

# Smoke Signals

## Peat and its influence on whisky

Gary Pickard, CSE

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### What is peat?

Peat is an accumulation of partially decayed vegetation or organic matter formed over thousands of years in anaerobic conditions. It can be formed in wetland areas such as peatlands, bogs, mires, and moors.

Stagnant water obstructs the flow of oxygen to decaying plant matter, thus slowing decomposition rates.

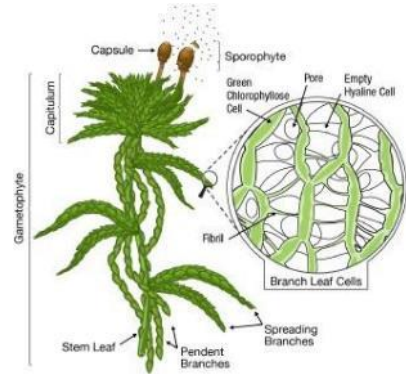


2

## Common misconceptions

Peat and peat moss are the same thing.

Sphagnum moss, also called peat moss, is one of the most common components in peat, although many other plants can contribute. The biological features of sphagnum mosses act to create a habitat which helps in peat formation.



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## Common misconceptions

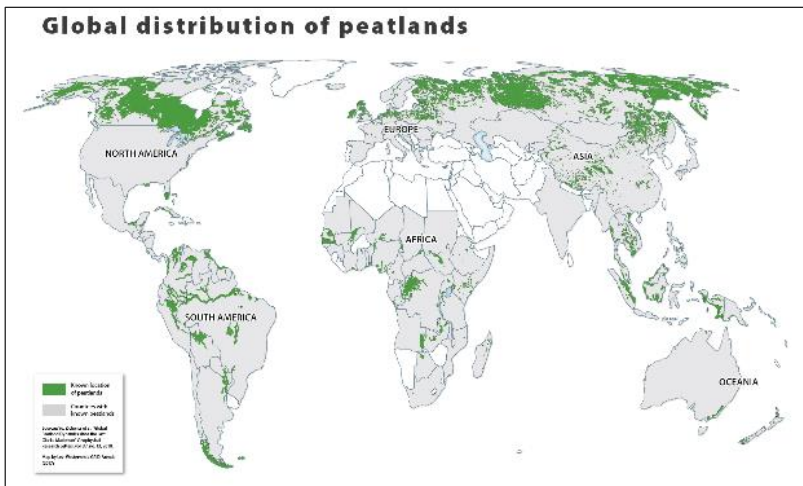
All peat is grown in Scotland.

The peatland ecosystem covers 3.7 million square kilometres (1.4 million square miles) and is the most efficient carbon sink on the planet, because peatland plants capture carbon dioxide (CO<sub>2</sub>) naturally released from the peat, maintaining an equilibrium.

It takes "thousands of years for peatlands to develop the deposits of 1.5 to 2.3 m [4.9 to 7.5 ft], which is the average depth of the boreal [northern] peatlands", which store around 415 gigatonnes (Gt) of carbon (about 46 times 2019 global CO<sub>2</sub> emissions). Globally, peat stores up to 550 Gt of carbon, 42% of all soil carbon, which exceeds the carbon stored in all other vegetation types, including the world's forests, although it covers just 3% of the land's surface.

Source: <https://en.wikipedia.org/wiki/Peat>

### Global distribution of peatlands



Source: <https://www.grida.no/resources/12546>

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Peat is a renewable source of energy.

Peat is not a renewable source of energy, due to its extraction rate in industrialized countries far exceeding its slow regrowth rate of 1 mm (0.04 in) per year.

It is also reported that peat regrowth only takes place in 30–40% of peatlands.

Peat grows at a very slow rate, only **1/32 of an inch per year**. With some of the bogs being as deep as 40 feet, that means we are potting plants and starting seeds in a resource that takes centuries to grow! **It is unclear whether restoration efforts ever fully succeed.**



This is where peat comes from.

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How did it all start?



GOING FOR PEAT.

Going for Peat, Isle of Skye, Scotland  
Victorian Engraving, 1840  
(Crofters)



Interior of Traditional Scottish Home with  
Peat Fire, Isle of Lewis

Source: <https://www.odysseytraveller.com/articles/peat-and-scotland/>

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## How did it all start?



The Distillery Map of Scotland, Chas. MacKinlay & Co., 1902 Edition



Postcard for the reopened Machrihanish Colliery (coal mine) in Argyll, Scotland, circa 1940s



Gas lines from England first reached Scotland in 1970 through the Leeds-Newcastle pipeline. That same year, offshore production started with the discovery of the Forties Oil Field off the coast of Aberdeen.

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## Peat usage

### Agriculture

- Regulates global climate
- Retains water to feed plants
- Used to help grow food crops

### Forestry

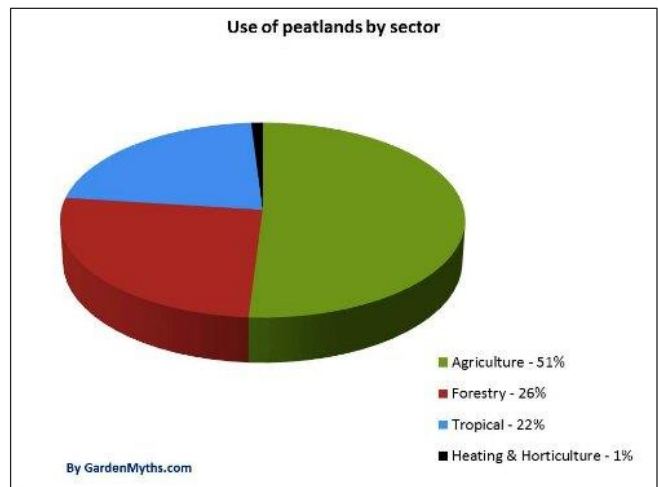
- Promotes biodiversity

### Horticulture

- Fertilizers - rich in nitrogen, phosphorous, and potassium

### Fuel for heat and energy

### Traditional flavoring for whisky



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## Peat usage in whisky



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## How do you add peat flavor to whisky?



