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**BREWING BEER IN THE MIDDLE AGES (750-1500):  
BEER PRODUCTION AND PRODUCT DIFFERENTIATION  
IN MEDIEVAL NORTHERN GERMANY. PART I****JOHANNE STEENSGAARD NIELSEN****Introduction**

In recent years, consumption and the emergence of consumerism in the late Middle Ages have received increased attention from scholars in a variety of disciplines.<sup>1</sup> The ‘miracle’ of economic development after the Industrial Revolution is now more often set within its historical context.<sup>2</sup> Today, economic historians frequently refer to an ‘Industrious Revolution’<sup>3</sup> between 1600-1800, they debate a ‘Consumer Revolution’<sup>4</sup> in the Early Modern period, and discuss to what degree we can speak of (proto)industrial activities in the Middle Ages.<sup>5</sup> Thus, the Industrial Revolution is increasingly explained as a phenomenon of continuity from emerging economically integrated and progressive Northern European societies, which had been developing for centuries, rather than a sudden break with old, ineffective economic systems.<sup>6</sup>

However, we still have precious little knowledge of economic development in the Pre-Modern period. In this framework, it is important to investigate how ‘industries’ transformed as real wages rose in the late Middle Ages.<sup>7</sup> Consequently, we can expect that an increasing part of the population became capable of consuming beyond the bare necessities of life and, thus, generated the basis for economic progress. From the 11<sup>th</sup> century urbanisation increased together with specialisation and professionalism.<sup>8</sup> In this context, beer brewing is an important ‘industry’ to examine as beer was a commodity in daily demand and the industry evolved from mainly home production towards becoming highly professionalised in the late Middle Ages.<sup>9</sup>

This investigation will focus on the production of beer from the Early Middle Ages to the end of 15<sup>th</sup> century in Northern Germany, as it was in this region that long distance trade in beer first evolved.<sup>10</sup> The study of beer production suffers from some major issues in the current literature which will be analysed below, yet detailed knowledge of the transformations and innovations of its production can reveal nuances of what was possible both to achieve as a producer and as a consumer - in sum, the basis of economic exchange within one of the most significant industries of the time.

The challenge of studying pre-modern production is the scarcity and inconsistency of source material. Particularly, no detailed recipes exist, although some statutes reveal regulations of some of the ingredients. Also missing are explanations of how brewing was conducted, but testaments and statutes describe some of the utensils used and the issues the industry created for other producers and neighbours. Furthermore, brewers did not keep detailed account books of their products or, if they did, they are no longer extant. However, household accounts, price statutes, and tolls reveal the names of products which were in circulation. Thus, as historians can see only part of the picture, models from other disciplines can be used as a gateway for grasping medieval economic and industrial developments beyond what is directly discernable.

For beer production, product differentiation is a useful ‘model’, because it helps the scholar focus on the real and perceived differences between goods and, when analysed, reveals insights into demand, consumer pref-

erences, and the scope of products available. Generally, more differentiated products means more choice and this can be viewed as beneficial to individual welfare. Consequently, if consumers are able to stretch their resources to attain more desirable goods, the producers are faced with an incentive to innovate and improve. By studying product differentiation we can model preference patterns and selection, which in effect reveals demand, and show how beer production responded to economic developments. Ultimately this may bring greater depth to our understanding of the medieval economy.<sup>11</sup>

While beer production is of great interest due to the potential of a more nuanced understanding of the medieval economy, it is also a research area which is particularly prone to misconceptions and ‘myths’.<sup>12</sup> Oftentimes, narratives about brewing and beer have been presented as medieval whilst in fact being modern.<sup>13</sup> Scholars have also tended to refer to each others work, rather than original sources, so perpetuating inaccuracies and resulting in several misconceptions finding their way into ‘general beer knowledge’.<sup>14</sup> Therefore, a reinvestigation of beer history is in fact much needed in order to challenge these numerous myths.

Furthermore, historians often have difficulties when discussing the longevity of medieval beers as well as its taste and character. This in turn makes it and its production difficult to understand and appreciate any possible innovation.<sup>15</sup> Specifically, production methods and the microbial properties of ingredients have not been investigated fully considering how much brewing science has expanded since the ‘Micro-Brewery Revolution’.<sup>16</sup> The central issue is that beer brewing is subject to the same chemical and physical conditions today as it was in the Middle Ages and therefore studying the production of beer from both a historian’s and a brewer’s perspective will help debunk some of the myths, while simultaneously revealing new insights into brewing history. Thus, while this study has a specific economic-historical aim it also attempts to investigate medieval beer production in its own right by employing brewing science.

In summary, the aim of this work is to investigate beer production in the Middle Ages and to connect the development of beer production in Northern Germany to general economic developments in Northern Europe. A

reinvestigation of Northern German brewing is much needed as the current state of research reveal questionable findings, which call for a new examination of the source material and can be further refined by the employment of modern brewing science in historical investigation. The results will be modelled according to product differentiation theory as this will help organise and systemise inconsistent evidence in order to learn more about producers’ and consumers’ economic options and the economy as a whole.

### **Labelling ‘Beer’**

One major issue in studying beer is to determine how to define it, because in the field of beer history various definitions of ‘beer’ are found. As variations of ‘beer’ have not been used consistently for the same sort of beverage throughout history, it is very common that historians begin their investigation by defining the term ‘beer’ in relation to ‘ale’, especially when investigating the Middle Ages.<sup>17</sup> At first sight, this distinction seem sensible as it was during the Middle Ages that there has been found a distinction between the old ‘ale’; a brew made from malted grains, but without hops, and the new ‘Hoppenbier’; a brew made from malted grains with hops, later shortened to ‘Bier’.<sup>18</sup>

Problematically, historians often stray from this strict definition and use the term ‘beer’ for any beverage that underwent a brewing process without distillation, though not necessarily with malted grain and certainly without hops, before the Middle Ages.<sup>19</sup> Hence, the definition of ‘beer’ as a brew made from hops and malt seems to be exclusively applicable to the Middle Ages and Early Modern Period.<sup>20</sup> Furthermore, and more importantly, we find that this strong separation between beer and ale risks simplifying a complex relationship and cause confusion.

A number of issues therefore arise. Hops were added to brews before the term ‘hoppenbier’ was invented, though scholars generally agree that they do not know if hops were used frequently, thus the term creates confusion with regard to these periods.<sup>21</sup> Secondly, the term ‘Bier’, ‘beer’, ‘bierre’ or similar spread at different speeds geographically and therefore we cannot be sure if a beer named ‘ale’ or similar was brewed without hops or the name simply had not yet changed in that

area (and in some places it never did).<sup>22</sup> Thirdly, other names exist for beer which are not accounted for in this definition, but which were used in the European region.<sup>23</sup> Finally, dividing beer strongly into a 'with' or 'without' relationship risks simplifying the brewing process and the multitude of options possible when brewing beer, hence skewing investigation towards a too simple perspective on how brewing may have evolved.

A common definition in brewing science is more suitable.<sup>24</sup> In the present study, 'beer' is defined as a liquid that has been brewed, but not distilled, meaning, at a minimum, processed through mashing, boiling, and fermentation. This limits the investigation to products made from a combination of primarily malted grains, water, microorganisms capable of fermentation, and possibly flavouring, as medieval beers which were consumed on a large basis were all made from a composition of malted grains and flavouring.<sup>25</sup>

This wide definition is preferred as it expresses the fundamental trademark of 'beer' which is a product that has been brewed rather than vinified, such as mead, cider, or wine, and which has not been distilled, like whisky, without limiting the several different forms beer can take. From this basic foundation the term is more agile and better suited to investigate the many possible kinds of beers medieval brewers could produce and to open up to discussion the different brewing methods as a tool for differentiation, rather than a narrow focus on ingredients, which seems to have been the norm.

### **Previous Studies in Beer History and the State of Research**

In 1889, British author John Bickerdyke wrote *The Curiosities of Ale & Beer*, in which he pondered on the lack of comprehensive works of beer history in a nation of beer drinkers.<sup>26</sup> Rather impressively, this almost 130 years old work contains several historical findings which are still repeated almost unchanged today. In essence, the 'grand' history of beer has not evolved much since and shows the strength of Bickerdyke's work, but this must also inspire scepticism. Has more than a century of historical investigation not broadened and developed our knowledge of medieval beer production more acutely? Certainly, the appendix in

Bickerdyke's work, which salutes the relatively recent discoveries of Louis Pasteur in the 1870s,<sup>27</sup> must be expanded considerably in a contemporary work.

In Bickerdyke's book he accentuates the presumed innovation of brewing with hops during the Middle Ages, which supposedly improved beer's durability and made it eligible for trade over longer distances. He dates the regular use of hops in England to the beginning of the Early Modern period, when Flemmings emigrated to Kent and began growing hops, but mentions that hopped beer was also drunk for a least a century before in England.<sup>28</sup> His analysis of the origin and spread of hops from the Northern European Mainland to England during the late Middle Ages is in essence similar to what many contemporary scholars claim happened.<sup>29</sup> His claim that the introduction of hops made the beer last longer, which can be translated into more profitable and suitable for trade, is also a widely accepted historical explanation today as this chapter will show.

However, a critical examination of whether hops alone could prolong the durability of beers by such a margin that a product which supposedly would turn sour within days or weeks could suddenly last for months is lacking in the literature. Hops are generally not added in large amounts as they are very flavoursome and bittering, after being exposed to boiling temperatures, and hence a question of whether the adding of a small amount of flavouring was enough to change the industry ought to be examined more thoroughly. Specifically, when it is taken into account that it is by no means certain that consumers enjoyed highly bitter beer and may have needed time to adjust, as Bickerdyke reported on the changes in England.<sup>30</sup>

Some 20 years after Bickerdyke, Wolf Bing wrote an extensive article on Hamburg's breweries, which is still one of the most widely referenced beer studies.<sup>31</sup> Once again hops are credited with innovating the industry and paving the way for economic success by prolonging the durability of beer.<sup>32</sup> However, Bing also mentioned another interesting feature of medieval brewing. He introduced the idea that some beers, those most suitable for export, were 'untergärige März- und Marschbiere', that is cold fermented beers or lagers in modern terms.<sup>33</sup> The cold fermentation, often referred to as bottom-fermentation, further helped prolong durability and improved clearness and quality, Bing argued. This idea

has since been either abandoned or dismissed by most scholars, who have not believed that brewers would take the time to ferment the beers cold and slowly or been able to control the temperature.<sup>34</sup> However, the division of beers into bottom-fermented and top-fermented beers is inappropriate for medieval brewing, as will be argued later, and Wolf Bing may have had a very valid point in that fermentation could have played a key role in the commercialisation of beers. This will also be expanded upon later.

