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FROM HERBAL TO HOPPED BEER: THE DISPLACEMENT OF REGIONAL HERBAL BEER TRADITIONS BY COMMERCIAL EXPORT BREWING IN MEDIEVAL EUROPE

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Abstract

The history of the use of hops as a beer additive differs only partially from the use of bog myrtle. For centuries hopped beer existed side by side with other native beers; apparently the different types of beer were functionally comparable. This balance changed with the development of full isomerization techniques of brewing with hop, which opened up the possibility of long-term storage and international export. Archaeological evidence points to the use of bog myrtle and other herbs in brewing at a much earlier date than hops. The history of the use of bog myrtle can be solidly placed in the pre-Roman Iron Age, while the history of hops is only tentative in the Roman period and does not truly take hold until the Early Middle Ages. Most of the hop records of the early and later Middle Ages do not come from monastic sites. This would indicate beer production was not dominated by monasteries, as is often thought today.[1] Similarly, the production of gruit beer under the right to gruit was not solely in hands of the Church either. The right to (sell) gruit (to produce gruit beer) was a medieval franchise[2] granted by the empire of Charlemagne that over time changed hands to the rich and influential, which included monasteries, church dioceses, as well as nobility and, later, city governments. Archaeological evidence for the use of hops in brewing also places the practice before the first records of the right to gruit. This is in stark contrast to the commonly accepted idea that the discovery of the superiority of hops in the Late Middle Ages quickly supplanted the use of inferior gruit, as well as all other botanical brewing additives.

Introduction

Botanical additives to alcoholic beverages have been used since prehistoric times in western Europe. Finds from prehistory indicate fermentation with a variety of fermentable sugars and botanicals. The earliest trace evidence for alcoholic beverages dates to 9,000 years ago from the ancient Chinese village of Jiahu where residue analysis of ceramic vessel indicates a mixed beverage made with grapes, hawthorn fruit, rice and honey. [3]The Bronze Age burial mound at Egtveld, Denmark, dated to 1500-1300 BCE, contained a birch-bark container with dried up traces of a mixed beverage on the inside. The residue was identified as fermented cowberries (*Vaccinium vitis-idaea*) and cranberries (*Vaccinium oxycoccus*), wheat grains, bog myrtle (*Myrica gale*) as well as honey – making for a mix between beer and fruit wine, sweetened with honey.[4] Prehistoric fermenters used anything that could preserve, alter perception, heal the body, improve the flavour and that could ferment due to its sugar and/or yeast content. This way of fermentation resulted in a mash of fruits, malted and unmalted cereals and honey, combined with various regionally available herbs.

Where at first the different sources of fermentable sugar were combined into a sort of super-brew, over time these different base-sugars evolved into distinct beverages, with their own names; wine, mead, braggot (honey beer), and beer/ale.[5] Due to the high sugar content of grapes and honey, wine and mead could be fermented with fairly high alcoholic content and thus did not spoil as easily, negating the need for preserving additives. The Egyptians are credited with fine tuning the production of the beer, optimizing malting and yeast techniques to create a beverage to be enjoyed within a reasonable amount of time. The alcoholic content of beer is much lower and thus is more perishable, creating a need for added preservatives. The botanicals bog myrtle, hops and several others played an important role in this function.

Many different botanicals were used as beer additives over the centuries. Several with clear preservative properties, some with perceived medicinal properties, some with desired psychotropic or adulterating effects, and some perhaps just for an enjoyable flavour. Throughout the Middle Ages the two botanicals used consistently throughout Europe were bog myrtle and hops.[6] They could both be combined with

other herbal additives, whether for taste or for other purposes is not always entirely clear. Bog myrtle is mostly found in combination with other preservative herbs, likely to boost the combined preservative effect. Hops was mostly used by itself, sometimes with bog myrtle, and as a base ingredient for medicinal beers with many other botanical ingredients added for health benefits rather than flavour.

The early history of bog myrtle

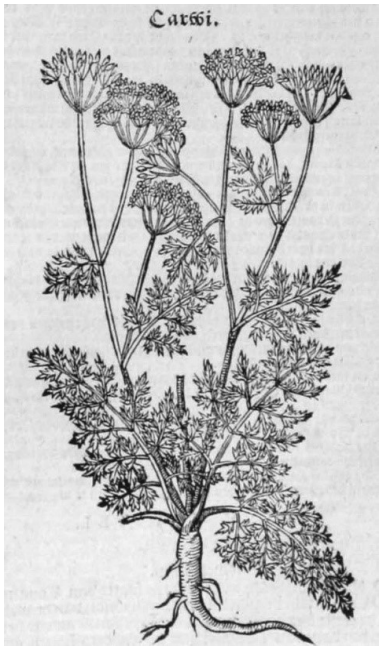
It seems surprising that bog myrtle, which played such an important role in the brewing in several countries, was nearly forgotten as a beer ingredient.[7] Also known as *sweet gale* in the United States and *gagel* and *pors* in Dutch and German as well as many other local variants, bog myrtle is an oceanic species and grows in acidic bogs and sandy soils. Its area of distribution includes the northernmost parts of central Europe, north-west Europe and the coastal zone of the Baltic Sea.[8] It blooms with a cluster of flowers on the top of one stem, called an *inflorescence,* and its flowers fruit as an *infructescence*, a cluster of fruits from an inflorescence flower. Generally, bog myrtle has male and female flowers on separate plants, but not always. The fruit is a dry drupe, a single-seed stone fruit, born in cone-like groups; a fruitlet is the single part of the multiple fruit catkin, and could contain one stone or pit (the seed is inside the pit). All parts of the shrub are aromatic due to the essential oils and resins excreted through glands in the leaves and catkins; the catkins are significantly more concentrated. The archaeological records of finds plausibly connected to brewing indicate the use of predominantly the catkins, and only sometimes the leaves.[9]

Figure 1. Bog Myrtle as illustrated in Dodoens, *Cruijdeboeck* (1554). With permission of www.biolib.de

Archaeological evidence for bog myrtle seems to indicate it has been used in the context of brewing as early as the centuries immediately before and around the start of the common era in a small area around the Rhine estuary, in the north of the Netherlands. There, remains of fruitlets (single pits with fruit remnants) were found at seven sites dating from pre-Roman Iron Age. Large amount of leaf and catkin remnants, undoubtedly employed for brewing, were recovered from Roman age Nieuwenhorn, the Netherlands, as well as from the 9th/10th - 13th century northwest Germany. Other large finds include 10th - 13th century and 8th - 12th/13th century finds from Viborg and Ribe, Denmark, as well as 11th - 15th century finds from Lund, Sweden, and 10th - 12th century finds from Lincoln, England.[10]

The regular occurrence and number of archaeological finds leads to the conclusion bog myrtle was already in use during the pre-Roman Iron Age, presumably for beer making. Bog myrtle is mentioned in 10th century Anglo-Saxon Leechdoms as a medicinal ingredient, with and without the use of ale.[11] By the 12th century written evidence for bog myrtle used in brewing is found in German Abbess Hildegard von Bingen's treatise *Physica Sacra* (c.1158 CE) in which she recommends the use of *Mirtelbaum* for making beer: 'If you want to brew beer, cook the leaves and fruits, the drink will be all the healthier'.[12] It is likely that *Mirtelbaum* indicates native bog myrtle.[13] Bog myrtle was an important plant is a traditional Scandinavian brewing traditions and is thought to be used before hops.[14] Some of the oldest written sources on Scandinavian plants mention 'gardens' of bog myrtle, likely referring to managed wild-growing areas.[15]

From the 13th century onwards, the use of bog myrtle is found in several Low Country city accounts, as part of purchases made by city *gruit houses* (production and distribution centres) to produce the brewing additive gruit. The ingredients are near-identical from one gruit house to another, centring around the purchasing of grain (generally oat or barley malt, chaff or flour), bog myrtle, laurel berries



Figures 2,3 & 4. Bay laurel (*Laurus nobilis L.*), caraway (*Carum carvi L.*) and juniper (*Juniperus communis L.*). Fig. 2: Lobel (1581) googlebooks; Fig 3 & 4: Dodoens (1644/1554) with permission of www.biolib.de.