### Traditional Method

After the steeping and malting process, the germinated malt is ready to be dried.

Germination is stopped by heat over 70 degrees Celsius (158 Fahrenheit).

The wet malt is spread on a malting floor usually above a kiln. This floor has holes smaller than the barley grains.

Hot air from the fire below extracts moisture from the barley, making it ready for milling.

**If peat is added to the fire, the smoke from that peat imparts its flavor on the barley drying on the floor above.**

\*It is important to not burn the peat, but let it smolder. Staff working the kiln stand by and spray water on the peat to ensure it never ignites, all the while stoking the flames of the fire.

\*\*In our modern world, distilleries can order malt from industrial maltings at whichever peat levels they prefer!

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The Malting Floor @ Laphroaig  
Port Ellen, Islay - Scotland



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The Peat Kilns  
Laphroaig Distillery  
Port Ellen, Islay  
Scotland



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How do you measure peat in whisky?

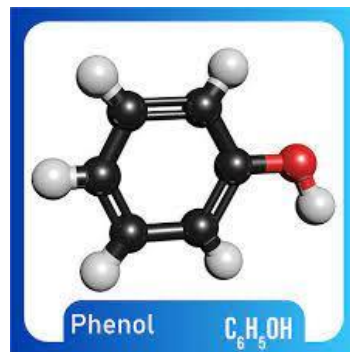
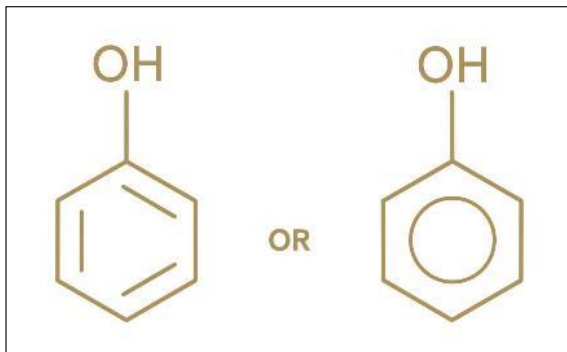


High-Performance Liquid Chromatograph (HPLC)

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How do you measure peat in whisky?

### Phenol


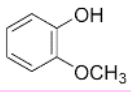

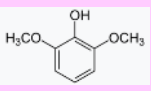

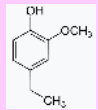

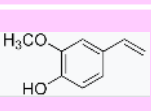

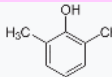


A phenol is a basic chemical compound that can be combined to make more complex phenols responsible for different flavors and aromas. These are also known as carbolic acid, phenolic acid, or benzenol. (C<sub>6</sub>H<sub>5</sub>OH). Combinations of the phenol molecules create the more complex *phenols*. Phenols are a classification group of chemical compounds, comprising many different molecular variations of aromatic and hydroxy structures. There are more than eight thousand phenolic compounds deriving from plants alone.

Source: <https://www.marklittler.com/what-is-peated-whisky-and-is-it-sustainable/>

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## Most Common Phenolic Compounds in Peated Malt

Name	Structure	Attributes	Name	Structure	Attributes
phenol <small>(Benzenol, carboric acid)</small>		Tar, Overly sweet	2-methoxyphenol <small>(Guaiacol/Creosol)</small>		Medicinal, Woody, Smoky
2-methylphenol <small>(o-cresol)</small>		Musty/Medicinal/Herbal	2,6-dimethoxyphenol <small>(Syringol)</small>		Bitter almond, Balsamic, Wood smoke aroma. Vanilla taste.
3-methylphenol <small>(m-cresol)</small>		Woody/Ethereal/Leathery	4-ethylguaiacol		Smoky, Bacon, Clove (also made by Brettanomyces)
4-methylphenol Buckwheat <small>(p-cresol)</small>		Medicinal, Floral, Barnyard	4-vinylguaiacol		Clove, Apple, Peanut, (also made by Saccharomyces)
4-(2-propenyl) guaiacol <small>(Eugenol)</small>		Clove, Cinnamon, Nutmeg Basil, Bay Leaf	dimethoxyphenols <small>(Xylenols)</small>		Sweet, Medicinal, Seaweed Camphor, Tar, Burnt Smell

(2,6-Xylenol pictured)

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## Compounds in Peated Malt by Olfactory Detectability

Odour	Compound	FD			
11 medicine, smoke	<i>2-methoxy phenol (Guaiacol)</i>	2048	5 Fruity, candy	ethyl-3-methyl butanoate	64
16 smoked meat	<i>4-ethyl-2-methoxy phenol</i>	2048	19 flowery, coconut	cis- whiskey lactone	64
10 burnt	<i>4-methyl phenol (P-Cresol)</i>	1024	22 smoked wood, herbal	unknown	64
18 spicy, smoke, meaty	<i>4-vinyl-2-methoxy phenol</i>	1024	1 malty	2-methylpropanol	32
14 smoke, roasted	<i>4-ethyl-2-methyl phenol</i>	512	6 flowery	3-methyl butyl acetate	32
13 phenolic, medicinal	4-ethyl phenol	256	8 roasted	unknown	32
20 smoked	4-propyl-2-methoxy phenol	256	9 phenolic	<i>phenol</i>	32
3 candy like	1,1-diethoxyethane	128	21 fruity	γ-decalactone	32
12 flowery, honey	2-phenyl ethanol	128	23 fruity	ethyl dodecanoate	32
4 burnt, whiskey	3-methyl-butanol	64	7 rancid	(E)-2-heptenal	16
			15 flowery, coconut	trans - whiskey-lactone	16
			17 cognac, fruity	ethyl undecanoate	16
			2 fruity	propan-2-ol	8