Bing's investigation was focused on Hamburg, a prominent beer town during the Hanseatic period and named 'Brauhaus der Hansa' in contemporary sources.<sup>35</sup> Despite concentrating Hamburg he also rated other beer producing towns<sup>36</sup> and named some, Einbeck for instance,<sup>37</sup> better than others. Both the assessment of some towns as better producers than others and the method of focusing on the beer trade and production in specific Northern German towns have been repeated in later research. Thus, Friedrich Techen wrote of Wismar beer in the early 20<sup>th</sup> century, Gerald Stefke performed an economic historical investigation of Hamburg's breweries in 1979, Erich Plümer has focused on Einbeck's beer development,<sup>38</sup> Hans Albrecht<sup>39</sup> and later Wolfgang Frontzek have examined Lübeck's breweries,<sup>40</sup> Mark Petersen has written broadly about the Wendish towns,<sup>41</sup> and lately Mathias Simmes has written on Dortmunder Bier<sup>42</sup> and a new anthology about Hamburger Bier was published in 2016.<sup>43</sup> Each work has added insights to the history of beer in those specific towns, but more wide ranging discussions on the development of beer production and trade have been absent.<sup>44</sup> However, when examining the source material scholars have used it is both easy to recognise why beer history has gone in this direction and yet it is also a little puzzling.

Most of the source material from the Northern German towns was published during the late 19<sup>th</sup> and early 20<sup>th</sup> century.<sup>45</sup> Particularly, the various *Urkundenbücher* and *Burspraken* have been frequently examined and provided the base for analysis in Northern German beer history, both for historians who have examined beer from an economic-historical perspective and those who have not.<sup>46</sup> Other potential source material which could have afforded more information has, for the most part, been lost in fires and war.<sup>47</sup> Very little material remains exclusive to the archives and scholars have for some

time reported that the remaining material does not bring insights into the history of beer production and trade, which is not already apparent in published sources and works.<sup>48</sup> Naturally, as it is a limited amount of source material which has formed the base of investigation, scholarly works have focused on specific towns. Furthermore, scholars have been examining the same materials repeatedly and it seems they have found similar answers although adding a little information each time.

However, as the source material does not generally provide direct answers, being inconsistent series of trade records, some correspondence and legal documents, and statutes which regulated brewing, but did not dictate it, it is puzzling that scholars have not been more at odds as there seems to be plenty of uncertainties to disagree on. The issue of hops as the definitive innovation, as mentioned earlier, is one. The assessment of towns, where some brewed specifically high-quality beers, although many towns seem to have been exporting high-quality beers that do not carry the same reputation, is another. The division of a supposedly lager producing south and an ale producing north is yet another issue which ought to be discussed, considering that all regions must have brewed with wild yeast or a domesticated sort of wild yeast. In sum, there is a real need for new scepticism towards received narratives which dominate beer history.

The most referenced works internationally within beer history in the last couple of decades are those by Richard Unger, Max Nelson, and Ian Hornsey.<sup>49</sup> Richard Unger has focused specifically on medieval beer history in the Netherlands and Northern Europe, Max Nelson has focused on ancient beer production and Ian Hornsey has written a history of beer and brewing from ancient findings to modern innovations with an emphasis on British beer. These works provide extensive and comprehensive views on medieval beer history and are moving towards becoming canonical on par with the work of Wolf Bing. However, these works also emphasise the 'myths' of medieval beer brewing and have thereby cemented the strong narratives of commercialisation through hopped beers even more.<sup>50</sup> This circumstance suggests that critical, and perhaps creative, approaches to beer history are needed before the strong historical explanations become perceived as 'facts'.

A monumental amount of smaller studies and articles exist, most from German scholars or leisure historians.

The issue with many of these works is that they rarely provide new insights and unfortunately rarely refer directly to original sources. Therefore, they also often convey the questionable narratives of beer history. Naturally, there are exceptions and some of the particularly interesting ones are those studies which incorporate archaeobotanical evidence.

Archaeobotanist Karl-Ernst Behre, who has written about beer history for decades, is one of the foremost beer historians when it comes to incorporating archaeobotanical evidence to historical investigation. Some of his considerations about finds of hops in Northern Germany will be inspirational for the following analysis as they conflict with the general established narratives of hop history.

Lastly, from an economic-historian perspective, results in beer history have only occasionally been modelled or tied to the discussion of economic development, despite the prominence of the beer industry in the Middle Ages.<sup>51</sup>

In sum, when considering the literature of the past 120 years, a vast number of works has been written yet there are few real conflicts. Some of the strong narratives of beer history are questionable, when considered from a technical perspective and some archaeobotanical evidence are in conflict with them. When examining the references in a large number of works, it is clear that they tend to refer to each other and unfortunately rarely to sources in newer works, so inspiring caution and reinvestigation. The development of beer history has rarely been tied to general economic development and therefore an explicit focus on the latter will be provided in the current study.

### **Structure, methods, and sources**

The study is divided into four parts. In the first part, brewing methods are examined, focusing on the development from the Early Medieval period until the 15<sup>th</sup> century and on innovations which made product differentiation possible. Also, some of the important findings which conflict with the established narratives of beer history will be investigated. In the second part, beer ingredients will be assessed in a similar fashion. In the two parts brewing science will be incorporated when

needed to explain the consequences of the innovations and methods used in order to achieve more insights into the products' development. Therefore, a section on the basics of brewing science is used as an introductory chapter to these two parts.

In the third part, the findings from the first two parts will be used to examine and compare the beer types which were recorded during the Middle Ages. Once again, the focus will be on differentiation to reveal the scope of different products and how they compare to each other. For a standard of reference, a comparison of medieval beers with modern industrial lager will be used. In this part, the brewing calculator *BerrSmith 2* is used to produce comparable statistics and visualisation of the beer types.

In the fourth part, the results on beer types are modelled according to product differentiation theory in order to systemise and organise the findings and reveal what they might tell us about the development of the economy and the possibilities for the producers and consumers during the Middle Ages.

As previously mentioned, many 'facts' about medieval brewing history do not have a basis in contemporary sources. When reading works on beer history, it is often difficult to learn where exactly the scholars' evidence come from and precisely which date they are writing about. For example, historians who write about Hamburg's brewing history often refer to Matthäus Schlüter's *Tractat* from 1698 when discussing medieval beers. While Schlüter's substantial work on Hamburg does have a large section on the medieval history of breweries, the sources he refers to often no longer exist and, importantly, similar findings cannot be found in the sources that remain. Therefore, one should be cautious not to over-emphasise the findings of a late 17<sup>th</sup> century work and treat them as contemporary sources, as it seems has sometime been the case.<sup>52</sup> Consequently, due to the specific state of beer history, only a very limited amount of Early Modern sources are used, instead contemporary sources are relied upon.

Primarily, the sources used are the *Urkundenbücher*, printed documentary books mostly published in the 19<sup>th</sup> century. In short, numbered sections they chronologically document statutes, certificates, letters, important events, diplomatic affairs etc. associated with an area or

association. The content is therefore very varied, which results in sporadic, irregular findings associated with brewing and beer. As a result, unlike in many studies in modern sources, where you can find a chain of information and analyse it systematically, the nature of the medieval sources requires that each reference is evaluated individually to extract what knowledge is possible, which ultimately make up only part of a picture. Specific focuses and research questions are key to extract useful information that can bring insights under these circumstances. Therefore, the investigation into brewing methods and ingredients will be divided into small sections that analyse and discuss the sporadic evidence which can be associated with one step in the brewing process at a time or one ingredient. Without this strict structure, it would be difficult to make sense and systemise the sporadic evidence when examining a wide topic like production.

The *Urkundenbücher* referred to most often are the *Hansisches Urkundenbuch* (HUB), *Mecklenburgisches Urkundenbuch* (MUB), *Urkundenbuch der Stadt Lübeck* (UdStL), and *Hamburgisches Urkundenbuch* (HamUB). During the 19<sup>th</sup> century, some industrious archivists, who were also agents for source-critical method, gathered sources and published them either as entire works or as part of monographies for specific towns. The editions of J.M. Lappenberg on Hamburg and Bremen, F. Techen on Wismar, and C.F. Wehrmann on Lübeck stand out and will also be referred to frequently in this work.

The few statutes on brewing that survive provide some of the most interesting evidence. They reveal some of the ingredients used and their combination in medieval beers. They are regulations on what ingredient must be used and their purpose was to obtain adequate amounts of grains for all producers in the towns and secure taxes, quality, and price. Therefore, they specify the amount of malts any brewer could use and the amount of beer they were allowed to produce from the malts, usually ending each statute with a variation of ‘no more’.<sup>53</sup> They do not regulate flavourings and, hence, are not truly ‘recipes’.

### **Brewing beer on a practical and microbiological level**

To understand how medieval brewers produced their beers and how they differ, an overview of brewing is

necessary. At each step of the brewing process, choices are made which determine the characteristics of the beer. This concise introduction will highlight the consequences of the choices made and how they affect each other.

To begin with - malt. The malt provides the backbone of beer and from that base it is possible to both add on and balance smell, flavour, texture, structure, and body. Malt is made from grains that are ‘malting’ to be used in brewing.<sup>54</sup> The purpose of malting is to make the vegetable material into a resource that can nourish yeast once extracted into a liquid. This is done through the process of steeping, where the grain is soaked in water to hydrate, activate, and clean it; germination, where the grain is left to sprout, traditionally spread out thinly on a floor; and finally kilning, where moisture is removed from the grain, germination stops and multiple different colours and flavours can be achieved.<sup>55</sup>

Different kilning techniques provide different flavours ranging from vegetable-like notes to bitterness, sweet toffee, coffee, and smoke.<sup>56</sup> Colours range from light pale yellow to bordering on black with brown and amber shades in between.<sup>57</sup> The malt can be smoked or roasted to provide different tastes and darker colours.<sup>58</sup> Thus, malting provides a multitude of options for product differentiation even if only one type of grain is used.