(*Laurus nobilis* L.), laserwort (*Laserpitium siler* L.) and pine resin. The odd one out is Cologne, Germany, where in 1391/93 the local gruit house purchased malt, bog myrtle, laurel berries, as well as hops, anise (*Pimpinella anisum* L.), caraway (*Carum carvi* L.) and juniper (*Juniperus communis* L.).[16] What is often overlooked is that the gruit master also made note of two items not available: both laserwort and resin are in the purchase list but marked as non-available. Apparently, the Cologne gruit house tried to purchase the same ingredients for their gruit as their surrounding colleagues but for some reason did not succeed.[17] The out-of-the-ordinary ingredients could be alternatives for the preferred items, likely in the hope to replicate the standardized end product of gruit, or perhaps are unrelated to the production of gruit.[18] Either way, in the words of their contemporaries as found in a Cologne charter of 1408: 'so is the gruit from Neuss much better than the gruit from Cologne'.[19]

Like Hildegard, the German Konrad von Megenberg also mentions *Mirtelbaum* in connection with brewing in his 14th century manuscript *Das Buch der Natur*. Assuming he also meant bog myrtle, he offers a bit more detail on the brew: 'man likes to lay this flower in beer, which one makes of water and of rye or barley'.[20] Sixteenth century Dutch botanist Matthias l'Obel wrote about *gagel* in his *Kruydtboeck* (1581) 'The same flower also sometimes, for lack of hops, is added to beer,' and goes on to include 'sometimes also to make the drunkards happy, because bog myrtle makes one dim in the head and makes people happy of spirit'.[21] This strong reputation is reiterated by Dutch professor Martin Schook, who wrote one of the first books on beer, *Libre de cervisiæ* (1661), and has the following to say about gruit beer: 'but he, having not had scent and taste of this beverage, especially of the bog myrtle, then quickly soak it, for those who are not habituated to it'.[22]

There are several historic accounts of condensing wort into a concentrated malt extract to 'strengthen' another brew. There are reasons for this: the malt extract would boost the ABV, it would boost yeast activity and thus fermentation, and it could carbonate the brew through secondary fermentation inside the barrel.[23] The medieval British *grout* is such a wort additive and was thought to enhance fermentation[24] to produce a heavy beer known in certain regions as White Ale. Current research indicates Low Country *gruit* is plausibly also a malt extract, similar to British *grout* except it also includes specific preserving botanicals, as well as the spent grains.[25] The addition of malt extract to a standard wort would promote vigorous fermentation, explaining the repu-

Figure 5. Hops as illustrated in Dodoens' *Cruijdeboeck* (1554). With permission of www.biolib.de

tation of gruit as a *fermentum*, as well as raise the ABV. This higher ABV would help preserve the beer, but could also contribute to drunkenness.

Modern research has failed to find elements within bog myrtle that enhance drunkenness.[26] Bog myrtle was used as a beer additive over an area coinciding with the natural distribution of the plant. It was probably not a cultivated, but rather a managed wild-growing resource.[27] City accounts indicate bog myrtle was not wild-harvested by the *gruithuis* producers but purchased at local trade centers alongside the non-native ingredients. It does not seem long-distance trade in this beer additive occurred.[28]

The early history of hops

Archaeological finds and written records relating to hops are a little less clear. Bog myrtle is generally not used for anything else but brewing whereas hops can also be used for food,[29] as a dye stuff,[30] as livestock bedding,[31] as rope and as a fibre or yarn to create fabric.[32] Generally, the stems and leaves are used for foodstuffs and fibre, and the cones for brewing. In traditional Scandinavian brewing, a concentrated infusion made from hop stalks was used to dye/darken the beer.[33] There also exists an intriguing medieval Muscovite mead recipe using hops leaves.[34] As these seem to be isolated occurrences, one can generally assume that when copious remnants of cones (fruitlets) are found then those were likely used in a brewing context.

The hop (*Humulus lupulus* L.) is an inland species, occurring naturally in flood-plain forests and fen woods, as well as forest edges and man-made habitats like hedges and buildings. Its natural distribution includes the temperate regions of Europe, up north into mid-Scandinavia as well as down south into the Mediterranean region. Like bog myrtle, hop plants generally flower with male and female flowers on separate plants. The flowers are shaped as an *inflorescence*, and fruit as *infructescence*, also in a cone shape. Unlike bog myrtle, hops produce nuts and are generally difficult to germinate. Modern hop plants are cultivated for females that produce neither fruit nor pollen. It is not possible to distinguish between cones from wild plants and from cultivated stock.[35] The cone is made up of protective leaves or petals (*bract*) that grow along the central stem (*stig*) which form small nooks (*bracteoles*). The bracteoles contain lupulin glands that produce yellow sticky globs of essential oils and resins – concentrated chemical bombs containing about 500 different substances including the bittering agents *lupulone* and *humulone*. Apart from the oils and resins, the hop cone also contains polyphenols, proteins, cellulose and tannins.[36] The typical hop scent comes from its fugitive essential oils which, combined with the resins, results in fragrant, sticky hand-picking. Perhaps not coincidentally, harvesting ripe bog myrtle catkins leaves similar yellow-greenish sticky marks with a similar scent, reminding the harvester of a sparkling cold pilsner on a bright sunny terrace.

Several archaeological sites, including some of an early date, recovered large numbers of cone fragments, plausibly pointing to their use in brewing. These includes sites such as 6-8th century Develier, Switzerland; 7-9th century Serris-Les Ruelles, France; 8-9th century Mikulčice, Czech Republic;

the medieval-period finds in Wolin, Poland, and the 13th century finds in Lübeck, Germany.[37] Scandinavian finds of cone fragments from the Viking Age were found at the 7th century Royal estate of Järrestad, Scania, Sweden;[38] early 8th century Ribe, Denmark;[39] 9th century Birka, Sweden; 9-10th century Hedeby (Haithabu),[40] in Schleswig, Germany (formerly Denmark) and early 11th century Viborg Søndersø, Denmark.[41] Throughout the Viking Age the available cultivated plants in southern Scandinavia diversifies, and many seem to have originated in south and central Europe – including the hops.[42]

Surprisingly, there are also several Viking Age finds of hops in suspected brewing contexts in Britain. The 10th century Graveney boat with the significant find of 411 nuts and 136 bracteoles[43] is the better known; other sites are the late Saxon site of Hungate, York,[44] and Viking Age Coppergate, York.[45] The Graveney boat is of a type used for Channel crossings, and while it is not possible to establish if the hops were native, or imported, what is important is that hops were deemed important enough to be traded.[46] Medieval sites with hop finds are common in central Europe as well as to the west and north, and the number of specimens per site is often high. The diversity of sites also indicates the use of hops in the brewing of beer was not restricted to monasteries, as is sometimes thought.[47] There are only a few finds from the Neolithic, pre-Roman Iron Age and Roman period. As hops are native to these areas it is unlikely these finds indicate household use of hops. In the Middle Ages a sharp increase takes place in the number of sites and finds. From an average number of cone fragments of 1.3 in Roman times to 209.9 during the early middle ages, this increase points to intentional use of hops, and that can best be explained by assuming that hops were now being used in brewing.[48]

Records indicate hops were grown as a crop in 736 CE in the garden of a Wendish prisoner at Greisenfeld, in the Hallertau region of Bavaria, Germany.[49] During the Middle Ages, German-speaking Europe used the term 'Wends' to indicate Eastern European West Slavs and South Slavs living within the Roman Empire. Corran, in *A History of Brewing*, believes it might be possible that the cultivation of hops dispersed when the Slavs reached the Caucasus and moved into Eastern Europe during the great migration north of peoples after the decline of the Roman Empire.[50] Another theory is that hops were first used in Western Asia and Central Europe and that the practice then spread westwards.[51] Central and Eastern European as well as Scandinavian oral traditions of brewing with hops – in beer and in mead – are prevalent and could be ancient. Finland, on the Continental side of the Scandinavian peninsula, had cultural connections with Central and Eastern Europe (the Finnish language is part of the Finnic group of the Uralic family of languages, which includes Eastern European Estonian and Hungarian). The Finnish saga, *The Kalevala*, is dated to the pre-Christian era with parts from the 11th and 14th century, but was not written down until the 17th century. It describes the making of beer, including the use of hops, and the boiling of the liquor. The folklore and etymology of *The Kalevala* suggest a timeline of when the Finns inhabited the Caucasus region,[52] suggesting there might be merit to the Central and Eastern European origin story of brewing with hops. The saga states: 'The origin of beer is barley, of the superior drink the hop plant; Though that is not produced without water or a good hot fire'.[53] The boiling step describes the process of mashing. It is unlikely the hops were boiled for any length of time because boiling grain would result in porridge, not mash. As we will see later, short-term heat would result in low-level isomerization, which reduces the preserving benefits to the brew. The saga goes on: ' … An Osmo descendant, a brewer of beer, a maiden, maker of table beers, took some grains [a measure] of barley, six grains of barley, seven hop pods, eight dippers of water; then she put the pot on the fire, brought the liquor to the boil …' [54]

