ŽATEC, CRADLE OF SAAZ HOPS AND LANDMARK OF COMMERCIAL HOP CULTIVATION

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Introduction

According to Josef Schöffl, a nineteenth century hop grower in the Bohemian town of Žatec and president of the regional agricultural union, hops could be cultivated in nearly any kind of soil, whether it be rubble, gravel, sandy, clay, loamy, peaty or with a basalt substratum. It was not the soil, nor the climate or the maintenance of the plants that made Žatec an exceptional hop growing region. Above all, its fame was due to the type of hop, Saaz.¹

Saaz hops are one of a handful traditional European hop cultivars. The variety bears the German name for Žatec, a little town in the Czech Republic where, until the end of World War II, the majority of the population spoke German. The Czech Republic is the second major hop producing country in Europe and ranks fourth in global production, after the USA, Germany and China.² There are three regions in the Czech Republic where hops are grown of which the area around Žatec is the largest, making up more than 75% of the country's total. Although new hop varieties have been introduced since the 1990s, the traditional Saaz hops are grown on nearly 90% of the entire acreage in 2017.³ Saaz hops are a favorite variety for brewing pilsners, lager beers and Belgian style ales.

In this article it is proposed that Žatec might be the oldest region of continuous commercial hop production. This assumption is based mainly on English and German literature devoted to brewing history and on scientific research concerning the qualities and DNA fingerprint of hop cultivars. By combining these two sources, the line of development and diffusion of commercial hop cultivation is revealed. Saaz hops proves to be the mother of some of the other noble hop cultivars. Although Žatec was not the first region to produce hops for the market, it might be the oldest of today's hop cultures. First, the use and qualities of hops in general and Saaz hops in particular are discussed. Then the rise and diffusion of commercial hop cultivation will be investigated and the age of some current European production areas determined.

Characterization of Saaz hops

Among the great and still increasing span of hop varieties that are marketed today, a small number have historical roots, dating back to pre-modern times. These traditional varieties are called 'noble hops', with regard to their pedigree, or 'land races', because their names refer to the regions and places of origin. Renowned traditional hop cultivars are Spalt, Hersbruck, Hallertau (Bavaria) and Tettnang (Württemberg) from Germany, Fuggle and Golding (Kent) from England, Saaz (Žatec) from the Czech Republic and Lubelski (Lublin) from Poland. However, the vast majority of hop varieties that are used by breweries consist of hybrid cultivars, composed of noble, other hybrid or wild elements.⁴ The Saaz hops are one of the most popular and replicated varietals in the world. It is highly prized for its classic herbal, earthy and spicy aroma.5

Hop varieties are roughly classified in three distinct categories: aroma hops, dual-purpose hops (aromatic and bitter) and bittering hops (very bitter).⁶ Classification is based on the composition and qualities of resins (alphaand beta-acids, cohumulone and colupulone) and oils (myrcene and terpenes), contained in the female cones. Saaz hops are characterized as fine aroma hops, being part of the first category. They feature a low content of alpha-acids, ranging 3 to 4%, and beta-acids at a level of 4 to 7%. The content of oils is also low, not exceeding 1%.7 This composition is different from other traditional cultivars such as English Fuggle and Golding, whose alpha-acids content (5 to 7%) is more than double that of their beta-acids (2 to 3%). Most European and American hybrid aroma hops have a slightly higher content of alpha-bitter acids than Saazer. However, the German noble hops from Spalt and Tettnang are very much akin, showing the same resin and oil profile, which also goes for the Polish Lubelski hops. In the brewing process aroma hops are added at the later stages of the hopping schedule, giving beers their finishing touch of flavour.

All dual-purpose hops are of hybrid origin and have a higher content of alpha-acids, ranging 7 to 10%. The proportion of oils (1 to 2%) is twice or three times higher compared to Saazer. Dual purpose hops can be added both in the initial and later stages of the hopping schedule and are popular for their versatility. Bittering hops - the third category - have an even higher content of alpha-acids, measuring 10 to 18%, and contain more oil (1,5 to 3%). These varieties are predominantly used for making hop extracts.