Today, most beers are made from barley, but malt can also be made from other grains which can be manipulated during kilning similarly. Wheat is still a popular grain type and its high protein level promotes higher head retention in beer, but wheat can also be difficult to control during boiling as it easily overflows due to too much foam in the kettle. Rye has a distinctive spicy flavour, but is rarely used as are oats which can provide a silky, full mouthfeel to the beer when added in small amounts.<sup>59</sup>

The composition of malt types and their characteristics determine the colour of the beer, the potential alcohol level and provide key characteristics to the beer.<sup>60</sup> A variety of malts or one malt type, but only if it contains the right type of starches, enzymes capable of deconstructing starch into fermentable sugars, specific minerals and vitamins, all of which are necessary to nourish yeast during fermentation.<sup>61</sup> Statutes from

Lübeck from c.1300 suggest that medieval brewers used a number of malts rather than relying on one type.<sup>62</sup>

Secondly, the volume needs to be considered. As a rule of thumb, the higher quantity of malt the stronger wort you will achieve,<sup>63</sup> as the fermentable sugars and most of the vitamins and minerals comes from the malt. However, the strength of the wort also depends on the efficiency of the mashing and the original amount of starch in the grain. Different grains contain different starch levels and a high starch level will provide a stronger beer per kg of malt used. The efficiency of the mashing determines how much extract is diluted into the water and this depends on the malt quality, its composition and the methods and equipment used.<sup>64</sup> Lastly, some of the extracted sugars cannot be converted into alcohol by yeast. This sugar will add sweetness to the final beer or nourish other kinds of microorganisms, which are able to transform the more complex carbohydrates.<sup>65</sup>

The malts are soaked in hot water for a period during the mashing process. During mashing, the extract from the malt is diluted into water at an ideal temperature of c.65°C (single step mash)<sup>66</sup> and the enzymes in the malt deconstructs the starch to sugar. As soon as the malt touches the water the starch begin to transform and pH levels drops.<sup>67</sup> The water profile greatly influences how the wort will turn out depending particularly on; the hardness of the water (amount of calcium) and the alkalinity (the amount of acid needed to change the pH level in a substance).<sup>68</sup> In modern breweries pH levels are controlled by adding acids or minerals.<sup>69</sup>

After mashing the brewer is left with a grainy, thick, sugary liquid. In modern breweries the liquid is now separated from the malt.<sup>70</sup> Modern breweries generally rely on electrical pumps for this process. In some home breweries, where the malts have been lowered into the mash tun in a container, the wort can be lifted out of the mash, which medieval brewers could also have done with smaller batches. Gravity can also be used to separate the wort if the brewhouse has enough room to keep the mash tun lifted over the boil kettle and hypothetically that technology could also be used in the medieval breweries. However, while we have testaments describing the utensil in breweries,<sup>71</sup> we do not have enough evidence from the Middle Ages of brew-houses' composition to determine the technology used.

The wort is then boiled. During boiling a number of defining processes occur. The malt enzymes are inactivated and no more starch or ill tasting tannins are extracted into the liquid. Protein materials are coagulate and protein complexes are formed, clarifying the beer. Chemical substances with properties of reduction are formed, which will protect the beer from quick oxidisation, thus prolonging the durability of the beer. The gravity of the wort is concentrated through evaporation, giving the beer higher alcohol potential. Volatile compounds from the wort and flavourings are evaporated and flavour and colour complexes form. Lastly, the wort is sanitised by the high temperature.<sup>72</sup>

The quality of the boil, and therefore also the final product, greatly depends on very high amounts of energy and good circulation in the boil kettle. Hence, an efficient boiling process with high circulation and temperature kept as high as possible is key to a durable, well tasting, and clear beer.<sup>73</sup>

The brewer can add flavouring at different stages during mashing and boiling. If hops are added during mashing, the hops add subtle flavours and aromas, but not bitterness, as the temperature remains too low.<sup>74</sup> Only if the grains are afterwards boiled with hops, bitterness will emerge. This may have been the case in early medieval breweries, where it can be hypothesised that brewers did not separate the grains from the wort before boiling.

Modern brewers usually add a small number of hops at the beginning of the boil for bittering and a larger amount at the end for aroma and flavour.<sup>75</sup> Hops have very different flavours and aromas from cheesy to piney, floral, herbal, spicy, fruity, and vine bouquets, which influences the aroma and taste of the beer.<sup>76</sup> The amount of bitterness they add depends on the amount and composition of alpha and beta acids in the hop, which are soluble at boiling temperature.<sup>77</sup> As a rule of thumb, old hop varieties, sometimes referred to as noble hops, have less soluble alpha and beta acids and are therefore less bittering than modern hops, which is an important consideration when discussing medieval beer.<sup>78</sup> Medieval hops were not as bitter as the modern hops which have been refined towards bitterness. The bitterness (measured in IBU) of the beer depends both on hop varieties, amounts, and how long the hops are subjected to boiling.

Hops, and other additives, attribute seven elements to brewing; aroma, flavour, bitterness, flavour stability, mouthfeel, foam and lacing, and preservative characteristics.<sup>79</sup> The bitterness from hops balances the sweetness from the malts. Fresh hops will keep their aroma and flavour for about a month and a half relatively, depending both on hop quality and storage, until they start to become oxidised and their aroma and flavour either disappear or go off.<sup>80</sup>

To achieve a well-tasting, balanced beer, the malt base and the flavouring composition should complement each other. For instance, if the brewer has chosen a light malt base of relatively small amounts of pale malts, they might consider using less hops in the beginning of the boil to avoid an overly bitter, thin beer, but add more hops towards the end to give the beer more aroma and flavour, thus making it appear more wholesome.<sup>81</sup>

After the boil, the wort needs to be cooled down before the yeast can survive in the liquid and fermentation can commence. Generally, the faster the wort is cooled down the better, as the wort is susceptible to infection during cooling which can affect the final flavour and durability.<sup>82</sup>

During fermentation the yeast transforms sugar to ethanol and small amounts of other alcohols and further aromas and flavours are formed as by-products.<sup>83</sup> The temperature during fermentation determines what kinds of yeast cells are capable of surviving. If the wort is kept at a temperature that is quite cold (0-7°C) most microorganism will not metabolise the sugars and remain 'sleeping'. The higher the temperature the more yeast cells will 'wake up' and start the fermentation process, but also provide other by-products.<sup>84</sup> Modern lager beers, which are 'cleaner' beers as the yeast produces very limited amounts of by-products, are therefore usually fermented at c. 10-13°C, while ale, which gain more flavours from the fermentation, is fermented at c.18-21°C.<sup>85</sup>

As the yeast ferments the sugars it creates heat which causes the yeast cells to die, create off flavours, or mutate if the temperature is not contained.<sup>86</sup> The flavours the yeast add to the beer are highly determined by the fermentation temperature and its stability as well as the type of yeast strain. Inconsistency in temperature due to, for instance, warm days and cold nights produces bad, off-tasting beers.<sup>87</sup>

Fermentation can be performed by a myriad of different yeast strains and all cause different results. Modern brewers choose different types of yeast strains specific to the style of beer they brew.<sup>88</sup> In medieval breweries, brewers used either 'pure' wild yeast or yeast domesticated through evolution, where a multitude of yeast strains would be present in their brews.<sup>89</sup> Numerous yeast varieties also means many kinds of aromas and flavours and in that light temperature levels become even more important.

A period of conditioning or secondary fermentation occurs after most of the easily fermentable sugars have been transformed to ethanol. In this process the yeast cells turn their attention to compounds that have been transformed during the first phase of fermentation, diacetyl for instance, and other off-tasting compounds in the liquid. Compounds which may lower the durability of the beer are also attacked by yeast cells during this process. The secondary fermentation or conditioning is sometimes followed by a period of cold storage in which the yeast cells settle, the beer becomes clearer and active ingredients settle, which can improve flavour.<sup>90</sup>

## **The medieval brewing process**

### *Malting*

Turning now to the medieval processes the first issue to consider is malting. Today, it is rare that brewers produce malts and most would not consider malting to be part of the brewing process as the industries are now fully specialised. This separation, which seems natural today, was rare at the beginning of the Middle Ages. Yet, with increased separation one can expect an increase in quality, skill, and technology as both industries become more specialised.<sup>91</sup> Therefore, it is worth taking a look at how malting evolved.

Looking at the period between the 8<sup>th</sup> and 11<sup>th</sup> century, the greater majority of production can be classified as 'rural' in the Northern German area as the majority of the population lived in the countryside and a few in manors, monasteries, and villages.<sup>92</sup> Trade between farms and villages was limited and unrecorded as few could write and even fewer would purchase ink and paper for noting if, for instance, two households



exchanged malts. It is therefore difficult to establish the amount of trade and barter in the population, but most likely the majority of households would be self-sufficient. A high level of self-sufficiency is a common consideration of life in the Middle Ages, which is why it can be asserted that at least the bigger farms and the manors produced their own malts before the 11<sup>th</sup> century.

However, producing malt required abundant space in a dry environment and work capacities throughout the day as the malt needed to be turned over frequently to avoid mould and attain an even malting.<sup>93</sup> This did not require a lot of skill or strength and could be conducted even by the young or fragile. However, making malt still required the household to be large enough and the farmhouse ground to be expansive enough to afford the room and time needed. As a result, being self-sufficient in malt production would fast become difficult for smaller households with too little space or too few hands, particularly during harvest season. Hence, it is easy to hypothesise that the smaller households were likely early dependent consumers of malts while the larger households might have been able to benefit from a welcome new source of income.<sup>94</sup> Therefore, not surprisingly, malting became one of the early manufacturing 'industries' which developed from household to other centres of production and as a result separate from the brewhouse.

One of the earliest sources which reveal a little about brewing and malting in Europe before 1000 is the *Capitulare de Villis*, which is a model version of the management of estates in the Carolingian area dated to c.800 and generally believed to originate from the area around Aquitaine.<sup>95</sup> In the text, it is instructed that stewards should bring malt to the palace where master brewers would produce good beer: '*Ut unusquisque iudex quando servierit suos bracios ad palatium ducere faciat, et simul veniant magistri qui cervisam bonam ibidem facere debeant*'.<sup>96</sup> It is also necessary that producers should be hygienic in their handling of malt<sup>97</sup> and brewers are listed as required workmen in every district.<sup>98</sup>

As brewers are listed as specific workers it can be asserted that there existed at least some level of occupational specialisation regarding brewers, but in contrast, it does not seem to be the case with malsters as they are not mentioned specifically anywhere. As considerations

are made regarding the hygiene in handling malt, it is clear that the author(s) were conscious of the malting process, yet who was responsible remains unclear. It could be that brewers produced the malt themselves, it could have been millers, both, or someone else entirely.

The German *Urkundenbücher* reveal that by the middle of the 13<sup>th</sup> century, malting frequently took place in mills where monasteries or other owners of mills could receive the privilege to produce specific types of malt or sell their malts to specified buyers. For instance, a monastery around the area of Rostock was granted rights to produce barley malts in a local mill in 1239.<sup>99</sup> Another monastery was allowed to produce two 'Wispeln'<sup>100</sup> of malt from the mill at Dömitz in 1259<sup>101</sup> and a lord allowed a monastery the right to make barley- and rye malts from a mill owned by a knight in 1293.<sup>102</sup> Other non-monastic agents are also recorded being granted rights to buy malt from a mill in 1301.<sup>103</sup> Thus, individual home production of malt, while still technically possible in large farmhouses, was to some degree replaced by production in mills by the middle of 13<sup>th</sup> century.