Then, in 768 CE, hops are mentioned in a grant to the Abbey of St. Denis, near Paris, by Pepin le Bref, the father of Charlemagne. Part of the grant consisted of a donation of '*Humulinarias cum integritate*' lands in the forest of Iveline, which contain areas known for wild hops. Interestingly, hops are not mentioned in Charlemagne's *Capitulare de Villis* (ca. 800); not as part of the quite specific directions on what each domain should plant and produce, and neither in the descriptions of who was responsible for brewing which beverages.[55] It is not clear if this only means hops were not yet cultivated as a matter of practice, and that the harvest of wild hops was enough to sustain demand, or that hops were not yet used in the brewing of beer in these areas. Large parts of Charlemagne's empire would embrace the practice of the right of gruit, which emphasized the use of bog myrtle, and that could explain this omission.

The first dated written reference specifying the use of hops in brewing comes from 9th century Germany. In 822 CE Abbot Adalhardus of the French monastery of Corvey (also known as new Corbie) defined the duties of millers on their monastic estate, releasing said millers from the gathering of wood and hops.[56]

De humlone quoque, postquam ad monasterium venerit, decima ei portio … detur. Si hoc ei non suffit, ipse … sibi adquirat unde ad cervisas suas faciendas sufficienter habeat.[57]

The description indicates that hops were gathered from the wild, just like fire wood, and that they were used in brewing. It states that a tithe (a tenth) of each malting was to be given

by the tenants to the porter of the monastery, as well as each hops harvest, and that in case the amount was insufficient to cover the needs of the monastery, the porter should take measures to obtain enough raw material elsewhere. The Benedictine monks from Hochstift monastery in Freising, Bavaria (Germany), are generally credited as the first to cultivate hops. Monastery records for the years 859-875 CE mention orchards, fields, and *humularia*, i.e. hop gardens, alluding to the possibility the hop gardens are cultivated, just as orchards and fields are.[58] Unfortunately, the presence of hop-gardens is not automatically evidence for the use of hops in brewing, as hops could be used in different ways, including medicinally.[59] Other monasteries of the same century also allude to the presence of hop cultivation. Documents from the French monasteries at St. Remi and St. Germain, and the Abbey at Lobbes relate to hop duties levied on the tenants of the monastic lands, implying intentional cultivation.[60]

Supporting the late Saxon and Viking Age archaeological finds in Britain, Anglo-Saxon leechdoms from predominantly the 10th century mention both bog myrtle and hops in connection with brewing. In regards to hops there is some confusion as several plants are indicated with '*hymele'* although it is fairly certain '*hegehymele'* (hedge hops) and '*humulus femina*' (female hops) indicated hops.[61] An old Irish poem, dating prior to the 12th century, describes Saxon ale as bitter – whether this indicates the use of hops, or other bittering agents is not certain.

> The Saxon ale of bitterness,
> is drank with pleasure about Inber in Rig.[62]

For unknown reasons, the use of hops did not take hold in Britain the way it did in Continental Europe. It is possible the use of hops in Britain was no more than a local phenomenon without much national impact.[63] The lack of evidence for the use of hops between the Anglo-Saxon era and the late middle ages is also found in the English word now used for hops. The Anglo-Saxon *hymele* (Old English) is derived from the Frankish *humilo* which corresponds to several similar words in the Germanic languages, including the Middle Dutch *hommel*, Old Norwegian *humli*, and Old Swedish *humbli*. Variants of this are still used in modern Scandinavian languages. The other Germanic languages adopted a different word, the Dutch (Low German) *hop* and (High) German *Hopfen*.[64] The English word *hop(s)* is not found before the 15th century and is likely a loan word from the Dutch from when hopped beer was reintroduced by Dutch immigrants around the same time. The word *hymele* is not the only word related to brewing that disappeared from the English language. The word *beor* disappeared as well,[65] to also be reintroduced by the Dutch. The English-Latin dictionary *Promptorium parvulorum* (1440) speaks of beer as a hopped beverage, in contrast to ale – a historic example of one of the now-modern distinctions between hopped beer and unhopped ale.

It is not until the 12th century that written proof is found for hops being used in a brewing context. The previously mentioned Abbess Hildegard from Bingen, Germany, also mentions the preservative properties of hops in beverages in her c.1158 CE treatise *Physica Sacra*.

> It is warm and dry, and has a moderate moisture, and is not very useful in benefiting man, Hops (*hoppho*) is a hot and dry herb, with a bit of moisture It is not much use for a human being, since it causes his melancholy to increase, gives him a sad mind, and makes his intestines heavy. Nevertheless, its bitterness inhibits some spoilage in beverages to which it is added, making them last longer.[66]

Albertus Magnus mentions the general preservative effects of hops in beverages as well, and that they cause headaches, in his 13th century *De Vegetabilitus*: '*et conservat a putredine liquores, quibus inmiscetur, sed gravat caput*'.[67] Simon of Genoa's *clavis sanationis*, a medical dictionary from the late thirteenth century, describes hops in detail, and mentions that the flower is used to brew mead.[68]

> *Lupulus est secundum Aben mesue species volubilis et est habens folia similia foliis vitis asperrima, flos eius est sicut ampule adherentes simul et ipsa planta serpit in sepibus, a gallis et theotonicis humulus vocatur cuius florem in medone ponunt.*'
> Lupulus is according to Aben mesue a species of volubilis ['climbing plant'], and it has leaves similar to the leaves of a very rough vine; its flower is like little flasks [ampulle; here: seed cones] clinging together, and this plant spreads in the hedges. It is called humulus by the French [Galli] and the Germans [Theotonici] who put its flower in mead.[69]

Until the 13th century, hops and bog myrtle are described as brewing herbs with comparable functions and apparently comparable preserving effects. Some brewers preferred the one, and some preferred the other. This balance tipped in favour of hops when it became possible to export hopped beer. Herbal beer commerce was mostly confined to its local and perhaps regional area as it did not travel well and would spoil quickly. The improved hopped beer could travel far and wide without ill effects and could keep for months. This made exported hopped beer one of the few foodstuffs of the Middle Ages that could keep for an extended period, which made it a very valuable commodity. Surprisingly, it would take until the 13th century for the export of hopped beer to take off. By this time, hops were widely cultivated in northern Europe. Was it the increase in hop cultivation and the

increased output of hop cones that resulted in the possibility of commercial export? Or was this increase in cultivation and output a direct result of an increase in demand, because hopped beer had become a superior product?

Hopped beer from Bremen, Germany,[70] was exported in large quantities to the Netherlands and Belgium by the 13th century. Hamburg followed Bremen as a major beer producer and exporter, became the beer town of the Hanseatic League, and by 1369 boasted 457 hop breweries.[71] German or Prussian beer, hopped beer from Lubeck, Wismar or Danzig, was exported in large quantities to Denmark and Sweden and by the 14th century hop beer was common. It is likely that by the first half of the 13th century the cultivation of hops had spread to Denmark, to then jump over to Sweden by the end of that century.[72] By the early 14th century, brewers in the northern parts of the Netherlands, recognizing the commercial possibilities, switched over from gruit beer and began producing hopped beer themselves.[73] By 1320 several cities in the northern parts of the Netherlands received the right to produce hopped beer, taxed under the right-to-gruit system,[74] and around the 1360s Dutch towns started growing hops for local production. In 1429 the monastery of Huize Bethlehem asked of the city of Roermond to pay *gruitgeld* in coin instead of brewing gruit beer, as the nuns 'now preferred to drink beer brewed with hop'.[75]