FD = Dilution Factor

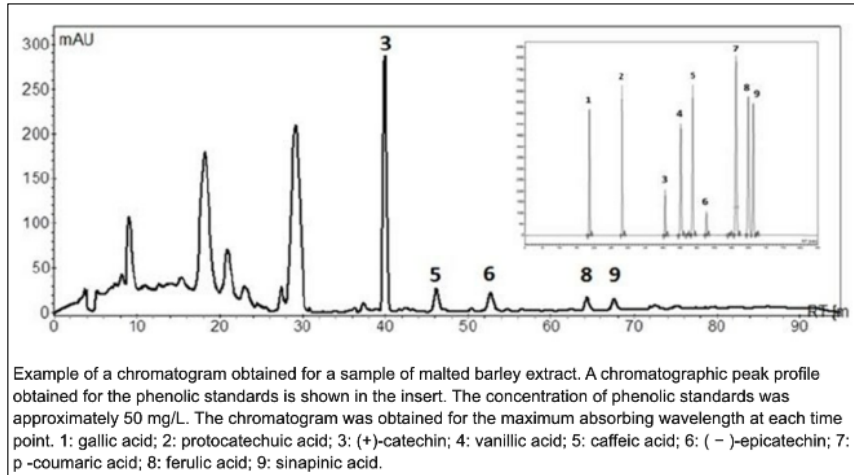
Note: Not all of these compounds are phenols!

Source: <https://iladdie.wordpress.com/2019/05/05/the-phenols-in-peaty-whisky-are-not-phenol/>

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How do you measure peat in whisky?



Chromatogram

Source: D. Carvalho, A. Curto and L. Guido, 2015. Determination of Phenolic Content in Different Barley Varieties and Corresponding Malts by Liquid Chromatography-diode Array Detection-Electrospray Ionization Tandem Mass Spectrometry

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## How Is Whisky Peatiness Measured?

### HPLC

- Solvent solvent: Solvents are stored here.
- Vacuum degasser: Gets rid of solvent bubbles
- Quaternary pump: Pumps and mixes the solvents
- Autosampler: Sample is mixed with the solvent
- Color compartment: Where the sample's components are separated
- Detector: Where the components are detected

### Colorimetry

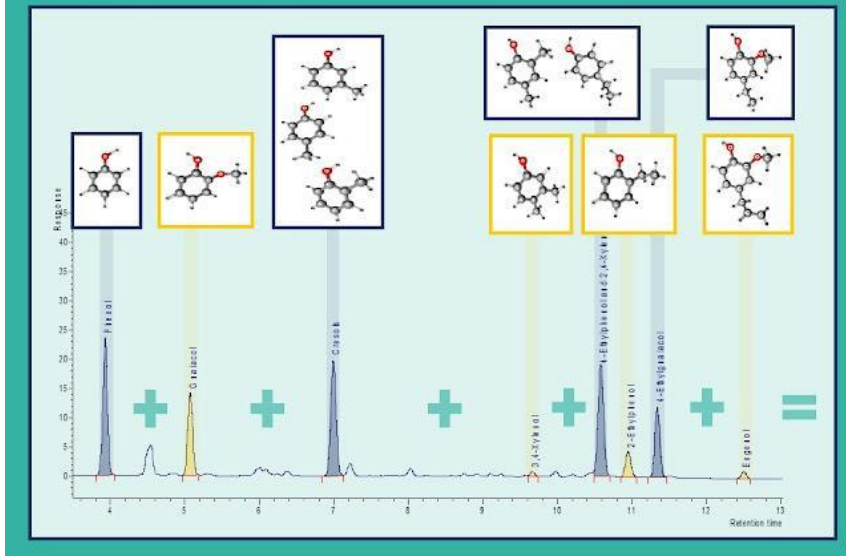
Fig. 1. Some distillation systems. A: Hot spring; B: Unpacked woodchips; C: Hot; C: Pellets; and D: Dried. (From the book "The Art of Distillation" by K. Sugibayaw, t al. Suntory Ltd. Osaka 618, Japan) Received 13 August 1982

COLORIMETRIC DETERMINATION OF PHENOLS IN PEATED MALTS USING MODIFIED KLEBER'S METHOD. By K. Sugibayaw, t al. Suntory Ltd. Osaka 618, Japan) Received 13 August 1982

Source: <http://manchesterpyromaniacs.blogspot.com/2017/07/whiskyology-science-of-peat.html>

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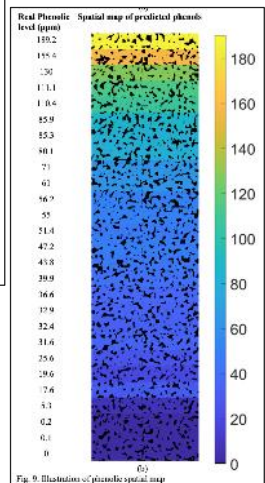
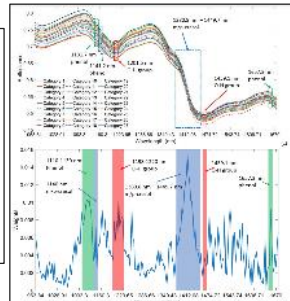
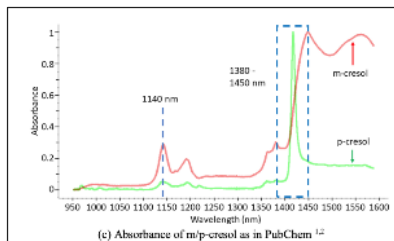
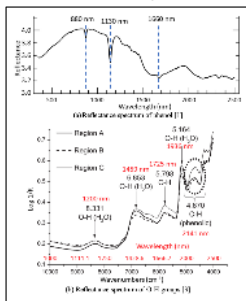
# U-HPLC Results



Source: <http://manchesterpyromaniacs.blogspot.com/2017/07/whiskyology-science-of-peat.html>

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## How do you measure peat in whisky?