Furthermore, trade in malt had by then become long-distance. For example, the trade between Norway (often Bergen) and Northern German towns (often Lübeck) is well-documented from 1247-1248.<sup>104</sup> With long-distance trade in manufactured goods, brewers did not have to rely on locally produced malts and malt production had become an industry in its own right which could be expanded beyond the demands of the local brewers.

A century later, by the 1362, the organisation of malt production was slowly reaching a new level of specialisation as towns are reported to have specific malthouses and kilns for those lacking such facilities.<sup>105</sup> This source reveals that while malts could be bought, it was still not uncommon for brewers to make it themselves if they had the space as otherwise there would be no need to mention that the malthouse were intended for those, who had no space outside the town. Space was an increasing issue in towns as urbanisation increased during the Middle Ages<sup>106</sup> and thus shared malthouses relieved some of the brewers and employees of these issues.

Despite the introduction of malthouses, there appears to be no evidence of complete specialisation in malting in

contemporary sources, which instead seems to have remained a side-occupation of either brewers, millers, or others for the most part during the Middle Ages. It has been shown that the same way towns like Hamburg and Bremen specialised in brewing from the early 13th century, Stralsund specialised in malting but this does not seem to appear before the 16<sup>th</sup> and 17<sup>th</sup> century.<sup>107</sup> However, while brewers could choose to malt their grains themselves throughout this period, the option not to increased as malt became a tradeable good, at the latest by the middle of the 13<sup>th</sup> century. As a result, it was then possible to specialise as a brewer without spending the additional effort of being a malster, too. Hence, brewers from the 13<sup>th</sup> century may have had better options for dedicating themselves to produce beer than in earlier times.

But how were malts made in the Middle Ages and what options were there for product differentiation? Unfortunately, there has been little discussion as to how exactly malts were produced. The simplest and cheapest method does not use artificial heat and the malt is turned as little as possible as this requires the least effort. In regions such as Egypt and Mesopotamia,<sup>108</sup> they may very well have been able to ‘kiln’ malt without additional heat and without risking the malts going sour or mouldy due to their hot climate. While that would be the easiest way to make malt, it would not encourage experimentation with different kilning methods and differentiation in malts. Due to the colder and wetter climate in Northern Europe, it is very unlikely that the medieval malsters could produce malts without the aid of some sort of heating and thus the Northern brewers would discover differentiation possibilities.<sup>109</sup>

Hypothetically, as medieval malsters utilised heat during malting they were able to speed up the process as well as have more control and options. Previously, I explained that the kilning process greatly affects the colour, aroma, and flavour of malt, which is ultimately reflected in the beer. Hence, as medieval malsters used heat they were also able to manipulate their malts to gain the taste and colours they preferred, resulting in better quality beers. While we do not have accounts of how much medieval producers manipulated the grains, we do know that they were able to produce red and yellow beers and beers of non-described colours by the late 15<sup>th</sup> century.<sup>110</sup> Thus, they did experiment and produce different types of malts for different types of beer.

Archaeological finds in an Early Celtic brewery suggests that kilning facilities utilising heat was used as early as in the Early Iron Age in modern day Baden-Württemberg. The malts were kilned over open fire causing the malt to be smoked. Furthermore, the excavations revealed that the Celts brewed with barley and succeeded in germinating and kilning their malts rather evenly, thus producing a high quality product.<sup>111</sup> Taking this example into account it is probable that medieval brewers, who conducted their work 800-1000 years later, were also able to produce even, good quality malts. Additionally, they also used oats, wheat, and rye in their beer production as will be elaborated later.

It is interesting that the Celts used an open fireplace to kiln their malt, because it would have resulted in smoked malts which greatly impact on the flavour of the beer. We currently do not have any evidence that medieval breweries used hypocausts or oven-like constructions to direct the smoke away from the malt. The earliest constructions of kilns which did do this have been found in Wismar and Lübeck and archaeologists believe they were in use at the latest by the 16<sup>th</sup> century and thus perhaps even by the end of the Middle Ages.<sup>112</sup> For the most of the period, however, the beers would have been at least a little smoked.

### *Heating*

How medieval producers obtained energy ought always to be of concern, as it was a scarce resource before the introduction of coal,<sup>113</sup> yet vital for many types of production, not least brewing.<sup>114</sup> For brewing, heating was the primary concern for energy input and, as previously explained, inadequate heating resulted in less durable and ill-tasting beers.<sup>115</sup>

Beginning again with a focus on the Early Middle Ages, one must consider that in this period almost the entire population lived in the countryside with easy access to natural resources.<sup>116</sup> Twigs, stubble, hay, and fallen branches would be relatively easy to collect from the land by women, who were typically responsible for beer production.<sup>117</sup>

Despite sources of fuel being easily accessible in this period, as opposed to later, fires were also more difficult to manage and inefficient with regards to energy loss.

Keeping the open fire going over long periods required frequent attention and it would have been difficult to keep an even temperature throughout the process, the result being that the early medieval countryside beer may have had various off-flavours.<sup>118</sup>

As the brewing industry became urbanised, the issue of fire became a concern. In closely built towns, fire from workshops was always a danger and, hence, heavily supervised and regulated by administrators. One early example of fire regulations in regards to breweries is from London, 1189, which states in modern language:

All ale-houses be forbidden except those which shall be licensed by the common council of the city Guild-hall, excepting those belonging to persons who will build of stone, that the city may secure. And that no baker or ale wife brew by night, either with reeds or straw or stubble, but with wood only.<sup>119</sup>

By decreeing that houses should be built of stone, the surroundings were less likely to catch fire and by requiring that only wood be used as a fuel ovens became more manageable.<sup>120</sup> However, the use of firewood also meant that the boiling process became more efficient as it burns stronger, more evenly, and better than straw and stubble.

During winter, it would also be necessary to keep a hearth in the breweries for the beer to ferment, which meant more danger as the fires were sometimes left unsupervised. Hence, as we can see in the quote, town administrators tried to limit the amount of night fires, but they realised that they were necessary for bakers and brewers and thus did not prohibit them completely. Monckton conveys that this was also the case in some Northern German towns,<sup>121</sup> and I have found similar regulations of night fires and the positioning of fires as well as handling of grains (which are flammable) in *Bürgersprachen der Stadt Wismar*.<sup>122</sup> Brewing at night was illegal as fines are recorded for ‘*quod braxavit nocte*’<sup>123</sup> - brewing at night. Sadly, not much information on fire regulations specific to brewers remain in German sources, but the risk of fire and necessary precautions are frequently referred to.

A considerable improvement in heating came with the introduction of copper kettles. Ovens could be built around the kettles, which were solid structures and con-

tained the flames.<sup>124</sup> Two such ovens, which archaeologist have dated to mid- 13<sup>th</sup> century, were uncovered in Dordrecht in 1969.

These are the earliest ovens found in breweries in the Northern European area, but they may have been in use as long as the copper kettles, which would imply from the late 12<sup>th</sup> century and onwards.<sup>125</sup> Brick ovens and copper kettles were expensive and therefore must have been attainable only by brewers, who produced beyond their own consumption. This meant that the beers for sale from bigger producers had far better likelihood of being well-made and more durable than beers from smaller or home producers, who could not afford the improvements in heating. Thus, considering heating technology alone, the well-off brewers had opportunity to produce a better quality product from the late 12<sup>th</sup> to mid- 13<sup>th</sup> century and onwards.

### *Mashing*

Detailed evidence from before 1600 concerning how Northern German brewers mashed and boiled is sadly lacking. Both processes impact on how beer can vary and they are amongst the most important processes. It ought to be assumed that mashing and boiling were carried out differently from today at least in the Early Middle Ages. Firstly, because it is unlikely that mashing and boiling were carried out in different containers as two large vessels would have been extravagant in the subsistence economy typical of most early medieval households. Secondly, we cannot be certain that the mash reached boiling temperature after a mashing process, as it required a great deal of energy and was perhaps not recognised as an optimising process before beer became a tradeable commodity and subject to competition.

It has been suggested that early medieval women produced so called ‘small beer’, where the mash would be produced over night in a kettle on relatively low heat and be left in other containers to ferment the day after.<sup>126</sup> This is a very simple way of producing beer, although on the border of what we would define as ‘beer’ today, and, perhaps due to its simplicity, it is a tempting assumption. Without written evidence, however, we cannot be certain that this was the standard procedure for brewing at the time. From experience and

experimentation early medieval women may have found better ways to brew, especially if they produced enough to sell a surplus, but this is purely hypothetical.

The likely method of mashing and boiling in the same container does entail that grains were probably not removed from the mash before boiling, if boiling occurred. However, including the grains in the boil limited the options of making second batches,<sup>127</sup> made it more difficult to attain a clear beer and it would affect flavour negatively.<sup>128</sup> Hypothetically, brewsters could have used a strainer to lower the malt into the warm water and then lifted it after the mashing, given that they made small batches of beer, but there remains no evidence of such a practice being performed then or later. It would, however, have given them some advantages.

By the late 12<sup>th</sup> century when copper kettles became customary in larger breweries, and perhaps resulting from that very innovation, mashing and boiling were conducted in separate containers. From testaments in contemporary sources, it is evident that tuns and kettles are specified as different objects to be inherited from the late 13<sup>th</sup> century in German towns<sup>129</sup> and, thus, from this period it can be asserted that mashing and boiling were recognised as two different procedures.<sup>130</sup> This dating is very conservative and it is possible in other works to find earlier dating of separate mash tuns and brew kettles, but it is not clear how scholars find evidence for these estimates in regard to German towns specifically.

With the separation of mashing and boiling in different containers it is likely that the grains were separated from the wort before boiling. This would create better possibilities for a clear beer and decrease the risk of tannins. For the brewers, who brewed larger batches for export (Bremen began exporting in the early 13<sup>th</sup> century and other towns soon followed)<sup>131</sup> the risk of a so called stop-mash, where grains block the pipes that transfer liquids, increased and so for the large-scale producers we must assume that brewers separated the wort from the grains before boiling. Therefore, the system of tuns and kettles and removing grains from the wort before boiling must have been common amongst 'larger scale' producers, but not necessarily so among smaller producers who had less equipment.

Furthermore, once the brewers began separating the wort from the grains they could also brew 'second run-

nings' and profit from the thinner beers of lower alcohol levels. In early modern sources, beers named 'Tafelbier' and 'Tischbier' are reported to be beers made from this procedure,<sup>132</sup> and those names also appear in contemporary sources.<sup>133</sup> Therefore, most likely, the professional brewers also used this method in the Middle Ages once they began boiling without grains.