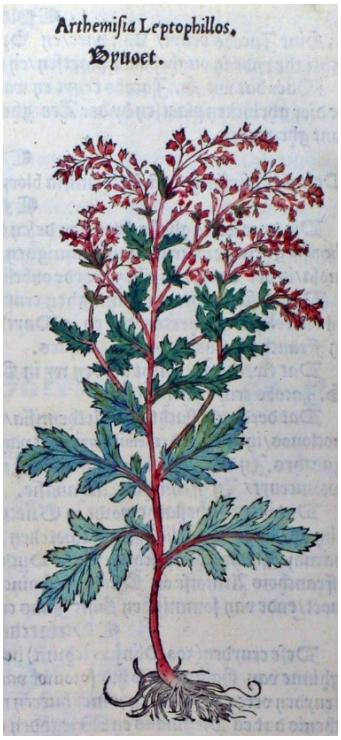
Complaints about the success of hopped beer in continental Europe start around the beginning of the 14th century; some 100 years later the same sort of comments are to be heard in Britain.[76] By the end of the 14th century the Dutch brewed hopped beer to compete with German hopped beer. This Low Countries beer was probably the first foreign hopped beer to enter Britain at around 1362/63. Once again, the English brewers did not adopt this new product as enthusiastically as the rest of Europe. English beer trade and production stayed in the hands of immigrants from the Low Countries for the next century. Caxton, in his 15th century *Boke for Travellers*, distinguishes 'Ale of England, Byre of Ale-mayne [Germany]'.[77] By the beginning of the 16th century, an early British beer recipe can be found in *Arnold's Chronicle* dating to 1503: 'To brewe Beer. X. quarters malte, ij. quarters wheet, ij. quarters ootes, xl. II'. weight of hoppys, To make Ix. harellj of sengyll beer'.[78] In 1531, hops were mentioned among various misuses in the royal household of Henry VIII, and the Royal brewer was instructed 'not to put any hops or brimstone into the ale'.[79] But no matter how conservative the locals were in regards to their unhopped ale, by the early part of the 16th century the first hop plants were cultivated on English soil, most likely in Kent.[80] By 1557 the first instructions for hops cultivation are found in Tusser's poetic *Husbandry*. The first dedicated publication on hops cultivation is published in 1574 by Reginald Scot, called *A Perfite Platform of a Hoppe Garden.* The production of hopped beer followed its export and so did the cultivation of hops, expanding to the north and west. Hops itself had become a valuable traded commodity.[81]

Other botanical beer additives

The archaeological record contains many plants that might have been used in brewing in a similar way to hops and bog myrtle, but there is no clear evidence. Several ancient and medieval herbals and medical manuscripts refer to the medicinal use of botanicals in connection with brewing. With the introduction of printing in the 16th century, the distribution of information became commercialized. Ancient botanical writings reappeared in book form, often under a new title and pretending to be original work.[82] The first books written specifically for brewers were printed in Germany and mention the addition of many botanicals.[83] The question arises: were the botanical additives only added to enhance taste, add medicinal properties - or did they have other, perhaps technical, purposes?

The various reasons attributed to the addition of herbs to beer are myriad, including the tempering of the overly sweet taste of malt-only beer (to explain why bitter herbs like hops were added because 'bitter' is not a naturally pleasant taste); enhancing otherwise bland beer when malt does not add much taste;[84] for personal taste preference; for perceived medical benefits; to make spoiling beer palatable[85] and, last but not the least: for their preserving properties. The answer probably lies somewhere in between: many of the botanicals attributed to brewing are aromatic but also have preservative / medicinal qualities ascribed to them. And many are aromatic due to their essential oils and resin content, and just like hops and bog myrtle, it is these essential oils and resins that have antimicrobial properties.

For instance, areas of northern Germany were part of the gruit tradition but did not have access to local bog myrtle as they were beyond its natural distribution range. Marsh rosemary was used instead of bog myrtle – often indicated under the same name of *pors*.[86] Reputedly, the leaves are more powerful than Labrador tea (*Ledum latifolium* JACQ.) and have some narcotic properties. There is a supposedly widespread belief in Sweden that elks in rutting season get intoxicated and fierce as a result of eating marsh rosemary. Elks eat bog myrtle and are on occasion observed to eat marsh rosemary, but quite rarely, and then only in the spring. The myth could have been inspired by the old tales of the effect of marsh rosemary, and by association bog myrtle, in beer.[87] Marsh rosemary (*Ledum palustre* L.) is a circumpolar aromatic shrub with similar preservative effects to bog myrtle,



Figures 6, 7 & 8. Mugwort (*Artemisia vulgaris L.*), yarrow (*Achillea millefolium L.*) and marsh rosemary (*Ledum palustre L.*). Fig. 7 & 8: Dodoens (1554) with permission of www.biolib.de; Fig. 9: Lobel (1581) googlebooks.

and in West Europe is found in swamps and wet places in northern Germany and Scandinavia. Archaeobotanist Karl-Ernst Behre in his *The History of Beer Additives in Europe*, states that while bog myrtle and hops are used as beer preservatives, the other botanicals – including marsh rosemary – found in the context of brewing 'did not act as preservatives.' This statement contradicts both modern research[88] as well as contemporary accounts. Botanist Tabernaemontanus mentioned in his *Neuw Kreuterbuch* (1588):

> This art of making beer taste better [by preventing it going sour] which our beer brewers seem to have learned from the Flemings and Netherlanders seems still to be carried on, as also the strengthening of beer with laurel, ivy or Dutch myrtle so that it stays well preserved and does not rapidly deteriorate or go sour.[89]

And 16th century botanist Dodonaeus wrote about marsh rosemary specifically, and mentions that: "this rosemary is cooked in the beer; from which it receives a lovely taste, and preserves it well'.[90]

Current research indicates marsh rosemary, as well as laurel berries (*Laurus nobilis* L.),[91] juniper (*Juniperus communis* L.), yarrow (*Achillea millefolium* L.), mugwort (*Artemisia vulgaris* L.),[92] broom (*Cytisus scoparius* L.), caraway (*Carum carvi* L.), *Iris* sp. and pine resin all add preservative properties to brewing, and they were supposedly often used in combination to boost this effect. Early written mentions of botanicals used in brewing in Britain are scarce, although there are a few. Scandinavian brewers used hops as well as bog myrtle, yarrow and pine resin and Low Country gruit brewers used a similar combination of bog myrtle, laurel berries, laserwort and pine resin. Other botanicals included in Behre's list of beer 'flavourings' include rosemary (*Rosmarinus officinalis* L.), sage (*Salvia officinalis* L.), thyme (*Thymus serpyllum* L.), oregano (*Origanum vulgare* L.) and lavender (*Lavandula angustifolia* L.)[93] - all fragrant herbs used in the kitchen as well as medicinally for the antioxidant and antimicrobial properties of their essential oils. Perhaps the use of beer additives in historic brewing was not solely for 'a lovely taste,' perhaps function also guided the choice of ingredients. When English botanist Culpepper discusses hops in his 17th century publication *Complete Herbal* he concludes 'By all these testimonies [hopped] beer appears to be better than [unhopped] ale,' and does not mention flavour, only its perceived health benefits.[94]

Figure 9. Wormwood (*Artemisia absinthium L.*) as illustrated by Dodoens (1554). with permission of www.biolib.de

An alternate, and intriguing, reason to use botanical additives in brewing is for intended intoxicating side-effects. Wormwood (*Artemisia absinthium* L.) is used to make the drink absinthe and might be the best known of the toxic herbal additives. Other, more deadly additives were henbane (*Hyoscyamus niger* L.),[95] deadly nightshade (*Atropa belladonna* L.), jimsonweed (*Datura stramonium* L.) and *Anamirta cocculus*, the source of the medieval c*occulus indicus* - all connected to the production of psychotropic beverages. Where henbane has a prehistoric reputation for hallucinating brews,[96] *Cocculus indicus* is a more recent historic adulteration. The berry *cocculus indicus* is the source of picrotoxin, a poisonous alkaloid with stimulant properties, which simulated the warming effects of alcohol giving the impression of a heavier beer. Other additives, in this case fraudulent adulterations, like horseradish, black pepper, cinnamon and ginger could in a similar fashion create the illusion of strength, enticing the customer to pay more for their brew.[97] 16th century German Tabernaemontanus mentioned in his *Neuw Kreuterbuch* under 'brewing beer':

> But those who strengthen the beer with seeds or soot, Indian beans [*cocculus indicus*] and other similar harmful things should be scorned or condemned.[98]

Dutch botanist Dodonaeus of the same era also had a low opinion of these adulterated brews, and laments on this High and Low Country (German and Dutch Low Countries) brewing of beer:

> [Brewed] with sometimes hops, gentian, laurel berries, zedoar [*Curcuma zedoaria*], bog myrtle, *Inula* sp. root, lavender, sage, flowers of Horminum or scharley [*Horminum pyrenaicum*], Cocculus indicus [*Anamirta cocculus*] or some of the species of dimming nightshade [*Atropa* sp.], *Physalis* sp., ground pine [*Ajuga chamaepitys*] and cooked with other similar herbs: and from this the beers become so diverse of force, that they should be called mixed drinks, and not beers.[99]

Perhaps to counteract brewing with fraudulent, and toxic, ingredients, beer laws stipulating which ingredients were allowed in brewing commercial beer came into being. The most well-known of these beer purity laws is the 1516 *Reinheitsgebot*, instated by Bavarian Duke Wilhelm IV and stipulating that only barley, water and hops could be used to brew beer,[100] but it is not always realized it was preceded by other purity laws. No less than 248 years earlier, in 1268, King Louis IX of France passed a beer purity law that stipulated that, in his realm, only malt and hops were to be used for brewing beer.[101] And in 1447, Munich, Germany, instated their version regulating brewers to only use malt, water and hops.[102] The fraudulent practice of adding psychotropic botanicals to beer might also account for the dangerous reputation of bog myrtle. As modern research has failed to find ingredients in bog myrtle that are poisonous,[103] perhaps, this harmful reputation had more to do with negative propaganda than with factual toxicity.

How hops outcompeted other herbal beers

By now, it should be well established that both hops and bog myrtle were in use as beer additives throughout the Middle Ages. In its natural distribution area of the Low Countries (currently the Netherlands, Belgium, a sliver of northern

Figure 10. Brewing beer in wooden vats; illustration from the *Historia de Gentibus Septentrionalibus* (A Description of the Northern Peoples) (1555) by Olaus Magnus. With permission from the Silver Special Collections Library, University of Vermont, Burlington VT

France and northern Germany), as well as Britain and southern Scandinavia, bog myrtle was often the main additive to the brewing of beer. During that same time, the rest of Europe, including eastern Europe and likely beyond, which was outside bog myrtle's habitat, commonly used hops as their main brewing additive. The history of bog myrtle and hops ran side by side for centuries. This makes it unlikely hops alone outcompeted bog myrtle, and all other botanical additives. Something else changed, which is what we will look at next.

The hop cone *bracteoles* contain lupulin glands that produce essential oils and resins - the main source of bittering agents *lupulone* and *humulone*. Humulone is a type of alpha-acid, one of several produced by hops, and alpha-acids do not dissolve easily in water. Undissolved alpha-acids do not get into contact with bacteria very easily and are not very bitter. Heating the liquid containing the hops makes the water molecules vibrate faster, causing them to collide with each other and the alpha-acids, more often and more strongly. This causes one of the alpha-acid chemical bonds to change angle, creating an iso-alpha acid. In this process of isomerization, the alpha acid molecule continues to be composed of the same atoms, indicated by the same formula, but with a different molecular shape. The level of isomerization, the amount of iso-alpha acids, is measured in IBUs. More heat, and more time, increases the stimulation, causing more of the alpha acids to become isomerized (a typical one-hour boil on average only causes about a 30% conversion). Iso-alpha acids dissolve much more effectively into beer, bringing them into closer contact with spoilage bacteria and thus significantly enhancing their inhibiting effects.[104]

Research into prehistoric and early modern brewing indicates pre-hop brewers likely did not boil wort as part of their brewing process – they brewed 'raw ale' which saves time, resources and can be done with limited equipment.[105] During the mash, the temperatures of the grain infusion would only be raised high enough for the best temperature for starch conversion. Once this stage finished the mash is filtered, and the run-out of the mash, the wort, would be immediately cooled down to prepare for fermentation, instead of first boiled and then cooled down. The starch conversion temperatures pasteurized the wort and boiling it as well would generally not be an effective use of resources. Any additives could be added either during the heating process in the mash, during the cool-down period in the wort, or in the fermenting tun.[106] Active boiling of the wort requires large equipment (large kettles were huge investments) and large amounts of resources (fuel) and why do so if there was no

perceived benefit. After the superior preservative effects of boiled hops became common knowledge, Eastern European brewers utilized an ingenious work-around as out of the way areas did not have easy access to large kettles. Rural brewers would mash using for instance heated rocks in wooden tuns, but then also boil a separate concentrated hop tisane in a smaller cooking vessel. This hop-tea would then be added back to the wort prior to fermentation.[107]

By the 13th century, hopped beer became an export product, even to areas that traditionally used gruit. This strong competition in frontier areas where both beers were available is visible in the many regulations set forth in historic documents. From the 14th century onwards, beer brewed with gruit and bog myrtle was in decline throughout the Low Countries. Local producers did not give up easily, as the right to gruit was very profitable to those in possession of it. By this time many cities had managed to come into possession of the right to gruit from the local nobility and churches, which meant city governments acquired a reliable system to generate city income by taxing the production of beer – a very lucrative endeavour indeed.[108] Then, in 1364 Bishop John of Utrecht complained that for the past 30 or 40 years a new method of brewing had been introduced, with the addition of a certain plant called humulus or hoppa, and that his income from gruitgeld had declined drastically as a result.

Nunc autem de novo triginta vel quadraginta annis nondum elapsis novus modus fermentandi cervisiam, videlicet per appositionem cujusdam herbæ, qua humulus vel hoppa vocatur, per incolas in tantum invaluit, ut episcopus Trajectensis in magna parte emolumenti, quod ex distributione fermenti sibi evenire conseuverat,diminutionem patiatur.[109]

As we've seen that hops had been used in brewing for centuries, the significance of this passage is not 'the addition of a certain plant called humulus' - what is significant is the '*novus modus fermentandi*.' This 'new method of brewing' with hops, possibly alluding to the discovery of optimal isomerization and the resulting possibility of export, was a significant threat to the existing small-scale regional beer trade. Not wanting anything to interfere with the lucrative franchise of gruit, at first hopped beer and later hops were banned from import and sale. This ban was not feasible, and instead hops was absorbed into the taxation system of gruit, and gruit taxation itself evolved into excise taxation. Late medieval city accounts show purchases of hops alongside the typical gruit ingredients of malt, bog myrtle, laurel berries, laserwort and pine resin.[110]

As indicated previously, to hasten the transition to hopped beers into non-hop areas, rumours were spread that beer made with bog myrtle was harmful for drinkers; that excessive drinking could lead to blindness and even death.[111] One would assume these rumours came from the area having the most to gain from the sales of hopped beer in areas otherwise drinking something else. And indeed, not only did Germany excel at producing and exporting hopped beer, it also first fined and then forbade altogether the production of bog myrtle and other herbal beers.[112] In the fine tradition of propaganda, this smear campaign turned around in Britain, where hopped beer was introduced a few centuries later to compete with the local ale. According to Andrew Boorde (1567) 'Ale for an englysh man is a natural drynke' as opposed to hopped beer which 'doth make a man fat, & doth inflate the bely, as it doth appere by the dutche mens faces & belyes'.[113] In London, Dutch brewers were forcibly prevented from brewing beer on the grounds it was not fit to drink, it was poisonous and caused drunkenness. But then, in 1436, the London sheriffs were informed all brewers of beer should continue their art as 'it is a wholesome drink, especially in summer'.[114] The commercial advantage of hopped beer proved too much for unhopped beer and ale. Hopped beer, brewed correctly, keeps much longer than unhopped beers, making it possible for the production of beer to become a professional occupation and the scale of brewing to increase. Gruit beer and other herbal beers had a relatively high alcohol content to preserve it for a reasonable amount of time. This required a larger amount of expensive malted grain, or the addition of concentrated malt extract, to boost the level of fermentable sugars. Hop farmer Reginald Scot proclaimed in his *A Perfite Platform of a Hoppe Garden* (1576):

> And in the favor of the Hoppe thus much more I say that whereas you cannot make above eyght or nyne gallons of indifferent Ale, out of one bushell of Mault, you may draw XVIII or XX gallons of very good Beere.[115]

Throughout the Middle Ages, grain shortages were common in the Low Countries and its scarcity had to be overcome by increased imports. Because the preservative effects of hops reduces contamination, the alcohol levels (and thus grain content) could be lower, making hopped beer more cost-effective to brew, as well as having significant shelf-life.[116]

Summary

During the Middle Ages, hopped and other botanical based beers were brewed side by side. Until the 13th century, bog myrtle was the prevailing beer additive inside its natural distribution area, and hops the most common additive beyond it.[117] Not until strong competition developed between hopped and native beers in the Late Middle Ages did this balance between the two types of brewing tip to favour hops.