From the 1990s the genetic parentage between cultivars of hops has been uncovered with the advent of DNA research, using different molecular methods.⁸ The results showed that Saaz hops and the German Spalt and Tettnang hops genetically have a high degree of similarity, although they do have some morphological differences. These genotypes proved to be very closely related to the Polish Lubelski hops, the Russian Iwanovecki and Urožaini varieties as well as the Ukrainian Žitomir clone 18. All these cultivars together can be designated as belonging to the 'Saaz-family', which differs genetically from the 'Bavarian family', the latter consisting of Hallertau and Hersbruck, and the 'English family', featured by Fuggle and Golding; all three groups known as typically fine aroma hops.

The distinction between families of hop cultivars, that differ in composition, qualities and DNA fingerprint, can be explained by the historical development of commercial hop cultivation.

The genesis of hop culture in Bohemia

In the early Middle Ages, wild and cultivated hops were found in many parts of central and northern Europe. Mainly based on archaeological finds and written sources from monasteries, we know that hops have been used for the preparation of beer since the ninth century at the latest. However, in the early and high Middle Ages hops were only one species in a whole array of herbs that were used for brewing beer.⁹

In the thirteenth century a true beer revolution caused a watershed in the history of brewing. Craftsmen and merchants in the Hanse towns of northern Germany started producing and trading beer with hops as the sole herbal ingredient. They had probably learned this method of preparation from the Slavic peoples that inhabited the north-eastern areas of the German empire. Hops give beer its bitter taste and its various aromas, it enhances the development of foam and gives beer a longer shelf life.¹⁰ Thanks to the preservative potential of hops, beer could be produced in bigger quantities and could be distributed over greater distances. Beer no longer was just a homemade product for family consumption, like bread, it was also a lucrative trading good. Hanseatic port towns like Bremen, Hamburg, Lubeck, Wismar and Rostock, became the first centres of large-scale beer production.¹¹ To supply sufficient raw materials the commercial cultivation of hops sprang up on the outskirts of beer producing towns, as well as in villages in the countryside. The territories of Mecklenburg, the Altmark, Brandenburg and Pomerania became important hop producing areas in the thirteenth and fourteenth centuries. Large scale hop cultivation also arose in more distant regions, such as Thüringen and Silesia, that were well connected with the Hanseatic port towns through the rivers Weser and Oder.¹²

In Bohemia hops had already been cultivated in the early and high Middle Ages. Large concentrations of macro-remains of hop have been found in the central and eastern parts of the Czech Republic.¹³ The deed of donation (1039) for the collegiate church of Stara Boleslav (Alt Bunzlau) mentioned farms in `atec, that were due to render tithes on cattle, grains and hops. A tithe on hops also appears in the foundation charter (1046) of the church of Vyšehrad, a district of Prague.¹⁴ However, a significant expansion of cultivation must have taken place in the fourteenth century, probably

instigated by the growing demand from the beer producing Hanse towns. In 1363 King Charles IV of Bohemia (r. 1346-1378), who was also elected as king of the German empire, encouraged the creation of hop gardens in the surrounding areas of his royal towns and strictly forbade exporting hop slips.¹⁵ On the one hand this promotion had a general character, whilst giving an impulse to agriculture - he also promoted the establishment of vineyards. But he must have been aware of growing market opportunities, too. In a letter he wrote to the Dutch bishop of Utrecht a year later, he stated that for 30 or 40 years a novus modus fermentandi cervisiam (new method of brewing/fermenting beer) had been introduced, for which hops were used.¹⁶ Commercial cultivation of hops in Žatec is confirmed by mid-fourteenth century documents (1348, 1357), indicating that civilians owned hop gardens in the vicinity of the town. Expanding gradually, the area that was used for growing hops had reached an impressive extent of about 400 hectares by the mid-sixteenth century, which was more than half of the aggregate production area in Bohemia.¹⁷

It is claimed that even around 1100 Czech hops were already exported to the Hamburg hop market (Forum humuli) via the Elbe river.18 This, however, is quite unlikely. Only at the end of the thirteenth century did the Hamburg brewers produce a surplus that could be exported abroad, which in turn would cause a rise in the demand for hops. Henceforth, the output grew rapidly and from the fourteenth to the sixteenth century the town was called the 'brewing house of the Hanseatic League'.¹⁹ Moreover, the Forum humuli, that still bears the name of Hopfenmarkt today, is mentioned in sources dating back no earlier than the mid-fourteenth century.²⁰ The square is situated next to Saint-Nicolas' church in the Neustadt, a new part of town that was built from the end of the twelfth century. Therefore, exports of Czech hops to Hamburg via the Elbe river is more likely to have occurred in the fourteenth century, which underlines the assumption of an expansion of hop cultivation in that period.