Factors other than what can be derived from medieval equipment would also affect the beer. Firstly, temperature control would have continued to be an issue. Too high a temperature would immediately spoil the mash. Therefore, it is likely that the brewers preferred to keep temperatures low and opt for a longer mashing session to gain as much fermentable sugar as possible.<sup>134</sup> The exact temperature is impossible to say, but from experience it is probable that professional brewers became more adept at keeping the mash at a reasonable level and gained an advantage over non-professional brewers, who could not afford the time and did not have as consistent a workflow.<sup>135</sup>

Another issue to consider is water quality and pollution and, in this respect, the rural brewers had a rare advantage over the urban. A country-side beer was quite possibly better quality than an urban beer, if the urban brewer did not have access to better equipment and other factors still to be revealed, due to different qualities of water.

Hence, the mashing process did improve during the Middle Ages, mostly for the big investors, but rural brewers also had some advantages due to their location. Considering differentiation, the producers of larger batches would have improved their mashing techniques and by working consistently, they would also have become far better than those who brewed occasionally and as mashing is one of the most critical procedures, they also had a clear advantage, despite poorer water.

### *Boiling*

After mashing, (and possibly sparging),<sup>136</sup> the brewers could begin boiling. As previously mentioned it is difficult to determine if the wort reached boiling temperature in household production of the Early Middle Ages and, if it did, for how long. The result from this production method would be of low quality and very low durabili-

ty. In the bigger production centres, boiling was certainly a part of brewing, but whether the grains from the mash were boiled or not is difficult to say.

While it may be hypothesised that small and early producers boiled the grains as this required a step less in the brewing process, it ought not to be expected in the larger breweries later on. Firstly, due to the investment in more equipment, which meant that the wort was transported from one vessel to another between mashing and boiling. The grains become heavy after soaking and it would be tiring to transfer the entire batch rather than just the liquid into the next vessel. Secondly, with bigger batches it would require more equipment to transfer the entire batch, because it could not be lifted by men. In case they used pipes, they would experience frequent stop-mash, if they insisted on pressing the mash through the pipes rather than letting the liquid run off. Therefore, the advantages of only transferring the liquid would become obvious, if they were not known all along. Without written records, it is impossible to date exactly when brewers started to boil the wort without grains, but at the latest it would have begun with the professionalisation of the trade and the emergence of larger copper kettles in the late 12<sup>th</sup> century. Perhaps even as a result of the very same.

In the Early Middle Ages large pottery vessels were used in the larger, commercial breweries and in monasteries.<sup>137</sup> They had a maximum capacity of c.100 - 150 l, as any larger they would break from the weight of the wort.<sup>138</sup> Naturally, these vessels limited the possibilities for large scale production. On the other hand, keeping the vessels at this size made boiling more achievable as more liquid came in contact with the hot stone. By brewing smaller batches, the brewers would also have more control during the different processes without the aid of modern machines.<sup>139</sup> In smaller household breweries, boiling techniques could also improve throughout the Middle Ages, as the community sometimes bought better brewing equipment for sharing.<sup>140</sup>

From the late 12<sup>th</sup> century copper kettles gradually became customary in larger commercial breweries and the few monasteries, which still produced beers on a large scale. The first ones in use could hold up to c.1000 l. By 1400 they had grown in size to a capacity of c.4.000 l. Copper kettles could not only produce bigger batches, thus taking advantage of economies of

scale, but they also had more heat efficiency,<sup>141</sup> making beers considerably cheaper and much better quality through a more proficient boil, which is vital for an efficient fermentation and to avoid off-flavours.<sup>142</sup>

Considering the cost of the large brewing pans, which are often noted in wills,<sup>143</sup> the scale of investment from the late 12<sup>th</sup> century and onwards meant that fewer producers were able to gain the advantages of the improved boiling technology. As the copper kettles continually grew in size they also became more expensive as more metal was needed and they required more space. They would also require more skill to manage as the batches were bigger. Ultimately, their introduction meant that the gap between those who brewed mostly for their own consumption and those who brewed for profit widened.

Therefore, the brewers who had access to the better kettles would have been able to produce more durable and cleaner beers than those who did not, which meant that product differentiation increased.<sup>144</sup>

### *Cooling*

After boiling, the wort needed to be cooled down to allow the yeast to initiate fermentation. Once again, this procedure affects the taste and durability of beers and, hence, needs to be considered. Most likely, the brewers would have used the exterior or underground environment to cool the wort.<sup>145</sup> This circumstance must have posed problems during warmer summers, especially for the brewers without access to cellars. Innovations during the period reveal that the professional brewers worked their way around the issue.

Generally, the faster the wort is cooled the better. Slow cooling allows so-called 'thermo-bacteria' to produce distasteful by-products in the beer before fermentation can occur and out-compete the yeast.<sup>146</sup> Hence, the quicker the brewers were able to cool down their wort, the better the result, which would be observable through experience.

The importance of cooling was recognised as early as c.820 as revealed by the plan for the monastery St. Gall. It depicts three breweries intended for brewing different beers for pilgrims and poor, nobles, and brothers. All the

breweries have separate rooms for brewing with the depiction of a hearth and a room specifically intended for cooling, which is set against the cooler walls.<sup>147</sup> After cooling, the beer probably went into barrels which were then put in the cellar where a stable temperature could be maintained, creating better conditions for fermentation.<sup>148</sup> Hence, from the Early Middle Ages and onwards cooling was an issue that, at least, the larger breweries were attentive to in the area in and around the Carolingian realm.

We do not have accounts on how Northern German brewers cooled their wort or if they were considerate of cooling the wort quickly, but archaeological finds give us a rough indication. By the 13<sup>th</sup> century, when copper kettles and separate mash tuns were in operation in the larger commercial breweries, some cooling systems had also been installed. Archaeological finds reveal that shallow, hollowed, wooden troughs were used to transport the hot wort from the boil kettles to the wort tuns.<sup>149</sup> This is an interesting innovation which requires some explanation.

While the boiled liquid was above 70 degrees most microorganisms would not be able to infect the beer, but as the liquid cooled in the open cooling troughs the wort would have been subjected to yeast both from the air and the wood, in which yeast would have flourished between batches. In effect, the wooden cooling system posed both a great danger as it could be infected with aggressive unwanted bacteria and fungi, but also an opportunity for a better fermentation and it limited the by-products of infection.

Wooden troughs and barrels provide ideal conditions for wild yeasts to flourish and even with modern technology, studies have shown that new wooden barrels containing sterile wine experience growth of wild yeasts even in the first batch.<sup>150</sup> Because wild yeasts can be aggressive and thrive so well in wood it is certain that medieval beers were infected, which characteristics will be explained later on. The cooling system would ensure that wild yeasts were present in high amounts even from the beginning of fermentation, both securing that fermentation would eventually begin, but also greatly affecting the flavour of the beer over time.

On the other hand, as underpitching<sup>151</sup> could have been an issue for brewers who kept their beer batches shield-

ed from the air, the cooling troughs would have helped keep a better fermentation. If too little yeast capable of fermenting the sugars were added, the fermentation would have been slower, perhaps even non-existent, and the flavour would be greatly influenced. The cooling troughs would have ensured that the wort was subjected to both plenty of air and wood at a temperature where yeast cells could infect the beer, out-compete unwanted bacteria and begin a fermentation.

What is also noticeable about this innovation is that it would not have been as unattainable as the previously discussed copper kettles. Hollowing planks of wood would be possible to craft for most households and affordable and therefore this innovation was accessible to all producers who had knowledge of it and could keep it clean.

### *Fermentation*

Many years ago, scholars believed that yeast adding and fermentation was not a recognised process during the Middle Ages and the belief still lingers on in popular literature, not least due to the *Reinheitsgebot* of 1516. In the *Reinheitsgebot*, brewers were restricted to *‘daß in keinem Bier mehr Stücke als allein Gersten, Hopfen und Wasser verwendet und gebraucht werden sollen’*.<sup>152</sup> Which does not mention yeast. Yet as beer was not traded and the *Reinheitsgebot* was a way of securing ample supplies, collect taxes, and regulate prices and arguably protect guilds and consumers from poisonous additives,<sup>153</sup> there was no reason to mention an ingredient which were always in the brewhouse and, in fact, unavoidable. Furthermore, the *Reinheitsgebot* was a regional Bavarian law until 1906.<sup>154</sup> Other brewers have long known and tried to control fermentation, a fact revealed both by written sources, e.g. statutes, archaeological excavations,<sup>155</sup> and the language used as will be discussed later.<sup>156</sup>

However, fermentation has not been investigated thoroughly and has never, as far as I have been able to discover, been reviewed with the use of brewing science beyond the discussions of bottom fermentation and top fermentation. This, however, reveals much about the medieval beers, and is a very helpful addition in this investigation as contemporary source material is particularly scarce.

Once again, beginning with the Early Middle Ages and the household production of beer, fermentation may have happened completely naturally through subjection to air and without thoughts of temperature control, at least, in the winter periods. If we return to the theory of women's 'small beer', where the wort was left to ferment in the same pot for a day or two before consumption, the theory poses an example of a very uncontrolled fermentation, which would not produce either durable or well tasting result. During summer periods, the beer would probably never be enjoyable as the fermentation would be too warm, thereby killing the yeast or producing foul flavours. Therefore, if we accept the theory of women's small beer as the first example of medieval brewing in Northern Germany, we may expect that even the domestic country-side production improved in the Early Middle Ages, simply due to the high incentive of improving fermentation methods, although we have no source material on the matter and, hence, cannot describe how.

The brewing industry in the monasteries did attempt to control fermentation temperature as we could see from *The Plan of St. Gall* where the barrels were positioned in cellars against the outer walls.<sup>157</sup> Thus, from the beginning of professionalized brewing, brewers probably knew that fermentation had to be kept below a certain temperature. The professional urban brewers of the High Middle Ages also kept their beers stored in cellars after cooling for a number of days,<sup>158</sup> thereby keeping a stable, relatively cool environment, shielded from dramatic temperature changes, suitable for a good fermentation.

Some scholars believe that in medieval breweries, brewers transferred a small part of the foam from a fermenting batch to new batches, thereby infecting the beer with productive yeast cells and activating fermentation. In effect, this would mean that brewers would domesticate 'house yeast', which would make the yeast stronger and adapted to produce desired flavours.<sup>160</sup> It would also mean that they would be able to differentiate their products as each brewery would develop its own particular yeast-combination. The close relationship between bakers and brewers is an indication that this practice might have existed, bakers and brewers were often positioned near each other<sup>161</sup> and in statutes they are often dealt with as a collective.<sup>162</sup> Bakers reused yeast from previous breads to begin fermentation in the next and this knowledge may well have been shared.<sup>163</sup>

Whether the practice was also in use in rural household production is more uncertain, but possible, as this practice is easily observed through experience and provides better results if the yeast cells are numerous and healthy. However, it does entail that brewing must be conducted continuously which could be difficult.<sup>164</sup>

How fermentation functions, when it is initiated by wild yeasts, reveals something interesting about urban medieval beers. Fermentation would be spurred by the mix of wild yeasts and bacteria, which are present in the air and wood, the most dominant being: *Enterobacter*, *Saccharomyces*, *Brettanomyces*, *Lactobacillus*, and *Pediococcus*.<sup>165</sup> Each of these, which have many different strains, provides specific characteristics, flavours, and aromas to the beer. Wild yeasts are activated at different periods in fermentation, which requires a little closer attention, as they affect how the beers would taste at different times after the brew day.