The embrace, with occasional challenges, of a competing product previously ignored by regions invested in a different technique can be explained if the new and improved product brings something to the table that the native products did not. For centuries hopped beer existed side by side with other native beers, because all were functionally comparable. Not until the discovery and development of full isomerization techniques did this equilibrium change, and hopped beer rose head and shoulders above its competitors – outcompeting all other herbal beers to the point the existence of unhopped beers was nearly forgotten.

References

1. Behre, K.-E. (1999) 'The history of beer additives in Europe - a review.' *Vegetation History and Archaeobotany*. 8, p.44 https://www.academia.edu/17566335/The_history_of_beer_additives_in_Europe_-_a_review

2. The dictionary description: 'an authorization granted by a government or company to an individual or group enabling them to carry out specified commercial activities' which adequately describes the right to gruit.

3. McGovern, P.E. et al (2004) 'Fermented beverages of pre- and proto-historic China', *PNAS*. http://www.pnas.org/content/101/51/17593.full.pdf

4. Hornsey, I.S. (2003) *A History of Beer and Brewing*. Cambridge: The Royal Society of Chemistry. p.363 https://www.academia.edu/22980855/A_History_of_Beer_and_Brewing; Dineley, M. (2004) 'Barley Malt and Ale in the Neolithic', *British Archaeological Report.* S1213, p.7. https://www.academia.edu/209786/Barley_Malt_and_Ale_in_the_Neolithic

5. The author chose to use the medieval definition of beer and ale throughout this paper, in which *beer* indicates hopped and non-hopped Continental malt beverages, and *ale* indicates the British non-hopped malt beverage.

6. Behre, K.-E. (1999) op. cit. p.36.

7. ibid., p.36.

8. ibid.

9. ibid.

10. ibid., p.39.

11. Cockayne, T.O. (1864-6) *Leechdoms, Wortcunning, and Starcraft of Early England: Being a Collection of Documents, for the Most Part Never Before Printed, Illustrating the History of Science in this Country Before the Norman Conquest.* Vol. I (1864). London: Longman, Green, Longman, Roberts, and Green, p.265-6 https://books.google.com/books?id=s8tdBaajK_wC&source=gbs_navlinks_s Vol. III (1866): Longman & Company https://books.google.com/books?id=UNU9AAAAcAAJ: 'A light drink; take gagel, or sweet gale, boil it in wort of beer, then let it stand a little, remove the gagel, then add new yeast, then wrap it up that it may rise well, then add helenium, and wormwood, and betony, and marche, and ontre; give the man this to drink.'

12. Berendes in Goslar, J. (1896 & 7) *Die Physica der heiligen Hildegard.* pp.62-63 https://publikationsserver.tu-braunschweig.de/receive/dbbs_mods_00036485

13. Throop did not provide modern identifications for the botanicals listed in her translation *Hildegard von Bingen's Physica: The Complete English Translation of Her Classic Work on Health and Healing* (1998). 19th century pharmaceutical historian Julius von Berendes did and provides *Myrtle communis* in his publication *Die Physica der heiligen Hildegard* (1896 & 7) pp.62-63: https://publikationsserver.tu-braunschweig.de/servlets/MCRFileNodeServlet/dbbs_derivate_00015880/gesamtwerk.pdf He identified Mirtelbaum as Myrtle communis, the common or true myrtle, a fragrant small tree native to the Mediterranean region, which is also the common modern German definition. True myrtle is comparable to the bay laurel, of which the leaves are used in cooking (bay leaves), and the berries in brewing (laurel berries). This makes Hildegards' description plausible for both true myrtle and bog myrtle. But as *Mirtelbaum* is listed as a local alternate for bog myrtle (https://de.wikipedia.org/wiki/Gagelstrauch) and the treatise does not contain an alternate entry for bog myrtle, it stands to reason Hildegard meant bog myrtle in her treatise.

14. Hofsten, N. von (1960) *Pors och andra humleersättningar och ölkryddor i äldre tider (Summary) Bog myrtle '(Myrica gale)' and other substitutes for hops in former times.* Acta Academiae Regiae Gustavi Adolphi, 36. Uppsala: A.-B. Lundequist i distr. Kbh.: Ejnar Munksgaard; Nordland, O. (1969) *Brewing and Beer Traditions in Norway.* Oslo: Universitesforlaget. p.216.

15. Nordland O. (1969) op. cit., p.216; Sloth, P.R. Hansen, U.L. & Karg, S. (2012) 'Viking Age garden plants from southern Scandinavia – diversity, taphonomy and cultural aspects,' *Danish Journal of Archaeology*. 1:1, p.28.

16. Verberg, S. (2018) 'The Rise and Fall of Gruit,' *Brewery History.* 174, p.60.

17. Technically, the different grout houses are not competitors as they are legally not allowed to sell in each other's territories.

18. Anise and caraway are of the same family as laserwort; juniper is a well-known source of resin.

19. Jappe Alberts, W. (1951) 'Bijdrage tot de geschiedenis der accijnzen te Arnhem in de Middeleeuwen,' *Tijdschrift voor geschiedenis.* p.338.

20. http://lcweb2.loc.gov/cgi-bin/ampage?collId=rbc3&fileName=rbc0001_2008rosen0080page.db&recNum=282

21. Lobel, M. de (L'Obel; Lobelius) (1581) *Kruydtboeck oft beschryvinghe van allerleye ghewassen, kruyderen, hesteren, ende gheboomten.* Christoffel Plantyn. (1st ed. 1551) https://books.google.com/books?id=77Z0c6tG6B8C; Meussdoerffer, F.G. (2009) 'A Comprehensive History of Beer Brewing' in Eßlinger, H.M. (ed.) *Handbook of Brewing: Process, Technology, Markets.* Weinheim: Wiley-VCH Verlag GmbH & Co. p.12; Verberg, S. (2018) op. cit., p.62.

22. Schookius, M. (Schook) *Libre de cervisiae* (1661) p.216;

Verberg, S. (2018) op. cit., p.62.

23. Verberg, S. (2018) op. cit., pp.58-59 *Nimweegse Mol* is an example of 16th century Dutch barrel-carbonated beer through the addition of malt extract *naerbier* just before barreling.

24. Karkeek, P.Q. (1877) 'White Ale', *Reports and Transactions of the Devonshire Association for the Advancement of Science, Literature and Art*. Vol. IX. Plymouth: W. Brendon & Son. p.188. https://archive.org/details/reportandtransa19artgoog/page/n5/mode/2up; Verberg, S. (2018) op. cit. pp.50-51.

25. There is no record of British *grout* including botanicals; Verberg, S. (2018) op. cit. pp.52-53.

26. Behre, K.-E. (1999) op. cit. p.43.

27. Sloth, P.R et al (2012) op. cit. p.28.

28. Behre, K.-E. (1999) op. cit. p.39.

29. Hop shoots were known in Sweden as 'poor man's asparagus' and were eaten like asparagus in the Low Countries. Dewes (1578) p.431: 'For the same purpose serueth the young springes and tender croppes, at their first comming foorth of the grounde in Marche and Aprill, to be eaten in Salade.' See 'The World's Most Expensive Vegetable' (2012) at https://www.smithsonianmag.com/arts-culture/the-worlds-most-expensive-vegetable-72826862/ for modern consumption of hop shoots.

30. Wilson, D.G. (1975) 'Plant Remains from the Graveney boat and the early history of Humulus lupulus L. in W. Europe', *New Phytology*. 75, p.638: the leaves and cones yield a yellow dye.

31. ibid., p.637.

32. Like hemp and nettles (both fiber crops), hops is part of the *Cannabaceae* family; Wilson, D.G (1975) op. cit. p.634: Macrofossils of *H. lupulus* are not easily confused with those of *Cannabis sativa* L. Unfortunately, pollen is very similar to hemp, complicating conclusive archaeological identification.