Simultaneously, commercial hop culture emerged to the west of Bohemia in Central Franconia, (Mittelfranken), Upper Franconia (Oberfranken) and Upper Palatinate (Oberpfalz), regions surrounding the town of Nuremberg - nowadays the north of Bavaria. It is assumed that the growth was due to the promotion by the abovementioned King Charles IV, who had expanded his family lands to the west, but also coincided with the decline of viniculture in these parts. In those times Nuremberg was the principal town of the German empire. Municipal bye-laws, dating from mid-fourteenth century, mention hops from the surrounding districts being brought to the town market, where a sworn official was ordained particularly to measure shipments of the crop. The origin of hop culture in these lands is demonstrated by the many technical expressions in the Bohemian language being used in the breweries of Nuremberg and its neighborhood.²¹

Special mention needs to be made of the rise of hop culture in the little town of Spalt, south of Nuremberg. Documents from the town council witness hop gardens that were laid-out in the course of the fourteenth century. Around 1900, from oral tradition, hop farmers from this area believed that hop culture was introduced in the first half of the fourteenth century, when a canon from a collegiate church in Žatec, Bohemia, came to plant the first crops in Spalt. From that time hop culture and trade grew steadily. Hops from Spalt became much sought-after and in 1511 town regulations were needed to forbid exporting hop slips. In 1538 the archbishop of Eichstätt granted the town council of Spalt their own hop seal as a proof of authentic origin. It was the first place in Germany to have such a special seal.²² Hop cultivation in this region still exists and Spalt is one of the outstanding noble hop varieties of today. Clearly, the similarity in DNA fingerprint between hops from Spalt and 'atec bears a historical explanation. Saaz hops must be the elder of the two.

The rise of hop culture in western Europe

The commercial success of hopped beers from the north German Hanse towns in the thirteenth and fourteenth century challenged brewers in the Netherlands. They watched the Hanse ships sailing along the Dutch waterways to the densely populated cities in Belgium, such as Ypres, Bruges, Gaunt and Antwerp. From the 1320s Dutch brewers obtained permission from their princes to cease the production of multi-herbal beers, called *gruitbier*, and switch over to brewing hopped beers. In the course of the fourteenth century hop cultivation spread all over the country, in places where there had previously been none at all. Beer production in the county of Holland increased rapidly and beers from Haarlem,

Gouda and Delft became popular brands in the Low Countries, northern France, the east of England and the German Rhineland.²³ In the first decades of the fifteenth century Belgian brewers emulated the Holland beers and began cultivating their own hops.²⁴ In particular hops from Poperinge (near Ypres) and Aalst (near Gaunt) became renowned and are still used in Belgian beers today.

The introduction of hopped beers to England occurred at a slow pace. Immigrants from the Netherlands started production in the outskirts of London and in the southeastern counties, from Norfolk to Kent. For a long time hopped beer was considered an abject drink for aliens, the English held tight to their traditional ales that were brewed without hops. Not until the sixteenth century consumers embrace beer as a healthy English drink and native entrepreneurs began brewing it.²⁵ Hops that were formerly imported from the Netherlands and Belgium by the boatload were now grown in Kent, Surrey and Essex. The knowledge about growing hops was sought for in the Low Countries, especially in Flemish Poperinge.²⁶ In the seventeenth and eighteenth centuries England became the leading country in beer production.