In the first day of fermentation, the ill-tasting *Enterobacter* would be the dominant yeast, but it would quickly cease to reproduce as the pH dropped from its by-products and *Saccharomyces* overtook it.<sup>166</sup>

*Saccharomyces cerevisiae* is the traditional brewer's yeast today and would be the dominant fermenter although several other strains of *Saccharomyces* would also be present.<sup>167</sup> The fermentation temperature would determine which strains of *Saccharomyces* were dominant in the fermentation along with the timespan and alcohol level.<sup>168</sup> The warmer the fermentation temperatures, the faster the fermentation would complete, but the warm temperature would also create multitudes of by-products which affected the beer's aroma and flavour.

The most critical part of fermentation would be the first 72 hours, where the yeast could potentially produce the most off-flavours if not kept at a relatively low temperature. After this period, ideally, the fermentation should be left at the same temperature for a couple of weeks before being allowed to rise a little. If the temperature increases towards the end of fermentation, the yeast cells would consume some by-products and kill bacteria resulting in a better final product.<sup>169</sup>

We know from statutes that in Northern German towns during the Middle Ages that administrators did attempt to control the amount of time beer should be allowed to

ferment in the cellars before it could be sold. One statute from 1483 Hamburg reveals that beers should be kept in the cellar for at least 72 hours during summer and 8 days during winter before it could be sold, which aligns with the minimum requirements for a good fermentation according to modern science.<sup>170</sup> Hence, these restrictions meant that the Northern German brewers had to keep their beer in their cellars until *Saccharomyces* reproduced to a degree where the beer would be more resilient to bacteria and off-flavours could be avoided. The *Saccharomyces* would continue to ferment the sugars after the beers were taken out of the cellars and sold or shipped to its destination. For the first month or so, *Saccharomyces* would continue to be dominant.<sup>171</sup>

Therefore, export beers would continue to ferment sugar, reaching higher alcohol levels and complexity and keeping bacteria at bay during shipping. This would improve both flavour and durability. The local beers which were consumed quickly would not reach as high alcohol levels or complexity. The minimum requirements of 3-8 days in the cellar were key to ensure that fermentation could occur during shipping.<sup>172</sup>

After a month or two, again depending on the temperature, which we can now expect to be changeable as the beers had left the cellars, fermentation by *Saccharomyces* would be superseded by *Lactobacillus* and *Pediococcus*, which would produce lactic acid in the beers, so beginning a souring process. Throughout the process, *Brettanomyces* would also be fermenting at a very low rate, but as time elapsed the flavour of *Brettanomyces* would become more dominant and the beer would become drier, tarter, and gain the specific characteristics of *Brettanomyces*.<sup>173</sup> Where the beers were stored for a period of time after reaching its destination, consumers would experience beer, comparable to old-fashioned farmhouse cider, a considerable change from their local beers.

### Barrelling

The final act before beer could be transported or consumed was its transference into a suitable container and, again, this procedure reveals something interesting about medieval beers that were exported. Oak barrels of varying sizes with tightened wooden lids and a bung were the common container for the transportation of

beer.<sup>174</sup> The barrels were tightened at the bottom and top,<sup>175</sup> thereby leaving a little flexibility on the middle of the barrel for the inevitable pressure from CO<sub>2</sub> production due to the presence of *Brettanomyces*.<sup>176</sup>

In general, the bigger the size of the barrels, the better the durability of the beer. In large barrels the beer would be kept at a slightly more stable temperature than in smaller barrels, where more liquid was exposed to the barrels' sides and, hence, the temperature changes outside. As wood is porous, the amounts of air that came through the oak relative to the amount of beer would result in the oxidation of the beer earlier in smaller barrels. Lastly, there would be more bacteria due to the high surface-to-volume ratio in smaller barrels than in bigger barrels and the bacteria would grow faster due to the higher oxygen level.<sup>177</sup> Therefore, the beer that reached the customers abroad would vary in flavour and durability, simply due to the different sizes of the barrels, which did not become standardised during the Middle Ages despite serious attempts to do so.<sup>178</sup>

The type of oak used for the barrels, the level of charring that the cooper decided on, and whether the barrel was new or reused also effected the flavour of the beer.<sup>179</sup> Oak was used due to its properties of robustness, resistant to decay, relative ease to work and it does not spoil the beer with its flavour. Oak contributes subtle aromas and flavours that are more palatable than, for instance, pine.<sup>180</sup> Specifically, all types of oak contain different levels of vanillin, which gives the beer a vanilla-like flavour and aroma. Oak also adds tannins, which over time further contributes to the dryness of the beer. The longer the beer stays in the barrel, the more flavour it will extract. Different kinds of oak provide different spicy flavours from the presence of Methyloctalactones in wood, which varies depending on its origin. In combination, these flavours gave the beer what we today call an 'oaky character'.

Both new and old barrels were used in Hamburg, for instance.<sup>181</sup> The new barrels would contribute considerably more to the flavour than the used barrels. This is because the liquid extracts the tannins, vanillin, and Methyloctalactones in the barrel, leaving less for the next batch, every time it was used.<sup>182</sup> Therefore, the beer contained in the new barrels would be far more 'oaked' than the beer contained in the used barrels, even if the barrels had only been used once before.



Hence, the beers which were exported acquired more flavours and characteristics from the wood than the locally consumed beers, but they were themselves also highly differentiated from each other, due to the many different ways the barrels could influence the flavour.

Once the beer had left the cellars it was subjected to temperature changes, especially if it was shipped. On board the barrels were tied together, standing up, and packed tightly so that no space was wasted little space and secured much as possible, limiting the amount of agitation.

### Cleaning

As a final note on production methods it is worth mentioning cleanliness as it is hallowed by modern brewers as the most vital procedure in beer brewing if one wishes to produce high quality beers.<sup>184</sup> Not a lot of notice has been given previously to the matter of cleanliness and hygiene in breweries, yet it is clear that it was a concern for professional brewers. In *Capitulare de Villis*, it is mentioned that beer should be prepared with the greatest attention to cleanliness.<sup>185</sup> It is also specified that buildings should be constructed in such a way as tasks can be carried out cleanly and properly, although breweries are not specifically mentioned in this context.<sup>186</sup> Hence cleanliness in food production was present from the beginning of the Middle Ages even if sources do not reveal much on its development thereafter.

### References

1. See Hatcher, J. & Bailey, M. (2001) *Modelling the Middle Ages: The History and Theory of England's Economic Development*. Oxford: Oxford University Press, Chapter 4.
2. Cipolla, C.M. (1994) *Before the Industrial Revolution: European Society and Economy, 1000-1700*. New York: W.W. Norton & Company, Preface.
3. See De Vries, J. (2008) *The Industrious Revolution: Consumer Behaviour and the Household Economy, 1650 to the Present*. Cambridge: Cambridge University Press.
4. See Ogilvie, S. (2010) 'Consumption, Social Capital, and the "Industrious Revolution" in Early Modern Germany', *The Journal of Economic History*. Vol. 70, Issue 2, pp.287-325.
5. Medick, H. (1976). 'The Proto-Industrial Family Economy: The Structural Function of Household and Family during the Transition from Peasant Society to Industrial Capitalism', *Social History*, Vol. 1, Bind. 3; Ogilvie, S. (1997) *State Corporatism and Proto-Industry: The Württemberg Black Forest, 1580-1797*. Cambridge: Cambridge University Press.
6. See Cipolla, C.M. (1994) op. cit. or Persson, K.G. (2010) *An Economic History of Europe: Knowledge, Institutions and Growth, 600 to the Present*. Cambridge: Cambridge University Press.
7. Cipolla, C.M. (1994) op. cit., p.201.
8. *ibid.*
9. Herborn, W. (1997) 'Bierbrauen im Mittelalter' in Lindgren, U. (ed.) *Europäische Technik im Mittelalter, 800 bis 1400, Tradition und Innovation - Ein Handbuch*. Berlin: Gebr. Mann Verlag, p.453.
10. Hornsey, I.S. (2003) *A History of Beer and Brewing*. Cambridge: Royal Society of Chemistry, pp.314-315.
11. Beath, J. & Katsoulacos, Y. (1991) *The Economic Theory of Product Differentiation*. Cambridge: Cambridge University Press, pp.56-66.
12. I use the term 'myths' for hypothesis which are mistakenly and generally asserted as facts in the scholarly environment, whilst not truly being supported by evidence.
13. I will expand on this point in the section on literature and sources.
14. *ibid.*
15. This statement I will also support in the section on literature.
16. See Buglass, A.J., Hudson, J.A., Lee, C.G., Caven-Quantrill, D.J., Fuller, N.J., Lee, S.H. & McKay, M. (2011) *Handbook of Alcoholic Beverages: Technical, Analytical and Nutritional Aspects*, Vol. II, Chichester: John Wiley and Sons, pp.44-45 for more on brewing science since the Micro-Brewery Revolution.
17. Bennett, J.M. (1996) *Ale, Beer and Brewsters in England - Women's Work in a Changing World, 1300-1600*. Oxford: Oxford University Press, p.11; Meussdoerffer, F.G. (2009) 'A Comprehensive History of Beer Brewing' in Esslinger, H.M. (ed.) *Handbook of Brewing: Processes, Technology, Markets*. Weinheim: Wiley Verlag, pp.21-22, Phillips, R. (2014) *Alcohol - a History*. Chapel Hill: University of North Carolina Press, p.5.
18. Unger, R.W. (2004) *Beer in the Middle Ages and the Renaissance*. Philadelphia: University of Pennsylvania Press, p.78.
19. Nelson, M. (2005) *The Barbarian's Beverage: A History of Beer in Ancient Europe*. London: Routledge, Hornsey, I.S. (2003) op. cit.; Phillips, R. (2014) op. cit.

20. Mind that in modern terms, 'beer' is divided into the three overarching types of 'ale', 'lager' and 'spontaneously fermented' and hence 'ale' is a subdivision of beer and not a different type of brew. White, C. & J. Zainasheff (2010) *Yeast - The Practical Guide to Beer Fermentation*. Boulder, CO: Brewers Publications, p.44.

21. Behre, K.-E. (2016) 'Vom Getreide zum Bier, mit allen seinen Zutaten - seine Geschichte in Mitteleuropa' in Wiechmann, R. (ed.) *Kein Bier Ohne Alster - Hamburg - Brauhaus der Hanse*. Hamburg: Museum für Hamburgische Geschichte, p.28.