compensate the scattering distortions, i.e. for spectral correction [26]. Here, it is used to reduce the variability between pixels due to scattering. For any pixel with a reflectance spectrum  $r_i$  in  $\mathcal{D}_{\text{ROI}} \subset \mathbb{R}^{1 \times N \times 3}$  at the location  $(i, j)$  where  $i \in \{1, \dots, C\}$ ,  $j \in \{1, \dots, C\}$ , the process of SNV can be defined by:

$$r_i = \frac{r_i - \mu}{\sigma} \quad (6)$$

$$r_i \text{ (SNV)} = \frac{r_i - \mu}{\sigma} \quad (7)$$

$$\mu = \frac{1}{I \times J} \sum_{i=1}^I \sum_{j=1}^J r_i \quad (8)$$

$$\sigma = \sqrt{\frac{1}{I \times J} \sum_{i=1}^I \sum_{j=1}^J (r_i - \mu)^2} \quad (9)$$

where  $\theta_{i,j}$  is a spectral vector at location  $(i, j)$ ,  $\mu$  and  $\sigma$  are the mean and standard deviation of all pixels in  $\mathcal{D}_{\text{ROI}}$ .

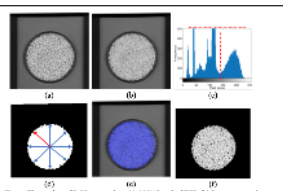


Fig. 4. Illustration of ROI extraction. (a) 100x100 Band of HSI; (b) Proposed ROI; (c) ROI of size 10x10. Step 1: Image crop of 10x10; Step 2: ROI; Step 3: ROI; Step 4: ROI; Step 5: ROI; Step 6: ROI; Step 7: ROI; Step 8: ROI; Step 9: ROI; Step 10: ROI.

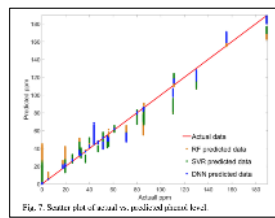
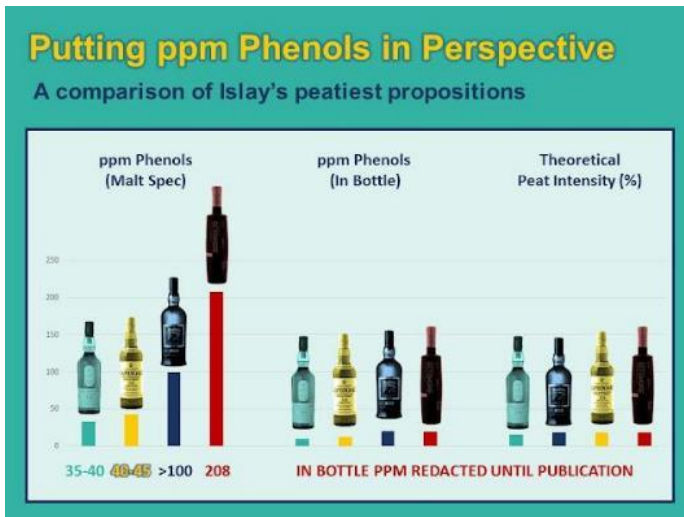


Fig. 9. Illustration of phenol spatial map.

Source: Yan, Y., Ren, J., Tschannerl, J., Zhao, H., Harrison, B. and Jack, F. 2021. Nondestructive phenolic compounds measurement and origin discrimination of peated barley malt using near-infrared hyperspectral imagery and machine learning. IEEE transactions on instrumentation and measurement [online], 70, article 5010715.

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## Important Points About Peat Measurement



Source: <http://manchesterpyromaniacs.blogspot.com/2017/07/whiskyology-science-of-peat.html>

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## BEWARE

**So What?**

Firstly, we had to move the goal posts :

<2ppm	Unpeated
2-8ppm	Lightly peated
8-30ppm	Medium peated
30-50ppm	Heavy Peated
50-100ppm	Very Heavy Peated
>100ppm	Peat Freak
>5000ppm	DEATH! <sup>o</sup>

<sup>o</sup> The oral LD<sub>50</sub> (dose needed to kill 50% of subjects) for Phenol is 50mg/kg, meaning that the average lethal dose (75kg human adult) is 3750mg. Of a 700mL bottle, 3750mg (3.8g) equates to 0.5% w/v or 5000ppm

Secondly, total phenol content in the malt isn't an accurate a measure of how peaty a whisky will taste:

- Phenol levels change during manufacture & aging.
- Not all Phenols were created equal.
  - Phenols have different flavours.
  - Phenols have different flavour strengths.
  - Different people have different sensitivities to them.

Source: <http://manchesterpyromaniacs.blogspot.com/2017/07/whiskyology-science-of-peat.html>

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Phenols are measured in parts per million (PPM). 10ppm has a phenolic content of 0.001%.

The barley is what is measured for phenolic content - NOT the whisky. Distilleries have the ability to measure the the PPM of whisky, but since those numbers are lower, they tend to utilize readings taken from the barley. 40-80% of phenols are lost between kilning and bottling

"Phenol is a severe irritant and highly toxic systemic poison that is absorbed well by inhalation and through the skin."

- Centers for Disease Control and Prevention (CDC)

"Phenol is a general protoplasmic poison (denatured protein) with corrosive local effects. Phenol derivatives are less toxic than pure phenol. The lethal dose is between 3 to 30 g, but may be as little as 1 g. Phenol is well absorbed by inhalation, dermal application, and ingestion."

"Phenol, a major metabolite of benzene, is a potentially immunotoxic and neurotoxic substance of environmental significance."