33. Nordland, O. (1969) op. cit. pp.205-227.

34. Suggs, M. (2018): https://mishabrews.com/2018/06/17/brew-day-june-2018-hopleaf-mead/ As part of the Venetian Embassy to the Shah of Iran from 1472-1475, Ambrosio Contarini visited Moscow for about six months. The following entry was found in their travelogue: 'They have no wine of any kind, but drink a beverage made of honey and the leaves of the hop, which is certainly not a bad drink, especially when aged.'

35. Behre, K.-E. (1999) op. cit. p.39.

36. http://www.brianstechschulte.com/wp-content/uploads/2014/08/Hop-Anatomy-BS.jpg

37. Behre, K.-E. (1999) op. cit. pp.39-40.

38. Sloth, P.R et al (2012) op. cit. p.31.

39. ibid.

40. Behre, K.-E. (1999) op. cit. p.40; Meussdoerffer, F.G. (2009) op. cit. p.11; Sloth, P.R. et al. (2012) op. cit. p.29; Wilson, D.G (1975) op. cit. p.637.

41. Sloth, P.R. et al. (2012) op. cit. p.29.

42. ibid. p.33

43. Behre, K.-E. (1999) op. cit. p. 40; Meussdoerffer, F.G. (2009) op. cit. p.11; Wilson, D.G (1975) op. cit.

44. Hagen, A. (2010) *Anglo-Saxon Food and Drink: Production, Processing, Distribution and Consumption*. Ely: Anglo-Saxon Books, p.206; Wilson, D.G (1975) op. cit. p.637.

45. Hagen, A. (2010) op. cit. p.206.

46. Cockayne, T.O. (1864-6) op. cit. p.393; Hagen, A. (2010) op. cit. p.206.

47. Behre, K.-E. (1999) op. cit. p.41; Hornsey, I.S. (2003) op. cit. p.307; Meussdoerffer, F.G. (2009) op. cit. p.11.

48. Behre, K.-E. (1999) op. cit. pp.39-41.

49. Hornsey, I.S. (2003) op. cit. p.304.

50. Corran, H.S (1975) *A History of Brewing*. Newton Abbot: David and Charles. p.42

51. Hornsey, I.S. (2003) op. cit. pp.306-7.

52. Wilson, D.G (1975) op. cit. p.640: The beer-words and intoxication-words used are linked with hop-words in Old Slavic, Estonian, Lettic, Finnish etc and not to the Germanic or Romance languages, but as the Kalevala was not written down until the 17th century, Wilson is not convinced the connection is conclusive. He goes on to say: 'If hopped beer *was* known at this time, trade links between the Roman world, Denmark and the Baltic, and C. Europe, including Bohemia and Hungary would have enabled the knowledge to spread throughout Europe.'

53. Hornsey, I.S. (2003) op. cit. p.304.

54. ibid.

55. ibid. pp.304-5.

56. Behre, K.-E. (1999) op. cit. p.42; Hornsey, I.S. (2003) op. cit. p.305; Meussdoerffer, F.G. (2009) op. cit. p.11.

57. Hornsey, I.S. (2003) op. cit. p.305.

58. Behre, K.-E. (1999) op. cit. p.42; Hornsey, I.S. (2003) op. cit. p.307; Wilson, D.G (1975) op. cit. p.644.

59. Cockayne, T.O. (1864-6) op. cit. p.50; The following 10th century medicinal salve recipe includes several brewing related plants: 'This is the green salve ; betony, rue, lovage, fennel, sage, stitchwort, savine, tansy, roots of comfrey, sclarea, marche, chervil, ravens foot, mugwort, origanum, orache, cinqfoil, valerian, burdock, meadwort [meadowsweet], pennyroyal, pimpernel, turnsol, bishop-wort, hazel, quince, hedgecliver, groundsel, brookmint, and other mints, chicken meat, sweet gale, hedge hop plant, costmary [alecost], earth navel or asparagus, nut beams leaves, laurel berries, cumin, oil, wax.'

60. Behre, K.-E. (1999) op. cit. p.42; Hornsey, I.S. (2003) op. cit. p.305.

61. Cockayne, T.O. (1864-6) op. cit. p.392-93.

62. Arnold, J.P. (1911) [2005] *Origin and History of Beer and Brewing*. Cleveland, Ohio: Beer Books.p.371

63. Wilson, D.G (1975) op. cit. p.645

64. http://www.simonofgenoa.org/index.php?title=Lupulus

65. Arnold, J.P. (1911) [2005] op. cit. p.373.

66. Throop, P. (1998) *Hildegard von Bingen's Physica: The Complete English Translation of Her Classic Work on Health and Healing.* New York: Simon and Schuster.

67. Saint Albertus (Magnus) *Alberti Magni ex ordine praedicatorum de vegetabilibus libri VII.* G. Reimeri (1867) pp.525-526: https://books.google.com/books?id=euAHAAAAIAAJ

&source=gbs_navlinks_s

68. Central Europe as well as Scandinavia have long-standing traditions of brewing mead with hops, but a surprising lack of written evidence. The following publications mention mead recipes including hops: *Historia de Gentibus Septentrionalibus* (1555) (The History of the Northern People), *Le Thresor de santé* (1607), the Danish *Koge Bog* (1616) and the anonymous *Domostroi* (1600-1625): Rules for Russian Households in the Time of Ivan the Terrible.

69. http://www.simonofgenoa.org/index.php?title=Lupulus

70. Behre, K.-E. (1999) op. cit. p.42; Meussdoerffer, F.G. (2009) op. cit. p.16: beer from Bremen is mentioned in the Netherlands in the provinces of Holland in 1252 and in the city of Groningen in 1278.

71. Behre, K.-E. (1999) op. cit. p.42; Meussdoerffer, F.G. (2009) op. cit. p.16.

72. Hornsey, I.S. (2003) op. cit. p.307; Nordland O. (1969) op. cit., p.203.

73. Hornsey, I.S. (2003) op. cit. pp.359-60: 'The difficulties experienced by brewers wishing to utilise hops in Holland must have been quite marked, however, for, not only did Dutch brewers leave their native land to ply their trade in Hamburg but, in other locations in Europe as well [...] and it becomes unsurprising that they sought pastures new, thus helping to disseminate the technology associated with brewing beer.'

74. Verberg, S. (2018) op. cit., p.57: 'The Dutch [provinces of Holland] production of hopped beer was permitted from 1321 and by 1322 Dordrecht brewed hopped beer called *ael*. Delft was brewing hopped beer by 1326 and Haarlem by 1327 all three northern cities went on to have great brewing and trading traditions.'

75. ibid. p.57.

76. Hornsey, I.S. (2003) op. cit. p.306.

77. Way, A. (1843) *Promptorium pravulorum sive clericorum: dictionarius anglo-latinus princeps*, Vol. 1. sumptibus Societatis camdenensis. https://books.google.com/books?id=G_DgAAAAMAAJ p.245.

78. Richard Arnold (1503) The Customs of London, otherwise called Arnold's Chronicle (To brew beer: 10 quarters of malt, 2 quarters of wheat, and 2 quarters of oats, with 40 pounds of hops. To make 60 barrels of single beer). https://babel.hathitrust.org/cgi/pt?id=gri.ark:/13960/t8sb6k294;view=1up;seq=349

79. Way, A. (1843) op. cit. p.245: A similar quote mentioned that the 'the wicked weed called hops' was forbidden by Henry VI but Way found no record of the prohibition, the petition does not appear on the Rolls of Parliament.

80. Cornell, M. (2009): http://zythophile.co.uk/2009/11/20/a-short-history-of-hops/; Way, A. (1843) op. cit. p.245: Bullein, in the 'Bulwarke of defence,' (ca. 1550) speaks of hops as growing in Suffolk. Hops are mentioned in statutes 5 and 6 by Edward VI, 1552, as cultivated in England.

81. Behre, K.-E. (1999) op. cit. p.42.

82. Wilson, D.G (1975) op. cit. p.638.

83. Behre, K.-E. (1999) op. cit. p.43.

84. ibid. p.35: 'Starch, however, does not have much taste, so additional flavouring agents are necessary to improve the quality and taste of beer.'

85. De Vreese, W. (1894) *Middelnederlandsche geneeskundige recepten en tractaten, zegeningen en tooverformules*: 'For to make beer, that went bad, better and taste like *herlantsbier*, take powder of bay[berries], powder of juniper, powder of bog myrtle seeds, and powder of the nuts of nutmegs. Do this in the barrel or the pitcher, let stand 1 night.'