22. E.g. in Scandinavia the name never changed. Unger, R.W. (2004) op. cit., p.78.

23. E.g. varieties of 'cervesia' was used instead of 'beer' or 'ale'. Unger, R.W. (2004) op. cit., p.78.

24. Modern definitions of 'beer' tend to be wide, as more differentiated beers have been brewed in recent years and it is therefore necessary to be explicit about the multifaceted varieties of beer that exists and have existed for centuries, some of which are not flavoured with hops or brewed with grains, e.g. traditional Asian beers. Janowski, M. (2011) 'Rice Beer and Social Cohesion in the Kelabit Highlands, Sarawak' in Schiefenhövel, W. & Macbeth, H. (ed.) *Liquid Bread: Beer and Brewing in Cross-Cultural Perspective*. New York: Berghahn, p.183.

25. Unger, R.W. (2004) op. cit., pp.3-4.

26. Bickerdyke, J. (1889) *The Curiosities of Ale and Beer*. London: Swan Sonnenschein.

27. *ibid.*, pp.442-444.

28. *ibid.*, p.67.

29. Bennett, J.M. (1996) op. cit., p.78.

30. Bickerdyke, J. (1889) op. cit., p.75.

31. Wolf Bing was not the first to write about the breweries in Hamburg, but his work has surpassed those before him in the attention that has been given to his work. Stefke, G. (1979) *Ein Städtisches Exportgewerbe des Spätmittelalters in seiner Entfaltung und Erste Blüte - Untersuchungen zur Geschichte der Hamburger Seebrauerei des 14. Jahrhunderts*, Dissertation, Universität Hamburg, pp.3, 8.

32. Bing, W. (1909) 'Hamburgs Bierbrauerei vom 14. bis zum 18. Jahrhundert', *Zeitschrift des Vereins für Hamburgische Geschichte*. Bind XIV p.216.

33. *ibid.*, p.212.

34. Huntemann, H. (1970) *Bierproduktion und Bierverbrauch vom 15. bis zum Beginn des 19. Jahrhunderts*, Dissertation, University of Göttingen, p.15 or Petersen, M. E. (2000) *Innovation, Investment, and the Development of Commercial Beer Brewing within the Wendish Towns of Late Medieval Germany*. Dissertation, University of Wisconsin-

Madison, Bell and Howell Information and Learning Company, p.78.

35. Bing, W. (1909) op. cit., p.212.

36. *ibid.*: 213.

37. *ibid.*: 210.

38. Plümer, E. (1981) 'Einbecks mittelalterlicher Bierhandel', *Hansische Geschichtsblätter*. Vol. 99, pp.10-32.

39. Albrecht, H. (1915) *Das Lübecker Braugewerbe bis zur Aufhebung der Brauerzunft 1865*. Rahtgens.

40. Frontzek, W. (2005) *Das städtische Braugewerbe und seine Bauten vom Mittelalter bis zur frühen Neuzeit*. Neumünster: Wachholtz.

41. Petersen, M. E. (2000) op. cit.

42. Simmes, M. (2016) 'Dortmunder Bier im späten Mittelalter um in früherer Neuzeit aus Sicht städtischer Policeyordnungen', *Beiträge zur Geschichte Dortmunds und der Grafschaft Mark*. Vol. 107, pp.7-70.

43. Wiechmann, R. (ed.) (2016) op. cit.

44. Smaller controversies and discussions exist, but I will investigate the literature more thoroughly later on and therefore, I leave the details out of this introduction to the literature on beer.

45. Stefke, G. (1979) op. cit., pp.3-10.

46. E.g. Wolf Bing, Gerald Stefke, Mark Peterson, Christine von Blanckenburg, and Richard Unger.

47. Stefke, G. (1979) op. cit., pp.3-10.

48. Petersen, M. E. (2000) op. cit., pp.4-5.

49. Hornsey, I.S. (2003) op. cit.; Unger, R. W. (2001) *History of Brewing in Holland, 900-1900: Economy, Technology, and the State*. Leiden: Brill; Unger, R.W. (2004) op. cit.; Nelson, M. (2005) op. cit.

50. Hornsey, I.S. (2003) op. cit., pp.269-273; Unger, R.W. (2004) op. cit., p.3; Nelson, M. (2005) op. cit., p.3.

51. The works of Unger and Stefke are some of the most obvious exceptions of this consideration.

52. Beer types are sometimes named in works, where at first sight, they seem to be medieval, yet are only recorded in Early Modern works, e.g. Wiechmann, R. & Freudenthal, G. (2016) 'Hamburg - Brauhaus der Hanse' in: Wiechmann, R. (ed.) *Kein Bier Ohne Alster - Hamburg - Brauhaus der Hanse*. Hamburg: Museum für Hamburgische Geschichte, p.74. Changes in beer colours are also often mentioned as a specific medieval trademark, yet they are rarely mentioned in contemporary sources, but very emphasized in Schlüter's work. Schlüter, M. (1698) *Tractat von denen Erben in Hamburg*. pp.122-126.

53. E.g. in *Rostocker Bursprachen*, periodic regulation on the amount of malt each brewer is allowed to brew with and how much beer he can produce from it is recorded. It is also

mentioned that the 'copman' will taste it to secure quality. *Rostocker Burspracken*. pp.54-56.

54. Mallett, J. (2014) *Malt - A Practical Guide from Field to Brewhouse*. Boulder, CO: Brewers Publications p.10.

55. *ibid.*, pp.52-60.

56. *ibid.*, 73-75.

57. *ibid.*

58. *ibid.*, pp.121-123

59. *ibid.*, pp.124-125.

60. *ibid.*, pp.9-11.

61. Yeast cannot ferment starch, so enzymes are necessary to deconstruct the starches into simpler sugar compositions. During fermentation the yeast also needs vitamins and minerals to flourish. *ibid.*

62. *Mecklenburgisches Urkundenbuch* (MUB) Vol. I-XXII, Accessed through <http://www.archive.org>, n.2759: 34.

63. The stronger the wort (unfermented beer), the higher alcohol percentage and body. *ibid.*, p.13.

64. Mallett, J. (2014) *op. cit.*, pp.12-13 called brewhouse's efficiency.

65. E.g. superattenuating yeasts, like *Brettanomyces* strains, will continue to ferment for several years. Sparrow, J. (2005) *Wild Brews - Beer Beyond the Influence of Brewer's Yeast*. Boulder, CO: Brewers Publications, p.107.

66. For several years, brewers used multiple step mashing, where temperature rises in different steps to create ideal conditions for enzymes. Karnowski, M. (2014) *Homebrew - Beyond the Basics*. New York, NY: Sterling Publishing, pp.52-54. However, as I assume that medieval brewers did not have the knowledge or technology to change mashing temperature precisely and timely, I will not elaborate more on this process.

67. *ibid.*, p.53.

68. Palmer, J. & C. Kaminski (2013) *Water - A Comprehensive Guide for Brewers*. Colorado, CO: Brewers Publications, pp.234-235.

69. *ibid.*, p.119.

70. Before or during separating the wort, brewers sparge, that is pour hot water over the grains using a variety of techniques. Sparging heightens efficiency as it rinses additional sugar off into the wort. Whether medieval brewers might have used sparging techniques rely on whether they ever separated the grains from the liquid before boiling. Karnowski, M. (2014) *op. cit.*, p.62.

71. E.g. *Alterthümer des Wismarschen Stadtrechtes aus ältesten bisher ungedruckten Stadtbüchern nebst den ältesten Zunftrollen aus dem vierzehnten Jahrhunderte*, ed. Burmeister, C., Druck und Verlag von F. D. Restler und Welle, 1838. pp.37, 42.

72. Briggs, D.E., Boulton, C.A., Brookes, P.A. & Stevens, R. (2004) *Brewing Science and Practice*. Cambridge: Woodhead Publishing Limited, pp.306-323.

73. *ibid.*, pp.306-323.

74. Karnowski, M. (2014) *op. cit.*, p.91.

75. *ibid.*, pp.91-92.

76. Hieronymus, S. (2012) *For the Love of Hops - A Practical Guide to Aroma, Bitterness and the Culture of Hops*. Colorado, CO: Brewers Publications, pp.20-24

77. *ibid.*, pp.176-177.

78. Attokaran, M. (2011) *Natural Food Flavors and Colorants*. Chichester: Wiley, p.242.

79. Hieronymus, S. (2012) *op. cit.* p.19.

80. *ibid.*, pp.234-235, Buglass, A.J. et. al. (2011) *op. cit.*, p.194.

81. Steele, M. (2012) *IPA - Brewing Techniques, Recipes and the Evolution of India Pale Ale*. Colorado, CO: Brewers Publications, pp.154-155.

82. Sparrow, J. (2005) *op. cit.*, p.149.

83. White, C. & Zainasheff, J. (2010) *op. cit.*, p.11.

84. *ibid.*, pp.94-98.

85. *ibid.*, pp.44, 50.

86. *ibid.*, pp.94-95.

87. *ibid.*, p.14.

88. *ibid.*, pp.41-57.

89. Yeast properties will be discussed further in the sections on fermentation and yeast.

90. White, C. & Zainasheff, J. (2010) *op. cit.*, pp.107-115.

91. See e.g. Persson, K.G. (2010) *op. cit.* on the benefits of specialisation in the Pre-modern period.

92. Cipolla, C.M. (1994) *op. cit.*, pp.53, 100.

93. Unger, R.W. (2004) *op. cit.*, p.40; Meussdoerffer, F.G. (2009) *op. cit.*, p.8.

94. It was common that men and women had one or more by-occupations and skills in the Middle Ages which they could rely on. Hatcher, J. & Bailey, M. (2001) *op. cit.* p.51.

95. <https://www.le.ac.uk/hi/polyptyques/capitulare/site.html>. Accessed on 18/06/2018.

96. *Capitulare de Villis*, n. 61.

97. *ibid.*: n.34.

98. *ibid.*: n.45.

99. MUB I, *op. cit.*, n.499: 492.

100. Between 9-13.5 barrels depended on region and content. Lorenzen-Schmidt, K.J. (1990) *Kleines Lexikon alter schleswig-holsteinischer Gewichte, Masse und Währungseinheiten*. Kiel: Wachholtz Verlag, p.76.

