want to know more about the PCA and other multivariate methods, we encourage you to have a look at the links below, where you can also find a series of video tutorials that show in a graphical and intuitive way the mathematical procedure for extracting principal components.

Q&T group homepage:

www.models.life.ku.dk/

Tutorials:

www.youtube.com/user/QualityAndTechnology

‘The micro-brewing industry ... has traditionally sought to distinguish itself from the macro-domestic industry by typically making ales more than lager and inter alia by including substantial levels of hop bitterness, by the adventurous use of specialty malts and roasted materials, by all-malt brewing and high gravity alcoholic beers ...’

This opening quote comes from the inspiring article recently published by Prof. Lewis in a very recent issue of *Scandinavian Brewers' Review*, where he brings forth the vivid image of an American beer industry characterised by a ‘dash to the extreme’ where micro breweries specialise in brewing increasingly heavy ales, much to counter the opposite tendency by large breweries to brew mostly light lagers.

We asked ourselves whether the Danish beer industry reflected that description, and we resolved to answer this question by making a little statistical experiment: first, we collected information on about 300 Danish beers from the majority of Danish breweries, using self-reported information on each beer

provided by the brewery. For each beer, we used the following information: 1) producer's size and 2) producer's emphasis on local identity, 3) type of fermentation, 4) bitterness (IBU) by beer style, 5) alcohol by volume, 6) type(s) of malt, 7) type(s) of hops, and 8) usage of special flavouring ingredients.

Statistics requires numbers, so we had to transform all the information about the characteristics of beers into data suitable for statistical analysis. Table 1, below, gives an account of how we actually did it.

What resulted after this was a data matrix with exactly 297 beers. They represent beers from nearly all main breweries in Denmark and they were only chosen if sufficient information for classification were provided either on the company's website or on the beer label. We also used ratebeer.com with regards to beer style in case this information was not listed by the producer. Because of the way the data were gathered,

some breweries are more represented than others, and so are certain types of beers. Nevertheless, we think it represents what you can find on the Danish beer market. Table 2, overleaf, lists all the beers we used for the analysis and their corresponding number in the plots.

Figure 1, on page 15, shows the frequency of different beer styles (according to average IBU) in our sample database.

METHODS, AKA MULTIVARIATE STATISTICS IN A NUTSHELL

Beers can vary widely in many things: alcohol content, colour, style, producer, etc. When you want to compare few beers, you can just collect all your info in a simple table and look at them side by side. A table with hundreds of beers, however, would be quite problematic to look at and, most importantly, it would be almost impossible to get an overview. That's where multivariate statistics can be of great assistance. →

TABLE 1

VARIABLE	Data type	Explanation
Brewery Size	Semi-continuous	(# of employees – Source: Danmarks Statistik)
Local Identity	Category	'Yes' if active use of their origin in their communication and/or presence of beer pub/restaurant
Fermentation	Category	Bottom, Top, or both
Bitterness – IBU	Continuous	Average beer style IBU according to the Brewers Association 2010 Beer Style Guide, or listed by the producer.
Malt Type (Malt colour, Lovibond)	Continuous	For obvious reasons, exact fractions of individual malt types are rarely listed by producer. As an approximation, we summed degrees Lovibond for individual listed malts for each beer.
Alcohol By Volume – ABV	Continuous	No explanation needed
Hops	Category	Aroma or Bitter. Here, we adopted a restrictive definition of 'aroma hops', including in the category only those varieties with an alpha acid percentage up to 6% (such as saaz, styrian golding, crystal, etc.), whereas intermediate hops variety (e.g. centennial) are still listed as bitter hops.
Special Flavouring Ingredients	Category	Increasingly, other ingredients than malts, hops, yeast and water are used in beer. In some of the beers, up to five other ingredients are used. Further elaboration on this topic is given later.