86. ibid. p.61: 'In Western Germany *gagel* ordinarily meant marsh rosemary but could also refer bog myrtle, and in Germany and Scandinavia *pors* ordinarily meant marsh rosemary but could also refer to bog myrtle. This made identification rather confusing, until their habitats are checked: the two plants mostly grow in exclusive habitats.'

87. Von Hofsten, N. (1960) *Pors och andra humleersättningar och ölkryddor i äldre tider (Summary) Bog myrtle '(Myrica gale)' and other substitutes for hops in former times.* Acta Academiae Regiae Gustavi Adolphi, 36. Uppsala: A.-B. Lundequist i distr. Kbh.: Ejnar Munksgaard. p.216.

88. Cursory internet queries confirm the antimicrobial effects of these and many of the botanicals mentioned by name by Behre.

89. Hornsey, I.S. (2003) op. cit. pp.357-58.

90. De Vreese, W. (1894) op. cit. p.62.

91. The use of bayberries (the berries of the bay laurel) was not restricted to Continental Europe, Britain also was familiar with this now forgotten brewing additive: 'Two amusing notes are of the rainy season of 1563, which caused such a dearth of hops that beer was brewed with broom (*Cytisus scoparius* L.) and bay-berries, and of the abundance of fruit in the following summer.' Stow, John (1910) *A Brief London Chronicle: 1547-1564*. Camden Miscellany Vol XII. Reprint of the 1564 ed. Edited by Charles Lethbridge Kingsford. London: Royal Historical Society. https://archive.org/details/twolondonchronic00stowrich/page/n0 as well as 'she addeth to her brackwoort or charwoort half an ounce of arras [orris or *Iris* root], and half a quarter of an ounce of bayberries, finely powdered, and then, putting the same into her woort,' in William Harrison (1577) *Description of Elizabethan England*.

92. Dodoens, R. (Dodonaeus) (1554) *Cruijdeboek*. https://leesmaar.nl/cruijdeboeck/index.htm p.20: '*Byvoet es oock van dijer cracht dat zy bier daer zy in ghehanghen oft gheworpen wordt bewaert dattet niet lichtelijcken suer en wordt*.' Mugwort is also of such strength that it suspended or thrown in beer prevents that it does not somewhat sours; Dewes (1578), p.17: 'mugworte. If it be hanged or cast into barrels or hoggesheads of Bier, it will preserue the same from sowring.'

93. Behre, K.-E. (1999) op. cit. p.42.

94. http://www.complete-herbal.com/culpepper/hops.htm; the health benefits mentioned include the curing of various skin diseases (due to its antimicrobial effect) and the killing of intestinal worms (pesticide). This function as a pesticide is also found for bog myrtle, marsh rosemary and other botanicals with preserving effects.

95. Dewes (1578), p.451: 'The leaues, seede, and iuyce of Henbane, but especially of the blacke kinde, the which is very common in this Countrie, taken either alone or with wine, causeth raging, and long sleepe, almost like unto dronkenesse, which remayneth a long space, and afterwarde killeth the partie.'

96. Dineley, M. (2004) op. cit. http://merryn.dineley.com/2014/05/controversy-in-grooved-ware-bucket.html

97. https://beerandbrewing.com/dictionary/qNVpX9ISBa/

98. Hornsey, I.S. (2003) op. cit. p.358.

99. Dodonaeus, R. (1644) p.815, 2nd column, top; also found in Lobel (1581) p.42.

100. Corran, H.S (1975) op. cit. p.47; https://beerandbrewing.com/dictionary/7SMpZlapQl/

101. https://beerandbrewing.com/dictionary/pWIUh7fyhy/

102. Corran, H.S (1975) op. cit. p.47: again in 1487 for Munich, and in 1493 for the Landsheit area; https://beerandbrewing.com/dictionary/JE21QkzMmR/

103. Behre, K.-E. (1999) op. cit. p.43.

104. Garshol, L.M. (2015): http://www.garshol.priv.no/blog/337.html

105. Dineley, M. (2004) op. cit.: 'ancient style ales, when the wort is not boiled, a raw ale.' http://merryn.dineley.com/2018/03/mashing-and-bit-on-fermentation.html More on traditional Scandinavian raw ale, regarded as a living-history example of ancient brewing techniques: Laitinen, M. (2019) *Viking Age Brew: The Craft of Brewing Sahti Farmhouse Ale*. Chicago, IL: Chicago Review Press; Nordland, O. (1969) op. cit. pp.190-94 and Garshol, L.M. (2015): http://www.garshol.priv.no/blog/331.html

106. Cornell, M. (2009): http://zythophile.co.uk/2009/11/20/a-short-history-of-hops/

107. Laitinen, M. (2019) op. cit.; Nordland, O. (1969) op. cit. pp.226-27.

108. Unger, R.W. (2004) *Beer in the Middle Ages and the Renaissance*. Philadelphia: University of Pennsylvania Press; p.197: The income from the taxation of beer could be more than 50% of the total tax income for towns and cities, even up to 88.5% for 1437-1438 in Haarlem, the Netherlands.

109. Corran, H.S (1975) op. cit. p. 44; Verberg (2018) pp.56/74: 'But now, these past 30 or 40 years, a new method of fermenting beer has been found. By the addition of certain plants or the humulus or hop as called by the natives, [the beer] is much stronger and it diminishes [the income] of the bishop of Utrecht, a big recipient of the benefit and distributor of gruit, and the result conserves [the beer] and diminishes things [i.e gruit].'

110. Verberg, S. (2018) op. cit., p.60.

111. Behre, K.-E. (1999) op. cit. p.43; Hornsey, I.S. (2003) op. cit. p.260.

112. Hornsey, I.S. (2003) op. cit. p.361: 'In some parts of Europe, notably Germany, pro-active measures were taken with a view to ensuring the universal popularity of the hop. Provincial laws in Bavaria, of 1553 and 1616, imposed severe penalties on anyone brewing ale with herbs and seeds not normally used for ale. Similar laws were passed in Holstein, one of which, in 1623, specifically banned the use of Post (bog myrtle) and other "unhealthy material", whilst as late as 1723, the laws of Brunswick-Luneburg prohibited the brewer from having Post, or other potent herbs, in his brewery.'

113. Andrewe Boorde (1567) *A compendyous regyment or a dyetary of healthe* https://quod.lib.umich.edu/e/eebo/A16471.0001.001/1:12.3?rgn=div2;view=fulltext 'Bere is made of malte, of hoppes, and wa|ter, it is a naturall drynke for a dutche man. And nowe of late dayes it is moche vsed in Englande to the detrime¯t of many englysshe me¯, specially it kylleth the¯ the which be trou¦bled with the colyke & the stone & the stra¯gu|lyon, for the drynke is a colde drynke: yet it doth make a man fat, & doth inflate the bely, as it doth appere by the dutche mens faces & belyes. If the bere be wel brude and fyned, it dothe qualyfye the heate of the iyuer.' Verberg, S. (2018) op. cit., p.57: 'This point of view changed swiftly and within a century their own ale was seen as an unmanly drink, fit only for women and the sick'; Wubs-Mrozewicz, J. (2005) 'Hopped Beer as an Innovation' in Brand, H. (ed.) *Trade, diplomacy and cultural exchange. Continuity and change in the North Sea area and the Baltic c.1350-1750.* Hilversum: Uitgeverij Verloren. https://www.academia.edu/3388347/_Hopped_beer_as_an_innovation._The_Bergen_beer_market_around_1200-1600_in_the_European_context_in_H._Brand_ed._Trade_Diplomacy_and_Cultural_Exchange_2005_pp._152-168 pp.155-6.

114. Corran, H.S (1975) op. cit. p.44.

115. ibid. p.45; Scot, R. (1576) *A perfite platforme of a hoppe garden: and necessarie instructions for the making and mayntenaunce thereof: with notes and rules for reformation of all abuses, commonly practised therein, very necessarie and expedient for all men to haue, which in any wise haue to doe with hops.* London: Henrie Denham (first edition 1574) https://www.loc.gov/item/2004574086/

116. Verberg, S. (2018) op. cit., p.56; Wubs-Mrozewicz, J. (2005) op. cit. pp.155-6, 167.

117. Behre, K.-E. (1999) op. cit. p.44.