Chapter 3

The impact of peat source on the flavour of Scotch malt whisky

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Introduction

In Scotch malt whisky production, the burning of peat during the kilning of malted barley is carried out to impart characteristic flavour attributes to certain whiskies (Swan and Howie, 1983). Traditionally, the levels of steam-volatile marker phenols and guaiacols are used as an indicator of peating level (Swan and Howie, 1983). Compounds belonging to these groups are generally considered to be important for peat smoke flavour, though a complete understanding of the compounds contributing to this flavour is yet to be obtained. The phenols and guaiacols found in peat smoke are derived from lignin or similar polyphenolic structural elements found in plants and these polyphenolic structures can vary depending on plant species (Higuchi, 1978; Vanbreemen, 1995; Vanderheijden and Boon, 1994). In addition, the levels of phenols and guaiacols in peat can also be influenced by the level of decomposition which the peat has undergone (Kirk, 1971).

In Scotland there are over one million ha of peatlands. As of 2004, the area of peatland being extracted by the Scotch whisky industry was less than 300 ha (approximately 0.03% of the total area in Scotland) (Harrison, 2007). There is, therefore, a large peat resource available. However, peat forms slowly, taking approximately 3000–4000 years to accumulate a depth of 1 m (Fuchsman, 1980), so particularly in localised areas it may not be considered a renewable resource and it may be the case that malt producers will be required to change their peat source in the future. Also, difficulties in gaining and maintaining planning permission for particular peatland extraction sites may limit the choices of peat source for malt producers.

It has been shown that the peat used for the production of peated whiskies can vary in chemical composition (Harrison, 2009). In that work, the variance in composition was found to be influenced both by the geographical source and the age of the peat. Such variation could ultimately be important for defining the flavour of particular whiskies. Therefore, an improved understanding of the potential flavour impact of whisky source would be useful to the industry should malt producers change their peat source, through choice or necessity, in the future.

In this work, chemically distinct peats from different sources in Scotland have been used to make new make spirit under carefully controlled laboratory conditions. Analysis of the new make spirits was then carried out in order to determine the impact of peat source on whisky flavour.

Materials and Methods

New make spirits

Peated new make spirits were produced on a laboratory scale using peat from six different geographical locations in Scotland which are used by the Scotch whisky industry: Castlehill (Islay), Gartbreck (Islay), Glenmachrie (Islay), Orkney, St Fergus (mainland), Tomintoul (mainland). Additionally, a laboratory scale unpeated new make spirit was produced as a control. New make spirits were all produced using the same green malt and yeast. All kilning, mashing, fermentation and distillation parameters were controlled to ensure that the influence of peat source on spirit flavour and composition could be determined. New make spirits were made in triplicate from each peat to demonstrate the reproducibility of the process.

Sensory analysis

Quantitative Descriptive Analysis (QDA), carried out by the Scotch Whisky Research Institute (SWRI) sensory panel, was used to provide a measure of the relative intensity of a range of pre-determined sensory attributes. The attributes studied were the peaty aromas listed on the SWRI's Flavour Wheel (Jack, 2003), namely: intensity of peaty aroma, burnt, medicinal and smoky. Also, the presence of "other new-make spirit aromas" was used as a single attribute to define any additional aromas. Each test sample was presented in a random order to each assessor, who was asked to score them in terms of intensity of each attribute. Scores were given on a line scale of 0–3 with intervals of 0.1.

Gas chromatography olfactometry/mass spectrometry (GC-O/MS)

New-make spirit samples were extracted into ethanol using solid phase extraction. The extracts were then analysed using a gas chromatograph. The flow from the gas chromatograph was split between an olfactory detection port and a mass spectrometer. The olfactory detection port allowed the detection of aroma active compounds by nose whilst the mass spectrometer was used to determine the identity of these compounds. To help determine which compounds were organoleptically most important, aroma extraction dilution analysis (AEDA) was carried out using dilution factors of 10, 100 and 1000. For quantification of aroma active compounds, the entire flow from the gas chromatograph was passed into the mass spectrometer. Quantification was based on compound peak areas relative to an internal standard peak area.