TABLE 2

BREWERY	NUMBER IN PLOTS AND CORRESPONDING BEER
Thisted	(1) Limfjords Porter, (2) Triple Pilsner, (3) Thy Ale, (4) Porse Bock, (5) Brown Ale, (6) Thy Bock, (7) Thy Porter
Grauballe	(8) Enebær Stout, (9) Mørk Mosebryg, (10) River Beer, (11) Honey Gold, (12) Orange Blossom, (13) IPA Nørrebryg;
Thor	(14) Thor Pilsner, (15) Thor Classic, (16) Blå Thor;
Tuborg	(17) Tuborg Lime, (18) Grøn Tuborg, (19) Guld Tuborg, (20) Tuborg Classic, (21) Tuborg Rød, (22) Tuborg Julebryg, (23) Fine Festival, (24) Tuborg Super Light;
Carlsberg	(25) Abbey Ale, (26) Semper Ardens Christmas Ale, (27) Carls Hvede, (28) Carlsberg LITE, (29) Carls Lager, (30) Carls Porter, (31) Carls Ale, (32) Carls Special, (33) Carlsberg 47, (34) Carlsberg Elephant, (35) Carlsberg Light Pilsner, (36) Carlsberg Pilsner, (37) Semper Ardens Summer Dubbel, (38) Semper Ardens Blonde Bier, (39) Semper Ardens Keller Pils;
Albani	(40) Odense Classic, (41) Odense Pilsner, (42) Odense Rød Classic;
Refsvindinge	(43) Pilsner, (44) Prima Landøl, (45) Ale nr. 16, (46) Mors Stout, (47) Enkens Anden Lys, (48) Skibsøl, (49) HP Bock, (50) Den Sorte Enke, (51) Humlepilsner, (52) Solbær Ale, (53) Bedstemors Stout, (54) Ævleøl, (55) Hvid Guld;
Harboe	(56) Harboe Pilsner, (57) Harboe Pilsner Light, (58) Harboe Classic;
Skands	(59) Humlefryd, (60) New Stout, (61) Nicks Ale, (62) Porter, (63) Elmgade IPA, (64) Brüssel Wit, (65) Økofryd;
Nørrebro	(66) Bombay Pale Ale, (67) Ceske Böhmer, (68) King's County Brown Ale, (69) Furesø Framboise, (70) La Granja Stout, (71) Little Korkny Ale, (72) New York Lager, (73) Nørrebros Julebryg, (74) Pacific Summer Ale, (75) Påske Bock, (76) Ravnsborg Rød, (77) Skårugaards Porter, (78) Sorterdam Sauvage, (79) St Jørgen Stout, (80) Fanø Lyng, (81) Currant Practise, (82) NoPale NoAle, (83) Brugge Blonde, (84) Balders Blid, (85) Peblinge Pêche, (86) Montceau Ginger, (87) Oak Wise, (88) Tärnö Imperial Stout, (89) Rood Wit 32°, (90) Stuykman Wit;
Svaneke	(91) Staerk Preben, (92) Classic, (93) Stout, (94) Gul Påske, (95) Sejler Øl, (96) Choko Stout, (97) Weisse, (98) Gammeldags Pilsner, (99) Julebryg, (100) Rød Jul, (101) Den Eneste Ene, (102) Porter, (103) Aurum, (104) Salmecyke, (105) Pivo;
Indslev	(106) Sort Hvede, (107) Hvede Bock, (108) Julehvede, (109) Påskehvede, (110) Hvede I.P.A.;
Jacobsen	(111) Saaz Blonde, (112) Sommer Wit, (113) Dark Lager, (114) Golden Naked Christmas Ale, (115) Brown Ale, (116) Extra Pilsner, (117) Forårsbryg, (118) Bramley Wit;
Mikkeller	(119) Big Worse Barrel Aged Edition, (120) Big Worse, (121) Beer Geek Breakfast Bourbon Barrel Aged Edition, (122) Single Hop Chinook IPA, (123) Single Hop Centennial IPA, (124) East Kent Golding Single Hop IPA, (125) Single Hop Amarillo IPA, (126) Single Hop Tomahawk IPA, (127) Beer Geek Breakfast, (128) Drink in the Sun, (129) Nugget Single Hop IPA, (130) Tjekket Pilsner, (131) Drikkeriget DIPA, (132) USAlive!, (133) Not Just Another Wit, (134) From To, (135) It's Alive!, (136) All Others Pale, (137) Green Gold;
Royal Unibrew	(138) Royal Classic, (139) Royal Pilsner, (140) Royal Stout, (141) Royal Export;
Herslev	(142) Pale Ale;
Ceres	(143) Ceres 2 Pilsner;
BrewPub	(144) Amarillo Red Ale, (145) Cole Porter, (146) PJ Harvey, (147) Ralf Hutter, (148) Schlager, (149) Smokin', (150) Stevie Ray, (151) James Brown Ale;