Over time, many hop cultivating regions in Western Europe have ceased production. In the seventeenth and eighteenth centuries the consumption of beer diminished with the introduction of new drinks such as gin, coffee, tea and chocolate. In the Netherlands hop cultivation languished and around 1900 brewers only used foreign hops. The same went for hop growing areas in the former Hanse region of northern Germany.²⁷ Only in England did hop cultivation survive due to the strength of its brewing industry and hop breeding programmes. Golding and Fuggles from Kent, bred since the eighteenth and nineteenth centuries respectively, are still popular hop varieties. Currently, in Poperinge and Aalst hops are grown, but production is on a small scale. It is very likely that the original Flemish hops have been parented in their DNA with the English cultivars.²⁸ However, in the first decades of the twentieth century the Flemish varietals were gradually replaced by hops from Hallertau, Žatec and Kent.²⁹

The conquest of Bavaria

The revolution of hopped beer, that had started in the north of the German empire, reached the south of Bavaria in the last decades of the fifteenth century, annihilating the production of the traditional Gräwzzing, a kind of gruitbier or ale, made without hops.³⁰ Although beer was produced on a small scale and hop gardens were already known in Hallertau in the ninth century, Bavaria predominantly was a nation of wine consumption and production.³¹ Two innovations in beer production gave an impulse to the industry. Immigrants from Upper Franconia (Oberfranken) and Upper Palatinate (Oberpfalz), east of Nuremberg, taught the practice of bottom fermentation in the brewing process. Beer was fermented at lower temperatures and was matured in mountain caves or cellars of breweries in a cool and stable climate for several weeks, which was called lager beer. Brewing servants from Bohemia, who settled in Bavarian towns, started producing beers in the Bohemian way: they made strong and bitter barley beers, using fine red hops - so called after their red bines - from their native country. Bottom fermentation became the typical method of Bavarian brewing for centuries and Bohemian beer was the most popular style. From the sixteenth to the twentieth centuries Bavarian brewers purchased a considerable proportion of their barley malt and red hops from Bohemia.³²

They also made a cheaper type of beer for which they used local green hops, having green bines.³³ The growth of hops in the south of Bavaria was stimulated under the reign of Ferdinand Maria (1636-1679) and in the second half of the seventeenth century the region of Hallertau came to be the second largest production area in the principality, after Spalt. However, it took another century before Bavarian hop experts claimed that their crop had reached the same level of quality as the Bohemian varieties.³⁴ From the beginning of the eighteenth century hops were grown on a larger scale in and around Hersbruck, northeast of Nuremberg.³⁵ Hops from this area are still used nowadays. Apparently, the quality and quantity were not satisfactory from the start, for in the 1730s additional hops were still imported from Bohemia. By mid-century, however, Hersbruck obtained its own hop seal, as a sign of its competitive potential. In the first half of the nineteenth century the acreage of hop cultivation in Hersbruck and Spalt increased substantially, through common grounds that were divided and brought to culture. The abolition of the levy on hops in these years paved the way for further growth. In 1853 this region counted for more than half of the production in Bavaria, meaning the principality

ranked second after England in total world production. At last, domestic and foreign brewers no longer considered Bavarian hops of a lower quality than its Bohemian rival.³⁶

Yet, there were significant morphological differences between hop cultivars. According to Olbricht, who was an expert grower of hops in the 1830s, fine red hops were cultivated in Žatec, Sokolov (Falkenau) and Úštek (Auscha) in Bohemia, and also in Spalt and Hersbruck in the north of Bavaria. These hops had soft and fine cones with golden or copper-coloured grains of pollen and gave a delicate and lovely aroma. In Hallertau and other places in the south of Bavaria, however, green hops were cultivated, probably of native origin. The female cones were slightly bigger and heavier than with red hops, but had a weaker aroma and oil content.³⁷ By examining these hop cultivars on quality and DNA, the differences appear clearly: hops from the south of Bavaria have a different pedigree from the 'Saaz-family'.³⁸

Diffusion of the 'Saaz-family'

Bavaria has been the principal export market for Bohemian hops from the sixteenth to the twentieth century. Brewers needed the fine red hops for making strong brown lager beers. Bohemian hops were also exported to several regions in Austria, Hungary and Poland. By mid-eighteenth century hop slips from Bohemia were purchased to improve the quality of Prussian hops and later Bohemian emigrants introduced red hops in the Polish region of Poznan. When, in the beginning of the nineteenth century, hop cultivation expanded significantly in the principalities of Baden and Württemberg, red hop slips from Žatec were used.39 In particular the hops from Tettnang, near Lake Constance, have gained great renown and are still a popular noble race these days. The exports of Bohemian hop slips explains the similarity of quality and DNA between hop races from Poland (Lubelski), southwest Germany (Tettnang) and Žatec (Saaz).