Results and discussion

Impact of peat source on flavour

Results of the QDA of peated new make spirits were analysed by principal components analysis (PCA) and the results are shown in Figure 1. This plot shows that, as a group, the spirits produced using the Islay peats generally gave the highest scores for peaty aroma attributes and the lowest for other new make characteristics. This was particularly true for Castlehill and Glenmachrie. St Fergus spirit generally scored low for peaty aromas. Tomintoul and Orkney were differentiated by a relatively high medicinal score for Tomintoul and a relatively high smoky score for Orkney. In this way, not only was the overall intensity of peaty aromas influenced by peat source, but also the balance of the individual peaty aroma attributes.

Relationship between new make spirit flavour and composition

Different peats were found to have an influence on new make spirit aroma. The next step was to try and determine the underlying compositional causes of these aroma differences. Therefore,

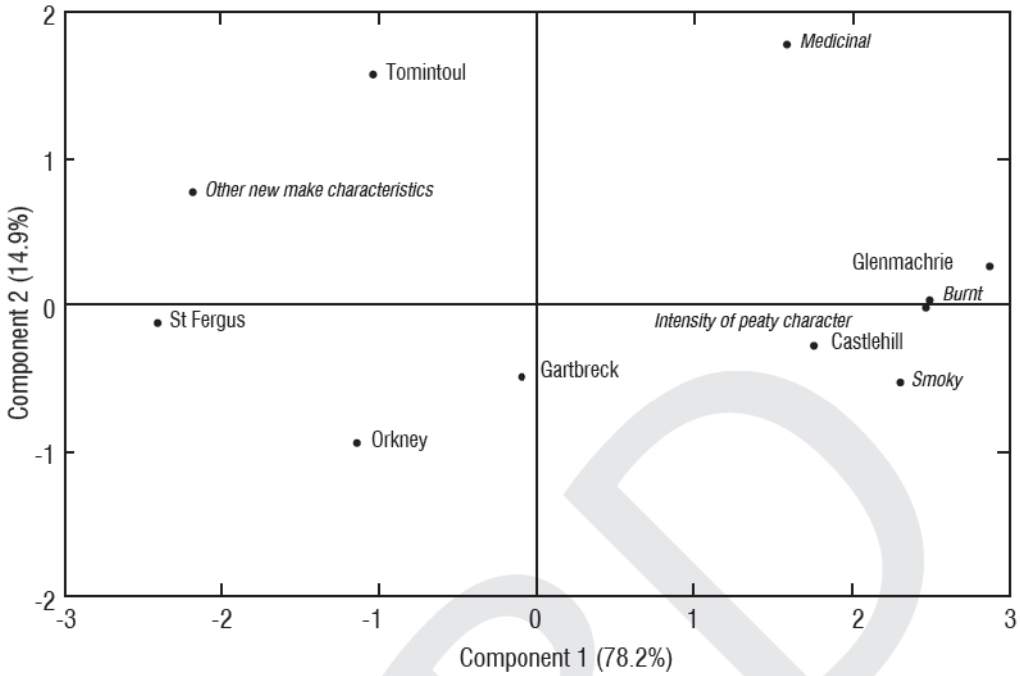


Figure 1. PCA of sensory scores for peaty aromas in new make spirits.

new make spirit samples produced from each of the six peat sources were extracted using SPE and the extracts analysed by GC-O/MS. One hundred and thirty nine aromas were detected in total. The aromas detected in these peated new make spirits were compared with those found in an unpeated new make spirit. In this way, it was possible to determine the aromas which were derived from peat. Seventy five peat-derived aromas were detected (Table 1). The peat-derived aromas represented a large proportion of the total number of aromas. It is clear, therefore, that the use of peat introduces a large number of potential variables which could influence spirit flavour. Forty two of the peat derived aromas had an identifiable compound or a clear mass spectrum associated with them (Table 1). Some aromas were found to have more than one compound eluting at that time making accurate identification difficult so all potential compounds are listed.

The GC-O/MS analysis yielded a large number of aromas derived from peat. To help determine which compounds were organoleptically most important, AEDA was carried out using the extract from the Castlehill spirit. There were 43 aromas with dilution values of 10 or more and compounds co-eluting with these aromas were detected in 33 cases (Table 1). All the identifiable phenols and guaiacols had dilution values of 10 or more. Twenty three aromas had dilution values of 100 or more and 21 of these had associated chromatographic peaks of which 11 were identified as relating to phenols or guaiacols. The four aromas with dilution values of 1000 or more were all identified as being derived from phenols or guaiacols. It was therefore apparent that phenols and guaiacols were major contributors to the peaty aromas of the new make spirits.