Amager Bryghus	(152) Bryggens Blonde, (153) Christianshavn Pale Ale, (154) Sundby Stout, (155) Dragørs Tripel, (156) IPA, (157) Amager Fælled, (158) Ryeking, (159) Dicentra Cucullaira, (160) Double Black IPA, (161) Galanthus Nivalis, (162) Hr. Frederiksen, (163) Rugporter, (164) Red Nitro, (165) Nitro, (166) Black Nitro, (167) Imperial Stout, (168) Høstbryg, (169) Summer Fusion, (170) Imperial Brown Ale, (171) Honning Porter;
Vejle Bryghus	(172) Vejle Forårsbryg, (173) Vejle Porter, (174) Vejle Bryghus Pilsner, (175) Vejle Belgian Strong Ale, (176) Vejle GrassHopper IPA, (177) Vejle Bryghus Klassik, (178) Vejle Bryghus Silent Night, (179) Vejle Bryghus Golden Ale, (180) Normaler Weisse, (181) Vejle Oktoberfest, (182) Vejle Brown Ale, (183) Vejle Holy Night;
Skovlyst	(184) Skovmærkebryg, (185) JuleBryg, (186) BirkeBryg, (187) Havre Stout, (188) India Pale Ale, (189) AhornBryg, (190) EgeBryg, (191) Bøgebryg;
Rise	(192) Premium Jule Ale, (193) Grolle Pilsner, (194) Marstal's IPA, (195) Ærøskøbing's Dark Ale, (196) Søby Stout, (197) No. 5 Valnød Hertug Hans, (198) Premium Dark Ale, (199) Premium India Pale Ale;
Midtøns Bryghus	(200) Midtøns Wheat, (201) Midtøns Sommer Wit, (202) Midtøns Ale, (203) Gunners Ale, (204) India Pale Ale, (205) Double India Pale Ale, (206) Chili Tripel, (207) Stout, (208) Imperial Stout, (209) Jule Ale, (210) Jule Stout;
Ølfabrikken	(211) Ølfabrikken Pale Ale, (212) Ølfabrikken Pilsner;
Raasted Bryghus	(213) Columbus Ale, (214) Black Gold Coffee Stout, (215) Raasted Rug IPA, (216) Raasted Cascade IPA, (217) Raasted Imperial Stout, (218) Raasted Trippel, (219) Raasted Dunkel, (220) Raasted Pilsner, (221) Raasted Juleøl;
DagmarBryggeriet	(222) Bengerd's Forår, (223) Byens Øl, (224) Broder Gregers IPA, (225) Skt. Bendt Porter;
Sogaards Bryghus	(226) Jomfruhumle, (227) Munkens Ale, (228) Brown Ale, (229) US Pale Ale, (230) Utzon Blond, (231) Utzon Dark;
Beer Here	(232) Jule IPA, (233) Påske, (234) Fat Cat Red Ale, (235) Tia Loca, (236) Dark Hops, (237) Mørke – Pumpernickel Porter, (238) Black Cat;
Aarhus Bryghus	(239) Aarhus Extra Pilsner, (240) Stout 2010, (241) Klosterbryg, (242) Sommer Hvede, (243) Fregatten Jylland, (244) Julebryg, (245) Classic Pale Ale;
Hornbeer	(246) Brown Ale, (247) Kiss the Frog, (248) Røgel, (249) Blonde, (250) IPA, (251) Vårøl, (252) Hornbock, (253) Imperial IPA, (254) Oak Aged Cranberry Bastard, (255) Russian Imperial Stout, (256) Funky Monk, (257) Caribbean Rum Stout, (258) Winter Porter, (259) Helge;
Bryggeriet Vestfyen	(260) Schwarzbier, (261) Pale Ale, (262) Pilsner, (263) Light Pilsner, (264) Willemoes Strong Lager, (265) Willemoes Stout, (266) Willem. Porter, (267) Willem. Påske Ale, (268) Willemoes Julebryg, (269) Willemoes 200 år, (270) Willemoes Classic;
Brøckhouse	(271) Classic Lager, (272) Premium Pilsner, (273) Premium Julebryg;
Ørbæk Bryggeri	(274) Fynsk Forår, (275) Blueberry Hill Ale;
Hancock	(276) Saaz Brew, (277) Høker Bajer, (278) Black Lager, (279) Old Gambrinus Light, (280) Old Gambrinus Dark;
Fur Bryghus	(281) Fur Frokost, (282) Fur Ale, (283) Fur Bock, (284) Fur Hvede, (285) Fur Lager, (286) Fur Porter, (287) Fur Renæssance, (288) Fur Steam Beer, (290) Fur Julebryg, (290) Fur Påskebryg, (291) Fur Barley Wine;
Faxe	(292) Faxe Premium, (293) Faxe 10%, (294) Faxe Royal Strong, (295) Faxe Amber, (296) Faxe Royal Export, (297) Faxe Festbock.