101. MUB II, *op. cit.*, n.845: 137.

102. MUB III, *op. cit.*, n.2234: 514.

103. E.g. MUB V, op. cit., n. 2738: 13.
104. *Urkundenbuch der Stadt Lübeck* (UdStL), Freidr. Aschenfeldt, 1843, n.153-154: 142-144; HUB I, op. cit., n.366: 120, HUB II, n.18: 9, HUB II, n.284: 117, HUB V, n. 721: 373.
105. HUB IV, op. cit., n.37: 22.
106. Unger, R.W. (2004) op. cit., p.40.
107. Gaessner, H. (1938) 'Bier, Malz und Hopfen im deutschen und besonders hansischen Überseeverkehr von 1562 bis 1657', in *Jahrbuch der Gesellschaft für die Geschichte und Bibliographie des Brauwesens 1938*. Berlin: Institut für Gärungsgewerbe, pp.80-100.
108. Nelson, M. (2005) op. cit., p.6.
109. Meussdoerffer, F.G. (2009) op. cit., p.8.
110. I will explain further in the section on malts.
111. Stika, H.-P. (2011) 'Early Iron Age and Late Medieval malt finds from Germany-attempts at reconstruction of early Celtic brewing and the taste of Celtic beer', *Archaeol Anthropol Sci*, Vol. 3, p.46.
112. Frontzek, W. (2005) op. cit., pp.47, 97.
113. See Malanima's chapter on energy in Pre-modern Europe. Before mechanical machines and fossilised energy, the majority of energy came from firewood, mills, and labour from animals and humans. Malanima, P. (2009) 'Pre-Modern European Economy: One Thousand Years (10th-19th Centuries)', *Global Economic History Series*, Vol. 5, Leiben: Brill pp.49-94.
114. In 'Fuelling the City' it is estimated that baking and brewing consumed app. 30,000 tons of firewood a year in 1300, making up for c.22 % of the city's total consumption in London. Galloway, J.A., Keene, D. & Murphy, M. (1996) 'Fuelling the City: Production and Distribution of Firewood and Fuel in London's Region, 1200-1400', *Economic History Review*, Vol.49, is.3, p.456.
115. See earlier section on brewing technology.
116. E.g. Cipolla, C.M. (1994) pp.117-118.
117. As beer was part of the household production at this time, it was typically produced by women. See Bennett, J.M. (1996) op. cit.
118. See the brewing section on the properties of efficient boiling.
119. Reproduced from King, F.A. (1947) *Beer has a History*. London: Hutchinson, p.22.
120. Building houses in stone was also more expensive, which theoretically meant that fewer could access the marked. However, the organization and social status of producers are beyond the scope of this investigation and therefore will not be discussed further here.
121. Monckton, H.A. (1966) *A History of English Ale and Beer*. London: Bodley Head, p.41.
122. Techen, F. (ed.) (1906) *Die Bürgersprachen der Stadt Wismar, Hansische Geschichtsquellen*, Vol.3, Verein für Hansische Geschichte, Verlag von Duncker & Humblot, pp.101-104.
123. E.g. MUB II, op. cit., n.1374: 525.
124. E.g. Unger, R.W. (2001) p.20.
125. The transition from pottery kettles to copper kettles are generally estimated to approx. late 12th century to the early 13th century and they became more common and larger in commercial breweries from then onwards. See e.g. Doorman, G. (1955) *De Middeleeuwse Brouwerij en de Gruut*. Leiden: Martinus Nijhoff, pp.54-58; Räsänen, M. (1975) *Vom Halm zum Fass - Die volkstümlichen alkoholarmen Getreidegetränke in Finnland*. Helsinki: Oy Weilin + Göös, pp.204-208; Techen, F. (1915) 'Das Brauwerk in Wismar', *Hansische Geschichtsblätter*, Vol.21 p.333; or Unger, R.W. (2004) op. cit. p.42.
126. E.g. Sinclair, T.R. & Sinclair, C.J. (2010) *Bread, Beer and the Seeds of Change - Agriculture's Imprint on World History*. Wallingford: CABI, p.140.
127. By removing the wort from the grains before boiling, the brewer can rinse the grains 1-2 times more and extract more wort, which can either be added to the first batch of wort before boiling or make a 'second running' beer, which is thinner. Briggs, D.E., et. al., (2004) op. cit. p.223.
128. See brewing section, where tannins in boiling is noted.
129. E.g. *Alterthümer* op. cit. p.37: Conradus de Zwerin leaves 'utensilibus in sartagine et in vasis braxatoriis et in aliis utensilibus' - a sartago (large copper vessel, see Petersen (2000): 69) and mash tuns and all other containers in the late 13th century (the dating is not precise), *Alterthümer*: 42. Henricus Niger leaves brewing utensils to his wife after his death, including the large copper brewing vessel, sartagine, and wooden tuns, dolia, and the 'necessaria' in the early 14th century.
130. Unger, R.W. (2004) op. cit., p. 42.
131. Lappenberg, J.M. (ed.) (1841) *Geschichtsquellen des Erzstiftes und der Stadt Bremen*. Johann Georg Heyse, p.75.
132. Schlüter, M. (1698) op. cit., pp. 122-126.
133. This will be explained further in the section on beer types.
134. There are certain indications that the working days in the breweries could be very long, which indicates long mashing and/or boil periods. Stefan Wulf, who has written of night work in Northern German towns, reveals that brewers in Lübeck began their preparations in the night-time in the 15th century. Wulf, S. (1990) *Arbeit und Nichtarbeit in nord-deutschen Städten des 14. Bis 16. Jahrhunderts. Studien zur*

*Gechichte sozialer Zeitordnung*. Göttingen: Dr. R. Krämer, p.114.

135. pH levels during mashing also influence the beer, but as medieval brewers did not have the knowledge of pH and sources do not reveal considerations of such, I will not elaborate on this here.

136. See the section on brewing science for information on sparging.

137. Phillips, R. (2014) op. cit., p.68.

138. Unger, R.W. (2001) op. cit., p.20.

139. E.g. distributing the grains equally through the liquid and controlling that the wort does not boil over is easier with smaller quantities.

140. Phillips, R. (2014) op. cit., p.67.

141. Due to metal's chemical heat properties.

142. Phillips, R. (2014) op. cit., p.68.

143. E.g. Thierfelder, H. (ed.) (1967) *Das älteste Rostocker Stadtbuch. Etwa 12-54-1273. Mit Beiträgen zur Geschichte Rostock zum 13. Jahrhunderts*. Vandenhoeck & Ruprecht, n.2/121: 248, MUB II, op. cit., n.1271: 445.

144. As previously mentioned, some communities did invest in shared equipment and so not all un-professionalised brewers were prevented by lack of funds.

145. Technically, water can also be used to cool the wort, but as I have found no indication of water-based cooling systems, I will leave this consideration out for now.

146. Sparrow, J. (2005) op. cit., p.149.

147. *The Plan of St. Gall*.

148. This has been suggested before by Unger, R.W. (2004) op. cit., p.28.

149. Unger, R.W. (2001) op. cit., p.20, Monckton, H.A. (1966) op. cit., p.21.

150. Sparrow, J. (2005) op. cit., pp.109-110.

151. Underpitching is a term for the situation where a brewer adds too small amount of yeast relative to sugar in the wort, causing the yeast to become stressed and weak. White, C. & Zainasheff, J. (2010) op. cit., p.121.

152. Wilhem IV: *Reinheitsgebot*.

153. Van Tongeren, F. (2011) 'Standards and International Trade Integration: A Historical Review of the German "Reinheitsgebot"', in Swinnen, J. (ed.) *The Economics of Beer*. Oxford: Oxford University Press, p.52.

154. *ibid.*

155. Positioning of barrels in cellars along the cooler walls indicates that brewers understood that the beers needed to be left in a calm environment to ferment well and that they stayed there for some time. The most obvious example of this is *The Plan of Saint Gall*.

156. For example, the German word for yeast, hefe, has

been part of the German language since the mid 1st millennium. White, C. & Zainasheff, J. (2010) op. cit., p.6, Wiechmann, R. & Freudenthal, G. (2016) p.64.

157. *The Plan of St. Gall*.

158. Bing, W. (1909) op. cit., p.212.

159. E.g. Lietz, P. (2016) 'Über Hefe und Gärung', in Wiechmann, R. (ed.) *Kein Bier Ohne Alster - Hamburg - Brauhaus der Hanse*. Hamburg: Museum für Hamburgische Geschichte, p.194, Petersen, M. E. (2000) op. cit., pp.14, 75-77.

160. White, C. & Zainasheff, J. (2010) op. cit., pp.161-165.

161. E.g. *The Plan of St. Gall*.

162. E.g. Rüdiger, O. (ed.) (1874) *Die ältesten Hamburgischen Zunftrollen und Bruderschaftsstatuten*. In commission bei Lucas Gräfe, pp.22-28.

163. Cauvain, S. & Young, L.S. (2007) *The Technology of Breadmaking*. Heidelberg: Springer, p.2.

164. Harvesting and reusing yeast is common practice in many breweries also today, but one risks a poor result if the same yeast is reused too many times as it can mutate towards the worse. Sparrow, J. (2005) op. cit., p.169.

165. *ibid.*, p.99.

166. *ibid.*, p.110.

167. *ibid.*, p.114.

168. *ibid.*, pp.114-115.

169. White, C. & Zainasheff, J. (2010) op. cit., pp.96-97.

170. Bolland, J. (ed.) *Hamburgische Burspraken 1346 bis 1594 mit Nachträgen bis 1699*, Vol. II. Hamburg: Hans Christians Druckerei und Verlag, n.78, pp.169-170.

171. Sparrow, J. (2005) op. cit., pp.159-167.

172. Interestingly, regional trade in beer is concentrated in the milder months of the year, further suggesting that brewers were considerate of the continued fermentation. I will elaborate on this towards the end of the study.

173. Sparrow, J. (2005) op. cit., pp.159-167.

174. Work, H.H. (2014) *Wood, Whiskey, and Wine: A History of Barrels*. London: Reaktion, p.15; Jahnke, C. (2016) 'Von Tonnen und Schiffen - Biertransporte', in Wiechmann, R. (ed.) *Kein Bier Ohne Alster - Hamburg - Brauhaus der Hanse*. Hamburg: Museum für Hamburgische Geschichte, pp.115-116.

175. Work, H.H. (2014) op. cit., p.15, Jahnke, C. (2016) op. cit., pp.115-116.

176. *Brettanomyces* continue to ferment long after the alcoholic fermentation of *Saccharomyces* has ceased and produces a smaller amount of carbon dioxide, which can ultimately lead to explosions if the beer is left for years before consumption. Sparrow, J. (2005) op. cit., pp.107-108.

177. *ibid.*, p.197.

178. Jahnke, C. (2016) op. cit., p.116.

179. Sparrow, J. (2005) op. cit., p.191.  
180. ibid.  
181. Jahnke, C. (2016) op. cit., p.117.  
182. Sparrow, J. (2005) op. cit., p.194.  
183. Twede, D. (2005) 'The Cask Ages: The Technology and History of Wooden Barrels', *Packaging Technology and Science*. Vol.18, iss.5, pp.262.  
184. Eg. Karnowski, M. (2014) op. cit., pp.20-21.  
185. *Capitulare de Villis*, n.34.  
186. ibid.: n.41.