To help identify the compounds responsible for the sensory differences detected in the new make spirits, peat derived aroma compound levels were correlated with sensory scores using PCA (Figure 2). For this analysis, only compounds with dilution factors of 10 or over

Table 1. GC-O/MS aromas.

Aroma no. [a]	*Compound*	*Compound group* [b]	*Odour*	*Dilution factor*
1	?		Sulphury, burnt	1
2	1,1-Diethoxyhexane	o	Solvent	10
3	3-Methylcyclopentanone	o	Solvent, stale	10
4	?		Earthy, vegetably, dirty	1
5	?		Earthy, woody, stale	1
6	Ethyl trans-2-pentenoate	o	Earthy, stale	100
7	Styrene	o	Sweet, solvent	1
8	Ethyl 3-hexenoate	o	Sweet, solvent	1
9	?		Sweet, solvent	1
10	?		Earthy, stale	1
11	Ethyl heptanoate	o	Sweet, estery, solvent	1
12	?		Burnt, stale, sulphurs	1
13	?		Earthy, meaty	1
14	3-Ethylcyclopentanone	o	Earthy, solvent, burnt	10
15	Unknown (95,140)	o	Solvent, burnt	100
16	Ethyl 5-heptenoate	o	Sweet, solvent	100
17	?		Earthy, solvent, burnt	10
18	?		Earthy, stale	10
19	Unknown (67,110)	o	Earthy, stale	100
20	Ethyl 7-octenoate	o	Plastic, sweet	10
21	?		Earthy, stale	10
22	6-Hepten-1-ol	o	Green, musty	10
23a	Trimethylcyclopentenone	o	Earthy, stale	1
23b	Acetylfuran	o	Earthy, stale	1
24	2,3-Dimethyl-2-cyclopenten-1-one	o	Earthy, stale	10
25	Ethyl 8-nonenoate	o	Sweet, plasticy	1
26	?		Estery, herbal, sweet, minty, boiled potatoes, waxy	1
27	?		Herbal, plasticy, sweet	1
28	?		Plasticy, solventy	1
29	?		Plasticy	1
30	?		Earthy, stale	1
31	Acetylmethylfuran	o	Earthy, stale, green	100
32	?		Plasticy, herbal, sweet, earthy	1
33	?		Earthy, stale	10
34	Methylfuranylpropanone	o	Earthy, solvent,	100
35	?		Solventy, sweaty, earthy	1
36a	Dimethoxybenzene	o	Burnt, plasticy, sour, oily, solventy	1
36b	Pentanoic acid	o	Burnt, plasticy, sour, oily, solventy	1
36c	Ethyl undecanoate	o	Burnt, plasticy, sour, oily, solventy	1
37	?		Estery	10
38	1-Phenyl-2-propanone	o	Sweet, stale, earthy	1
39	?		Earthy, stale	100
40	Methylacetophenone 1	o	Estery, phenolic	100
41	?		Dirty, sour	1
42	?		Stale, spicy	1
43	Methylacetophenone 2	o	Estery, phenolic	100
44	Dimethoxytoluene 1	o	Burnt	1
45	2-Chlorophenol	p	Medicinal, TCP, plasters	10
46	Dimethoxytoluene 2	o	Smoky, burnt	10
47	Guaiacol	g	Smoky, spicy	1000
48	Unknown (123,138)	o	Spicy, medicinal, sweet	1

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Aroma no. [a]	*Compound*	*Compound group* [b]	*Odour*	*Dilution factor*
49	Dimethylphenol 1	p	Plasters	1000
50	Hydroxymethylacetophenone	p	Plasters	10
51	Methoxymethylphenol	g	Smoky, sweet	1000
52	Methylguaiacol	g	Sweet, vanilla	10
53	Quinoline	o	Stale, earthy	100
54	o-Cresol	p	Medicinal	100
55	?		Plasters	10
56	Ethylguaiacol	g	Sweet, spicy	100
57	Unknown (137,152)	o	Sweet, spicy, burnt	100
58	2-Ethylphenol	p	Plasters	100
59	Dimethylphenol 2	p	Medicinal	100
60	Dimethylphenol 3	p	Medicinal	100
61a	p-Cresol	p	Barnyard	1000
61b	m-Cresol	p	Barnyard	1000
62	?		Vegetably, sour, manure	1
63	Propylguaiacol	g	Spicy	100
64	C3 phenol	p	Medicinal, burnt	10
65a	4-Ethylphenol	p	Barnyard, medicinal, spicy	100
65b	Eugenol	g	Barnyard, medicinal, spicy	100
66	3-Ethylphenol	p	Burnt, barnyard, medicinal	10
67	?		Burnt, stale	1
68	?		Plasticy, burnt, earthy	10
69	?		Plasters, burnt electrics	100
70	?		Burnt electrics	1
71	?		Burnt electrics, stale, oily	1
72	?		Burnt	10
73	?		Tarry, burnt	1
74	?		Tarry, burnt	1
75	?		Burnt	1