Generally speaking, multivariate statistics comprises a series of tools designed to deal with large data set containing many different variables. In this article, we used one of the simplest multivariate methods: Principal Component Analysis (PCA), which can be looked at as a transformation in which many original variables are transformed into a few important dimensions. The usefulness of PCA (or any multivariate method) is that it allows the observer to look at many different variables simultaneously in a graphical, easy-to-interpret way. In practice, what we did was transforming the variables in table 1 into fewer latent or underlying variables called principal components and these are the horizontal and the vertical axis in the following plots. Thus, we were able to map approximately 300 Danish beers in a few dimensions, according to the criteria mentioned before (brewery size, ABV, malt type, etc.), and ordered after the criteria's ability to explain differences between the beers.

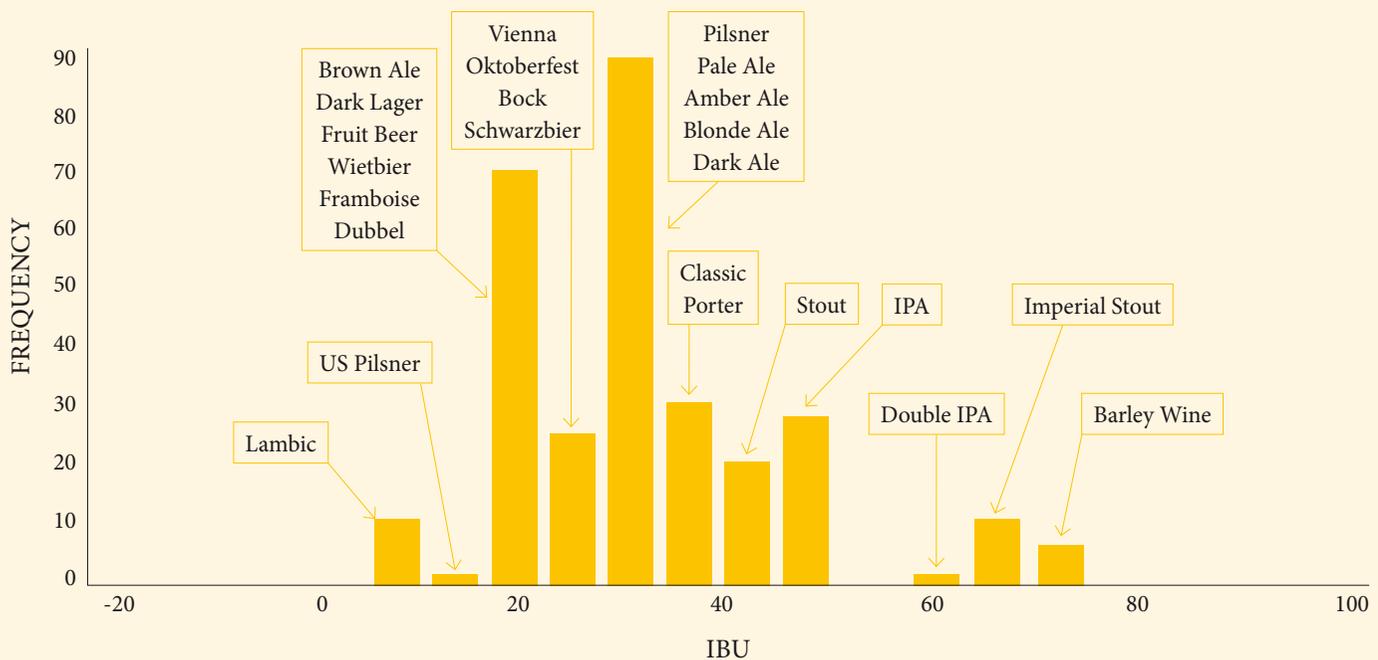
The results of our PCA model – represented graphically in the following figures – are organised into 'score plots' and 'loading plots.' Every point in the score plot represents a beer in our database. The loading plot represents how the original variables (Table 1) are correlated to each other. In other words, the score plots show which beers are most similar or different from each other and the loading plots explain *why*

they have a certain position on the score plot. The results, in short, show graphically how our Danish beers are different between themselves and why.