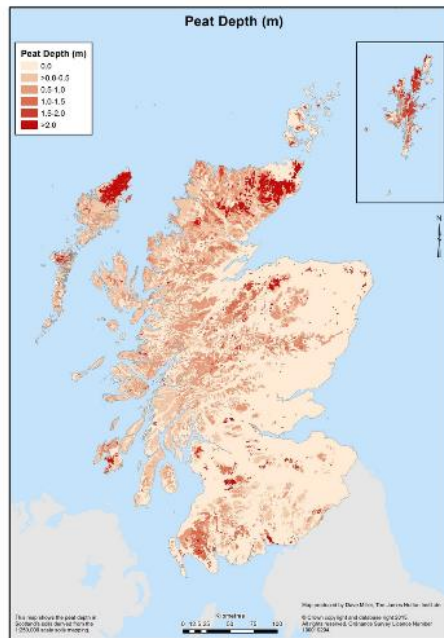
- National Institutes of Health (NIH)

## Common misconceptions

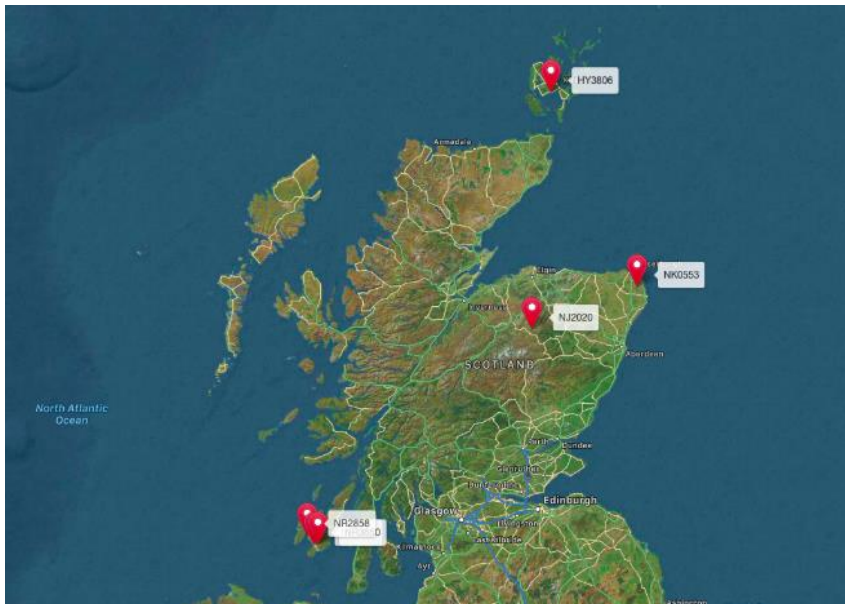
All peated whisky tastes the same.

Factors that can affect flavor/intensity:

- Location of peat
- Depth where peat is cut
- Production methodology
  - Milling
  - Mashing
  - Water source/temperature
  - Fermentation time
  - Yeast strain
  - Distillation cut points
  - Distillation still shape/size/type
- Aging
  - Time spent in cask
  - Type of cask used



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Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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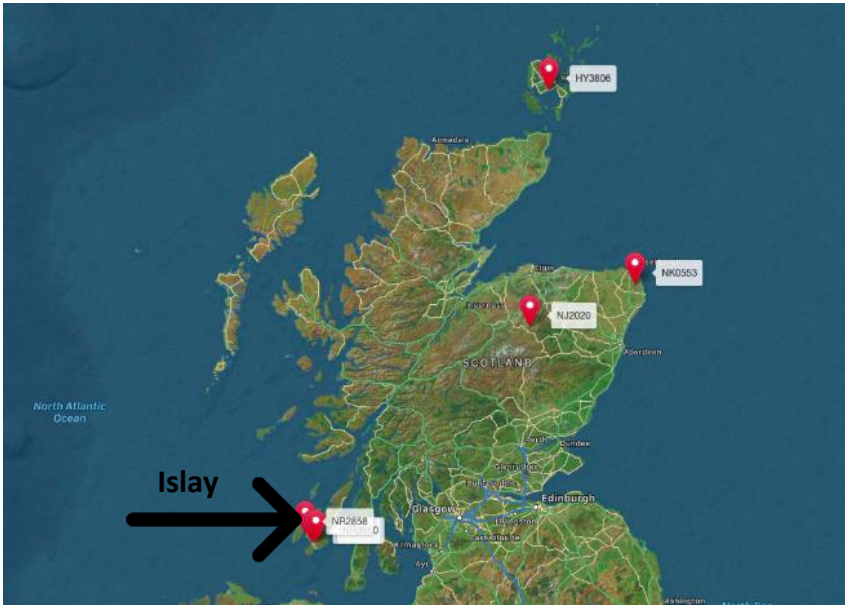
Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

26



Source: <http://whiskyscience.blogspot.com/2011/05/peat-terror.html>

Gartbreck  
Glenmachrie  
Castlehill



Distilleries

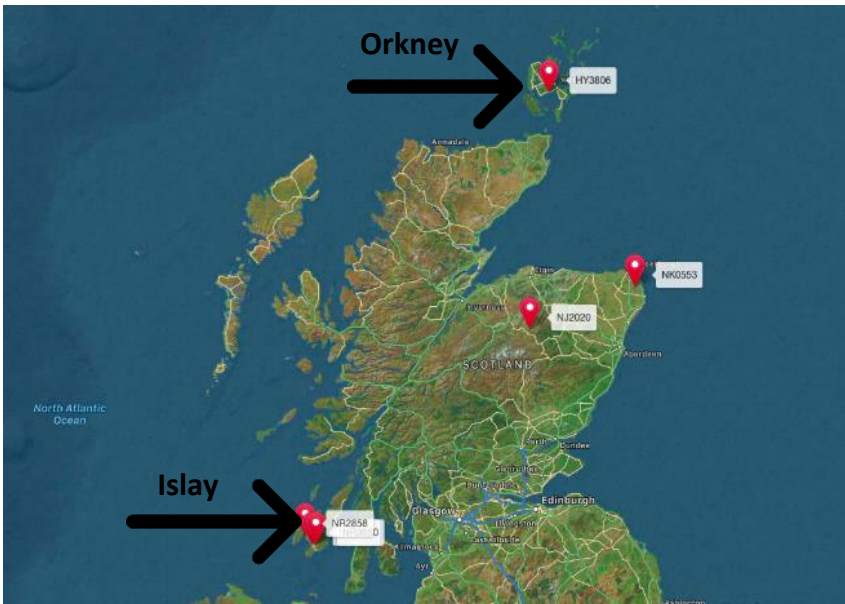
- Laphroaig
- Lagavulin
- Ardbeg
- Bunnahabhain
- Caol Ila
- Bruichladdich
- Bowmore
- Kilchoman
- Ardnahoe
- Port Ellen

\*Disclaimer\*

Distilleries may not necessarily utilize peat from their immediate geography!