[a] Where more than one compound coeluted with an aroma, coeluting compounds are indicated by a letter after the aroma number.
[b] Compound groups: g = guaiacol, p = phenol, o = other.

were used in order to focus on the most aroma active compounds in the new make spirits.

The peaty attributes were all co-localised in the upper right quadrant of the plot. This reflected the fact that all of these aromas were generally most intense in the Castlehill and Glenmachrie spirits. Also, along component 2 there was a shift from the top of the component from medicinal aroma down to smoky aroma. This reflected the relatively high score that the Tomintoul spirit gave for medicinal. Compounds co-localising with the aroma descriptors on the PCA plot would be the most likely contributors to these aromas.

As a group, the phenols were found to be the most prominent compounds in the upper right quadrant of the plot. The aromas of the phenols, as described by GC-O/MS analysis, were generally described as medicinal. This result, combined with the fact that these compounds all had dilution factors of 10 or more, suggested that these compounds were major contributors to the peaty aromas, and in particular the medicinal aroma, of the spirits. Para/meta cresol (61a and b) and a dimethylphenol (49) had particularly high dilution factors of over 1000 so might be expected to be of major importance as contributors to aroma. Para and meta cresol eluted from the GC column close together making it difficult to determine which one was the main contributor to the detected aroma. However, analysis by the SWRI sensory panel has shown that para cresol has a lower aroma detection threshold (51 ppb compared to 578

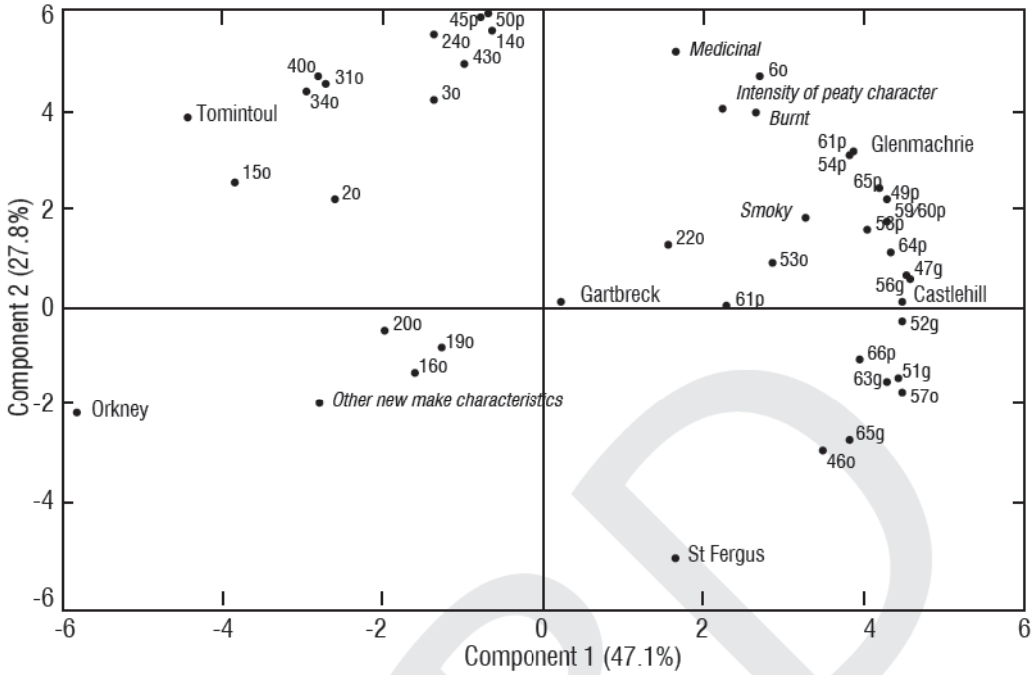


Figure 2. PCA of sensory and GC-O/MS data. Compounds are identified by aroma number and by compound group (see Table 1).

ppb for meta cresol) and was present in greater abundance in the new make spirits making this the more likely compound to have contributed to the strong aroma.