MAPPING OUT DANISH BEERS

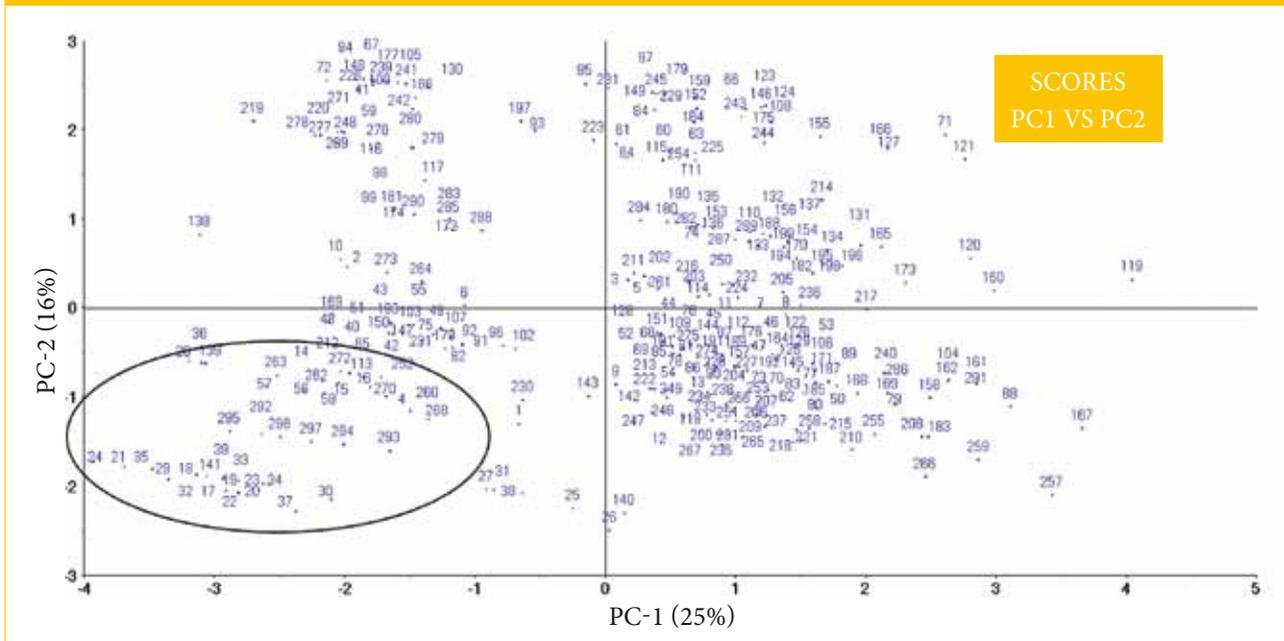
The horizontal and vertical axes are our principal components (underlying dimensions of difference instead of our original variables). Looking only at the score plot (the beers), we see can see that there is a cluster of beers in the lower left quadrant which contains many beers from the large breweries (Carlsberg – including Semper Ardens – and Royal Unibrew), whereas other breweries are distributed in all quadrants. Why is it so? The answer comes from looking at the loading plots, which shows the position of the variables. On the left quadrants, we find among others the variables Bottom fermentation and Brewery size. In the right side of the loading plot, we find the variables Top fermentation, IBU, Malt colour. This means that beers located in that direction in the score plot are top fermented beers, high in alcohol and brewed on darker malt types. The loading plot shows that the size of a brewery is negatively correlated to the top fermentation, which mean that Professor Lewis's argument is substantially confirmed by our statistical analysis of the Danish beer market: large breweries →

FIGURE 1



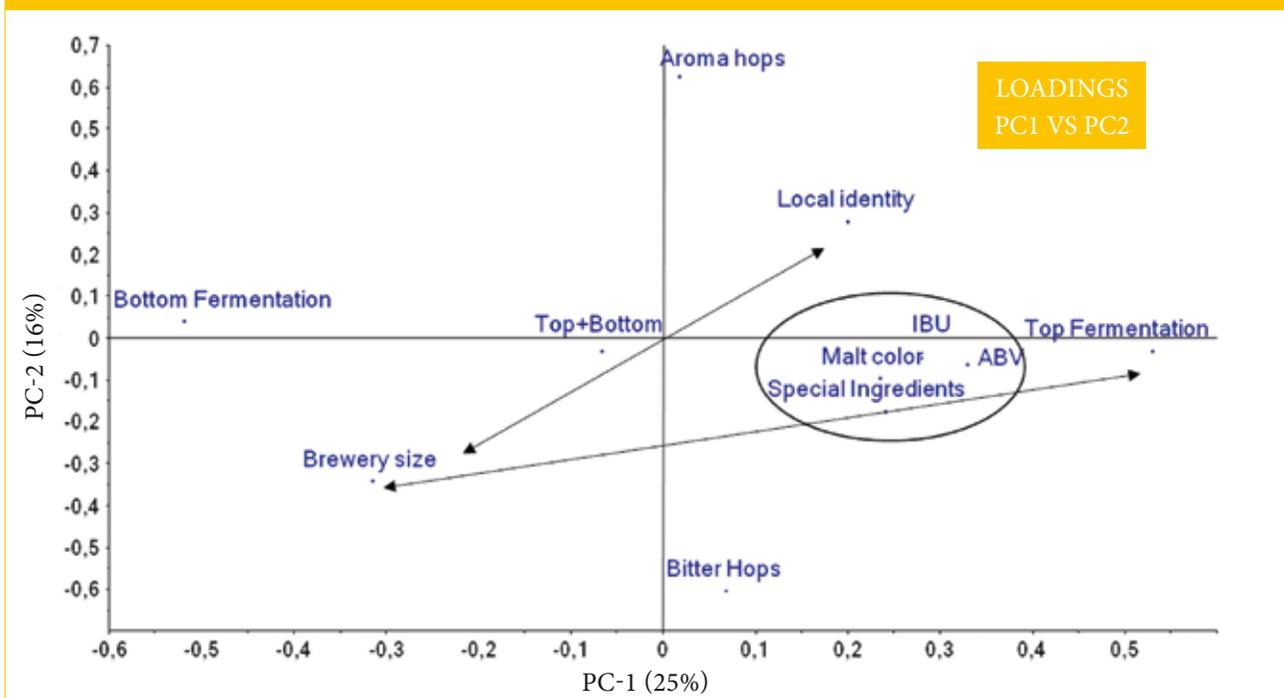
Histogram plot showing the distribution of our samples by beer style (measured by IBU). The beers are almost normally distributed, with a peak between 28 and 35 IBU (mostly Pilsners and light ales) and between 18-22 (in correspondence to e.g. wheat beers and brown ales) and a presence of high IBU beers (IPA, Imperial Stout, etc.). Interestingly, the highest peaks correspond to the beer categories that Michael Lewis indicates as the two consumer favourites in the US.