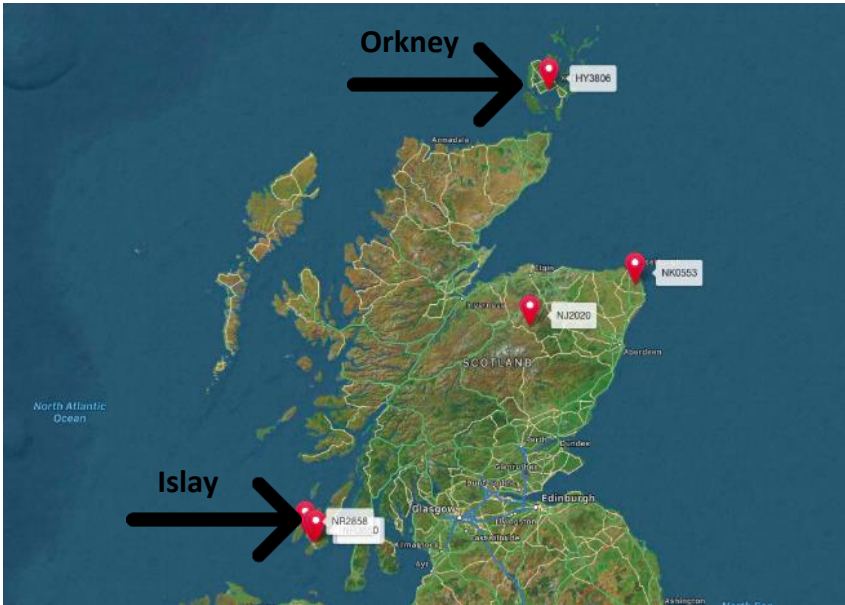
Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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Distilleries

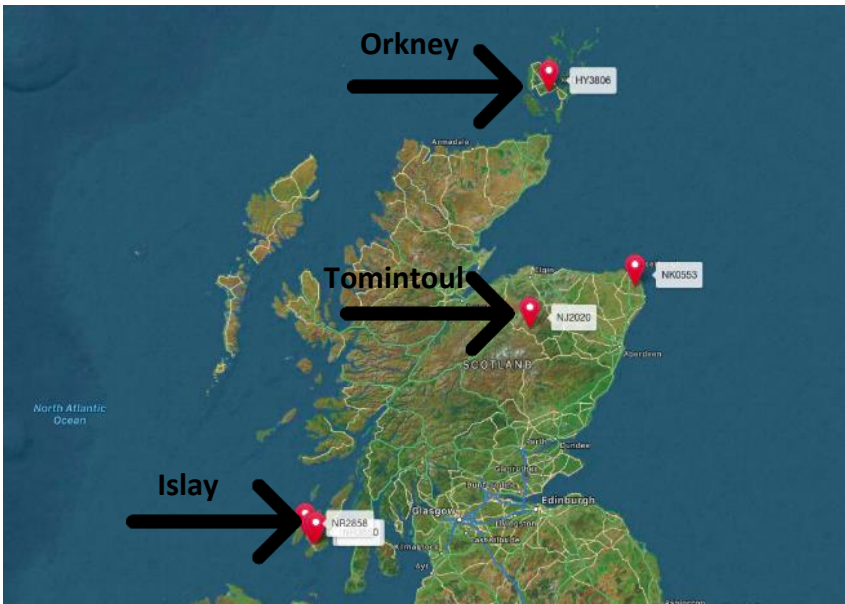
Highland Park  
Scapa

\*Disclaimer\*

Distilleries may not necessarily utilize peat from their immediate geography!

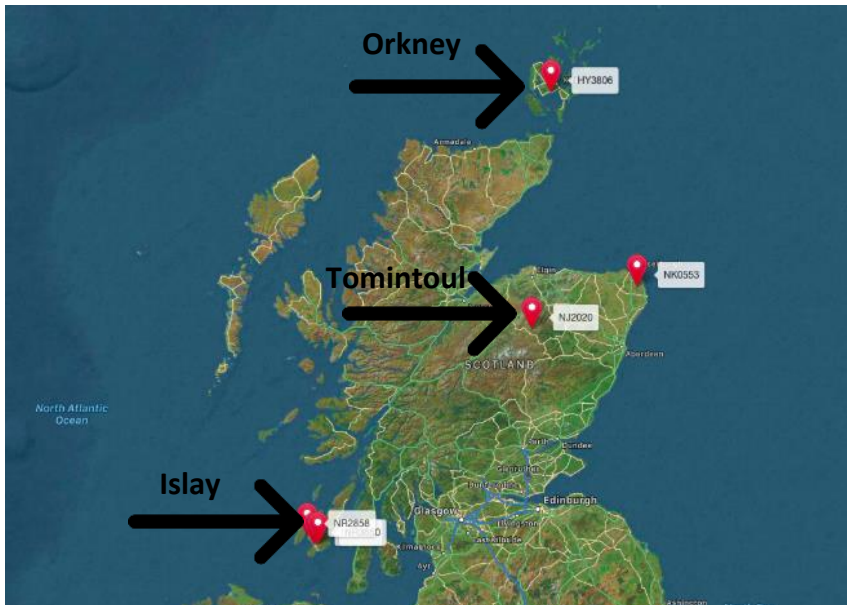
Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