Whilst the phenols appeared particularly good candidates for explaining the medicinal aroma of new make spirit, the shift from medicinal to smoky along component 2 correlated with a shift in composition from phenols to guaiacols. As a group, the guaiacols also had dilution factors of 10 or more and had smoky, spicy or sweet aroma descriptors. Guaiacol (47) itself, along with a methoxymethylphenol (51) were likely to be particularly potent contributors to aroma with dilution factors of over 1000.

An abundance of particular phenols and guaiacols were found to be important for the high levels of peaty aromas in Islay, notably Castlehill and Glenmachrie, spirits. In general terms, the levels of these compounds can be influenced by both peat decomposition level and the type of vegetation contributing to the peat, and a combination of these factors has resulted in the Islay peats being rich in these aroma active compounds. Whilst the exact reason for the high levels of these compounds in the Islay peats was not obvious, some evidence obtained from previous analysis of the peats themselves pointed to potential causes (Table 2). This research suggested that the Islay peats may have contained a relative abundance of grassy vegetation and that this vegetation appeared to have undergone a relatively high level of decomposition compared to the other peats analysed.

The other notable sensory finding was that the new make spirit produced from Tomintoul peat had a relatively medicinal aroma (Figure 1). This was found to be related to a relative abundance of phenols (Figure 2). It is known that *Sphagnum* moss derived peat tends to contain relatively high levels of phenols relative to guaiacols (Vanderheijden and Boon, 1994). On visual inspection, *Sphagnum* remains could be more readily detected in the Tomintoul peat than the others, and this may therefore account

Table 2. Peat compositional data (Harrison, 2007).

Peat	*Lignin/ polyphenol*	*Lignin/polyphenol decomposition*	*Characteristic vegetation*
Islay	High	High	Grass
Orkney	Low	High	Heather
St Fergus	High	Low	Woody plants/trees
Tomintoul	Low	Low	Moss

for the relatively high levels of phenols and, therefore, the particular medicinal note of the Tomintoul new make spirit.

The compositional results for the St Fergus new make spirit were also interesting as this new make spirit generally contained relatively high levels of phenols and guaiacols yet scored low for all the peaty aromas (Figures 1 and 2). From the data in Figure 2 it was apparent that the St Fergus new make spirit was separated from the Islay spirits as it contained a relative abundance of guaiacols, particularly derivatives with long side chains, compared to phenols. This relative abundance probably related to the high level of undegraded woody material detectable in the St Fergus peat (Table 2). It would therefore appear that not only was the overall levels of phenols and guaiacols important for determining the levels of the peaty aromas but also the ratio of these compounds. It may be that a relative abundance of those guaiacols with long side chains which have sweet and spicy aromas decreases the overall perception of peaty aromas in the St Fergus new make spirit. Spiking experiments may help confirm the reason for this finding.

Whilst phenols and guaiacols appeared to play the main role in contributing to peaty aromas in new make spirit, there were a number of other aroma active congeners detected. Figure 2 shows those which had dilution factors of 10 or more. These compounds covered a range of compound families: acetals, alcohols, aromatics, carbonyls, esters and nitrogen compounds. Aromatic compounds imparting burnt, smoky, spicy and sweet aromas (46 and 57) were probably guaiacyl derivatives and may have contributed to the peaty aromas in a similar way to the guaiacols. The remaining compounds, which tended to be relatively abundant in those spirits which contained relatively low levels of phenols and guaiacols (Orkney and Tomintoul), may have contributed a variety of notes to the overall aroma of the spirit: solventy, earthy, burnt, sweet, green and estery. However, as these notes are those that might be expected in an unpeated spirit as well, it would be difficult to determine exactly how much the presence of such notes was due to the presence of these compounds as their perception could also be enhanced by the presence of a relatively low level of phenols and guaiacols.

Conclusions

Producing peated new make spirit on a laboratory scale, it was possible to see that peat source has an impact on spirit flavour. Compositional analysis of these spirits demonstrated that differences in both the overall levels of guaiacols and phenols and in the relative levels of these compounds contributed to the flavour differences. These new make spirit compositional differences could be related directly to the composition of the peat. Therefore, should malt producers change their peat source, they should be aware of the potential impact on spirit flavour.

Acknowledgements

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