FIGURE 2A



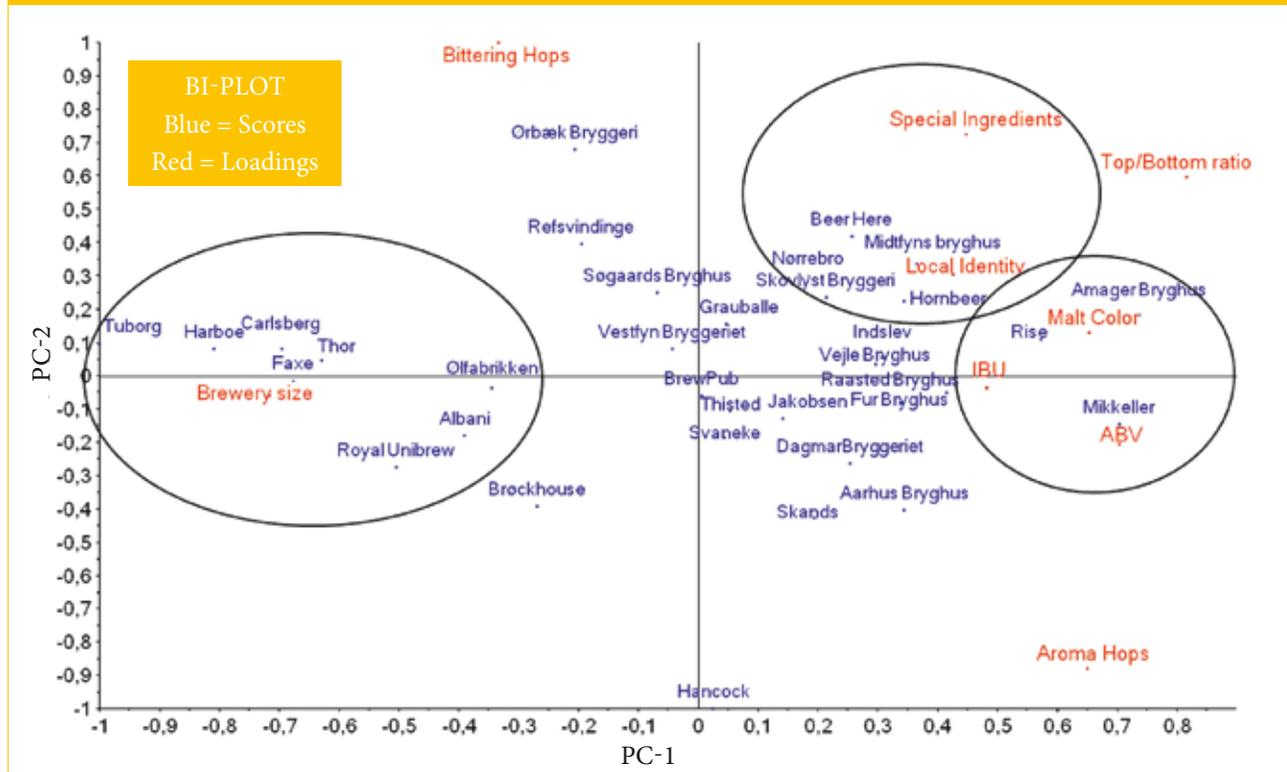
Score plot for the first two principal components. Every point in the figure represents a beer (see Table 2). Their distribution across the spatial distance indicates how different or similar they are to each other.