29



Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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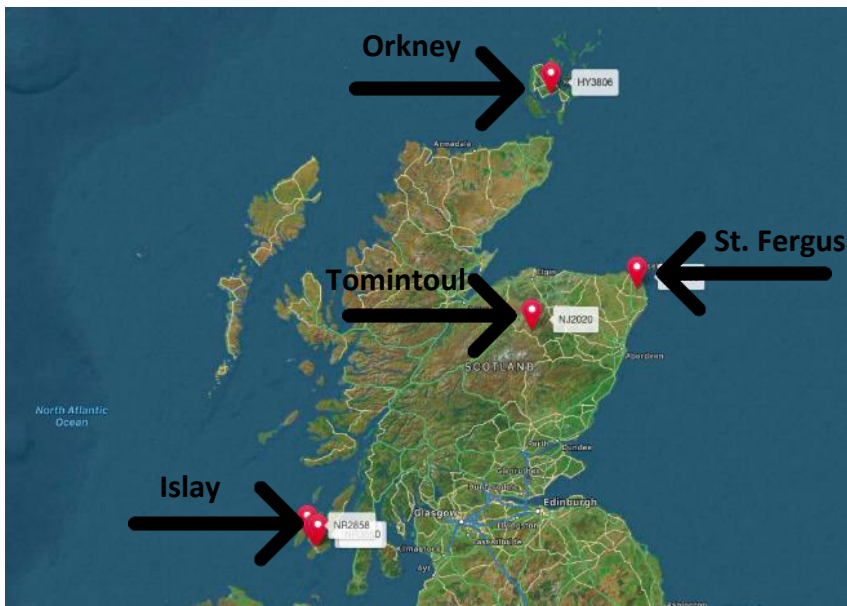
Distilleries

- Tomintoul
- Braeval
- Tamnavulin
- Balmenach
- Tormore
- Allt-A-Bhainne
- Ballindalloch
- Cragganmore

(Southern Speyside)

\*Disclaimer\*

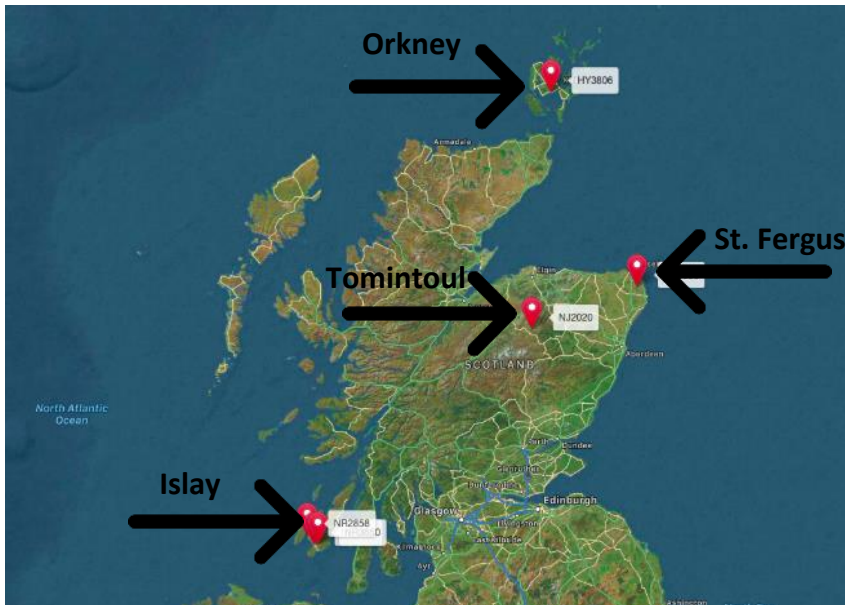
Distilleries may not necessarily utilize peat from their immediate geography!



Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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Distilleries

Glen Garioch  
Ardmore  
Glendronach

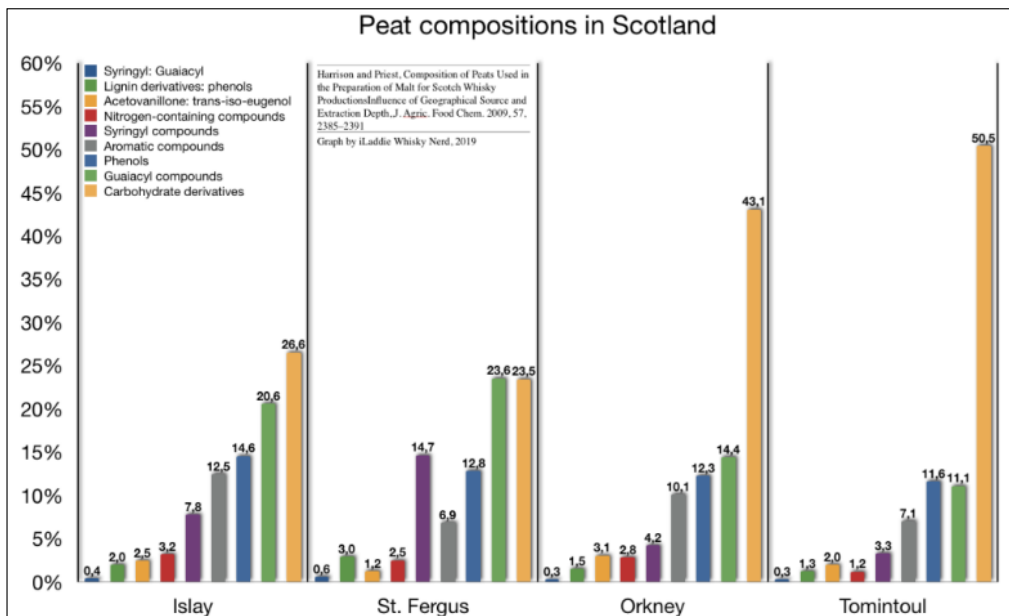
(Near Aberdeen)

\*Disclaimer\*

Distilleries may not necessarily utilize peat from their immediate geography!

Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>

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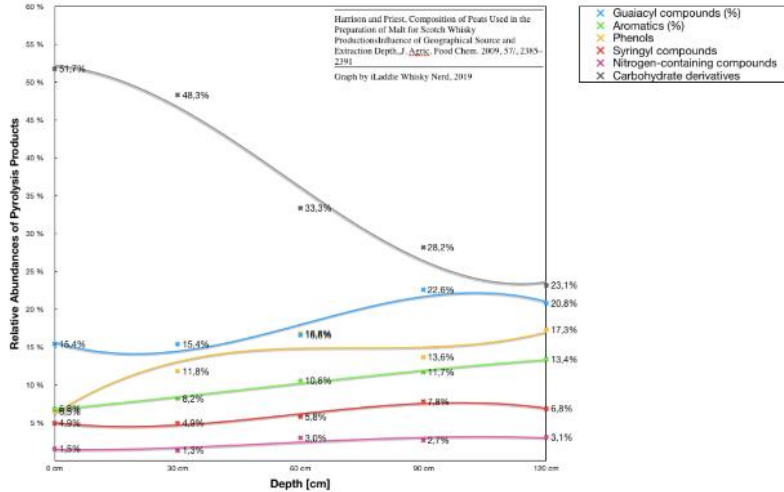


Source: <https://iladdie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>  
Derived from Harrison & Priest (2009)

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## INFLUENCE OF DEPTH

### Pyrolysis Products of Peat from Different Depths



Graph of Table 4, Orkney Peat, in Harrison and Priest, 2009 [1]

Source: <https://iladlie.wordpress.com/2019/09/15/islay-peat-is-not-orkney-peat/>  
Derived from Harrison & Priest (2009)

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MEDIUM PEATED

UNPEATED

### The Peat Arms Race



25 ppm

Bowmore 12 year



22 ppm

Talisker 10 year



20 ppm

Highland Park 12 year



15 ppm

Springbank 10 year



5 ppm

Balvenie 12 year Doublewood



2 ppm

Bunnahabhain 12 year

0 ppm

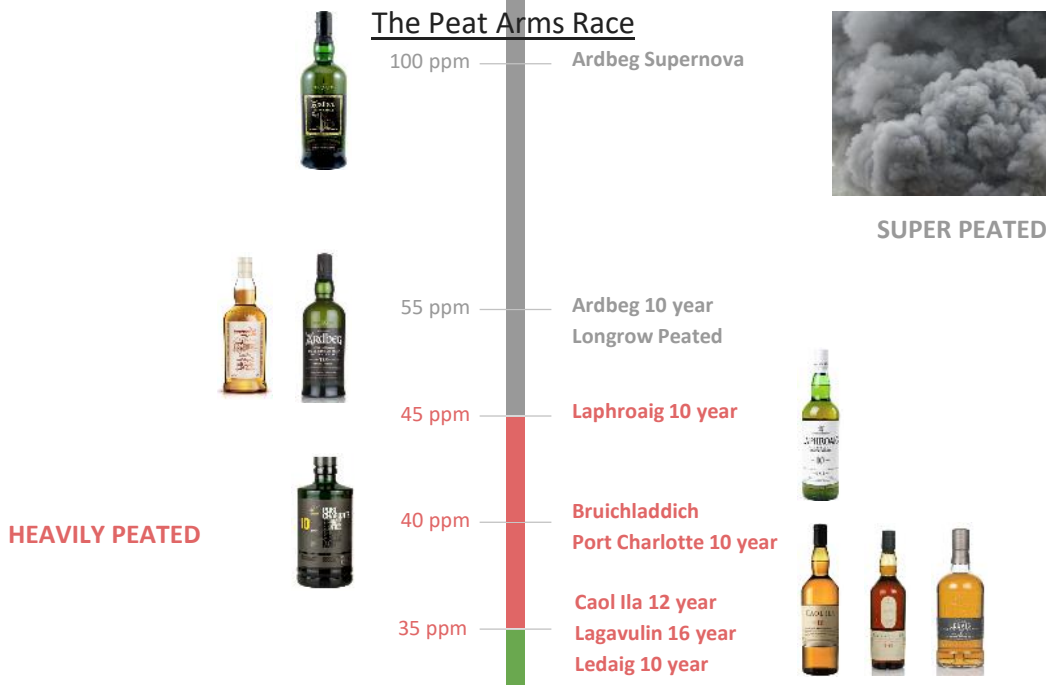
Hazelburn 10 year



LIGHTLY PEATED

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## The Peat Arms Race



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## The Peat Arms Race



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## Non-Islay Peated Scotches



Highland



Speyside



Lowland



Islands



Campbeltown

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## Islay Non-Peated Scotches



Bruichladdich Classic Laddie  
0 ppm



Bunnahabhain 12 and 18 year  
2 ppm



Islay's newest distillery  
plans to produce some  
non-peated whisky

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## Non-Scotch Peated Whiskies



Peated Bourbon



Peated Rye



Peated ASM



## Peated World Whiskies



Irish Whiskey



Indian Whisky



French Whisky



Japanese Whisky



German Rye Whisky



Canadian Rye Whisky

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## Non-Whisky Peated Expressions



Vodka



Gin



Brandy



Tequila



Rum



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## Peat papers for deeper digging

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[Carvalho DO, Curto AF, Guido LF. Determination of Phenolic Content in Different Barley Varieties and Corresponding Malts by Liquid Chromatography-diode Array Detection-Electrospray Ionization Tandem Mass Spectrometry. Antioxidants \(Basel\). 2015 Aug 14;4\(3\):563-76. doi: 10.3390/antiox4030563. PMID: 26783844; PMCID: PMC4665430](#)

[Y. Yan, J. Ren, J. Tschannerl, H. Zhao, B. Harrison and F. Jack, "Nondestructive Phenolic Compounds Measurement and Origin Discrimination of Peated Barley Malt Using Near-Infrared Hyperspectral Imagery and Machine Learning," in IEEE Transactions on Instrumentation and Measurement, vol. 70, pp. 1-15, 2021, Art no. 5010715, doi: 10.1109/TIM.2021.3082274](#)

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## Peat articles

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**Thank you**



**Sláinte**