FIGURE 2B



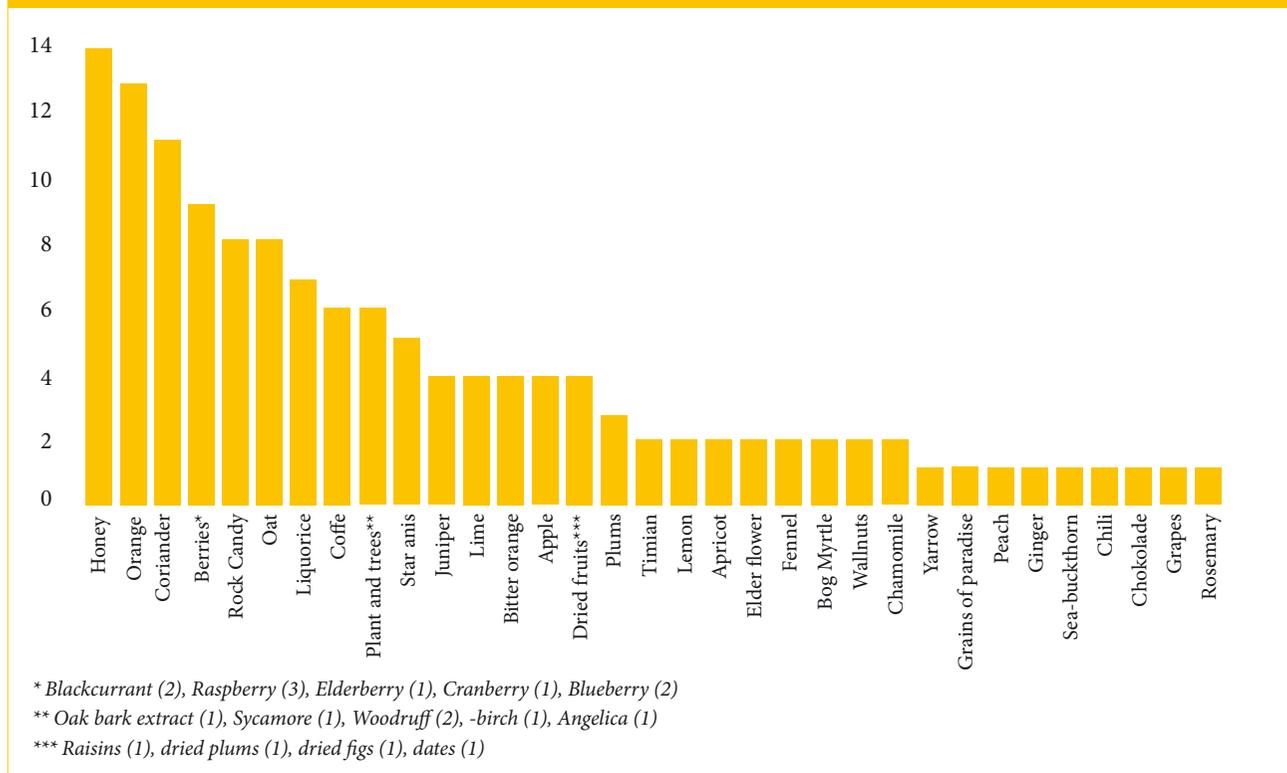
Loading plots for the first two principal components.

FIGURE 4



Biplot, breweries average data. The variable 'Top/bottom ratio' gives a measure of the internal (i.e. for each brewery) prevalence of either ales or lager.

FIGURE 5



specialise in the lager department, whereas smaller breweries seem to focus more on brewing ales.

Looking more closely at the first loading plot, we can see several other things. First of all, the variable 'brewery size' is inversely correlated to the variable 'local identity', i.e. small breweries stress the local aspect more in their communication efforts (e.g. Svanek's Bornholmish pride) and usually make active usage of their brewery as a pub/restaurant (e.g. Nørrebro Bryghus). Secondly, we can see that ABV, Bitterness (=IBU) and malt colour are very close, which indicate that more alcoholic beers are usually higher in bitterness and use generally darker types of malt. Thirdly, beers with these characteristics (high ABV, IBU, malt colour) are mostly ales and to some degree also contain more special ingredients, as indicated by the relative closeness of 'Top fermentation' and 'Special ingredients'. Surely, none of these considerations come as a big surprise, but it is always a good sign when common sense and statistics match. Plus, you now are more familiar with how to read these kinds of graphical plots.

Our analysis indicated that a third underlying variable also described important systematic differences. This is shown in figure 3a and b, where the interpretation can be focused on the vertical axis, as the horizontal axis is the same as in figure 2. The third dimension is more or less explained by use of special flavouring ingredients. Beers in the lower part of the figure are all flavoured with special ingredients, exemplified by Søgaard's Utzon Blond (nr. 230 in the plot 3a. It contains five ingredients: saffron, lime, ginger, lemon myrtle, and orange blossom honey); Beer Here's Tia Loca (nr. 235: unmalted wheat, oat meal, orange peel, and coriander), and Skovlyst's Julebryg (nr. 185: nuts, flavoured syrups, fresh pine, cinnamon and a number of soft brown sugars; among them clayed sugar).

Smaller breweries, also according to this plot, experiment more with special ingredients than large breweries, as brewery size is somewhat negatively correlated to special ingredients. Also, the special flavouring ingredients are more often found in ales than in lagers (the variables 'Top fermentation' and 'Special ingredients' are fairly well correlated).

If you look at the scores plot we have seen so far, it can be seen that although some clear patterns can be observed, smaller breweries' beers are often scattered on a quite large area – meaning that large internal differences in their beers exist.



SMALLER BREWERIES, ALSO ACCORDING TO THIS PLOT, EXPERIMENT MORE WITH SPECIAL INGREDIENTS THAN LARGE BREWERIES, AS BREWERY SIZE IS SOMEWHAT NEGATIVELY CORRELATED TO SPECIAL INGREDIENTS. ALSO, THE SPECIAL FLAVOURING INGREDIENTS ARE MORE OFTEN FOUND IN ALES THAN IN LAGERS



Thus, finally we tried to take an average of each brewery instead of treating each beer separately in order to see whether there are some consistent patterns. For this analysis, we excluded breweries with only one beer present in the database. Therefore, the results are hardly representative, but it was quite interesting to do especially because the resulting plot is highly interpretable. Figure 4 gives an account of the result, now as a biplot, with both scores and loadings in the same figure.

This plot is definitely more straightforward to interpret given that there are much fewer elements. However, interpretations must be taken with a grain of salt, as the generalisation from single beers to average for a brewery is a rough approximation. First of all, nearly all microbreweries are found on the right quadrants, 'pulled' by the variable Top fermentation, i.e. on average they produce more heavy ales than light lagers, and large breweries quite the opposite, as we had seen previously. Mikkeller and Amager Bryghus are the most representative examples of this cluster and seem to pull along a fairly crowded group of breweries (Rise, Raasted, Midtfyns, etc.) which share the same characteristics. Furthermore, some small breweries (upper part towards the right side) are characterized by use of special ingredients (Beer Here, Midtfyns), some with more focus on local identity (Skovlyst, Nørrebro), and for some also more use of bitter hops (Ørbæk, Refsvindinge). On the lower right part, we find breweries characterised by producing beers in the higher end of alcohol content and with a much larger use of aroma hops. And in case you are wondering just which special flavouring ingredients are used, figure 5 summarises our findings with regards to which ingredients are most often added →

to beers by Danish breweries (the counts do not account for how the ingredients are used – e.g. raw materials, dehydrated products, alcohol extracts, flavour extracts – and when – during the wort cooking or after. This was mainly because breweries seldom upfront that kind of information).

CONCLUSIONS

We could sum up our analysis by saying that most of the experimentation goes on in the ales department and is provided by craft breweries; a fundamental association has provided the Danish market with a rich variety of beers. However,

the elephant in the room of this discussion is obviously market share, which is overwhelmingly pending on the lager department. We did not include sales volume; it is enough to say that the official data (Danmarks Statistik) are only available for lager beers. Lager beer is, after all, the drink that conquered the world, accounting for more than 95 per cent of the consumption worldwide. But, to follow up Lewis' conclusion, it appears that also in Denmark there is plenty of room for reinventing more characteristic lagers, and we encourage brewers to do so – in particular craft brewers, as it has the potential to increase their sales dramatically. ¹

ABOUT THE AUTHORS

Davide, Helene and Michael work – respectively – as PhD Fellow, Assistant Professor and Associate Professor within the Sensory Science group at the Department of Food Science, University of Copenhagen. As partners of the consortium Dansk mikrobryg – produktinnovation og kvalitet, their current focus is on developing and applying several sensory methods to understand consumer preferences with regards to innovative beers.

Project home:

www.danishmicrobrew.com/Kvalitetsbryg.htm

Sensory Science Group:

www.en.ifv.life.ku.dk/faggrupper/sens.aspx

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