In the first decades of the nineteenth century Bohemian top fermenting beers were considered expensive and of poor quality. This prompted some citizens from Plzen (Pilsen) who had 'brewing rights', to erect their own Burghers' Brewery and invite a Bavarian brewmaster to demonstrate the method of bottom fermentation.⁴⁰ Until then, Bavaria was the only territory where this technique was dominant. A new type of beer was developed, named pilsner, after its place of origin. It was made of light coloured barley malt, sweet and soft brewing water, bottom fermenting yeast and was given a high hop addition. Although initially hops from other places were used, Saaz hops became the favourite variety for brewing pilsner. The new beer style was developed just in time to profit from the modernization of the brewing industry and the expansion of the railway network throughout Europe, in the second half of the nineteenth century. Within a few decades pilsner beer from Bohemia, together with other types of lager beers from Bavaria, gained popularity in nearly all beer consuming countries. Brewmasters from Germany and Bohemia, who were trained in practicing bottom fermentation and using modern equipment, were contracted with breweries in Europe, the United States, Australia and China, to emulate the Bohemian staple.⁴¹ The first beer revolution of the thirteenth century had affected all countries in north and central Europe, this second beer revolution of the nineteenth century affected the brewing industry in all continents of the world.

Nowadays, pilsner is the flagship of breweries like Pilsner Urquell, Heineken and Carlsberg, and lager beer is by far the world's most consumed beer style. By around 1900 Bavarian brewers claimed that they increasingly needed hops from Žatec for making fine lager beers.⁴² And even today, the most popular beer brand in the world, Snow from China, is brewed with Saaz hops. The ever growing production of pilsner and other lager beers gave a boost to the cultivation of this particular hop varietal. Since the nineteenth century the Czech Republic has been one of the world's largest hop producing countries. Saaz hops were introduced in many countries, from the United States to Japan, and were used to breed descendants and new hybrid hop cultivars.⁴³

Queen of hops

Based on historical and genetic evidence, Saaz hops have proved to be the mother of a few other premium hop varieties such as Spalt, Tettnang and Lubelski, as well as some cultivars from the Ukraine and Russia. She even has bastards in hybrid varieties on continents outside Europe. This makes Saaz a queen among today's noble hops. Its status among high quality aroma hops has by no means been achieved easily.44 It required a careful selection of the finest specimen of the crop, and the development of knowledge and skills that were handed down from generation to generation. In 1855 the hop grower Kryštof Semš from Vrbice, a Czech village near the river Elbe, observed one plant in his hop field that developed differently from the rest. It had a strikingly healthy appearance, an early blossom and extraordinarily rich and beautiful hop cones. This particular plant was selected for breeding and was put out on other fields. A century later Dr. Karel Osvald used Semš' hops, which by then was grown in many parts of Bohemia, for developing clones of the Saaz species.⁴⁵ At present, the purity and quality of Saaz hops is carefully watched by the national Hop Research Institute, located in Žatec. The Saaz hop variety is protected by EU-legislation and has a Protected Designation of Origin (PDO).46

In Žatec hops have been grown for about a thousand years. The právovárecnici, a group of privileged citizens with brewing rights, who are mentioned in a document from the thirteenth century, will probably have used hops for preparing their beers, since this assumedly was common amongst Slavic people. In the high Middle Ages hop cultivation must have occurred on a small scale, for local or regional use only. Žatec was a market town and owed its prosperity to the manufacture of cloth and other handicraft goods and to trade. Although evidence is scarce, hop production must have expanded in the fourteenth century. In the wake of the hopped beer revolution in the Hanse towns, hops became a commodity for interregional trade. Many latemedieval stone houses in the centre of the town still have roofs with 'oeil de boeuf', ventilation dormers for drying and storing hops in the lofts. Also the pilsner and lager beer revolution of the nineteenth century has left its marks on the town. Particularly the Prague-suburb, south of the town's centre, is characterized by multistorey warehouses that were built between the 1870s and 1930s, equipped with machinery for preserving and packing shipments of hops such as drying kilns, sulphuring chambers and tall brick chimneys.

When it comes to the level of market orientation and interregional trade, the Žatec region outdates other modern hop producing areas in Europe. Large-scale cultivation of hops in the Spalt region near Nuremberg also took off in the fourteenth century, but the growers used farming methods from Bohemia and chose Saaz hops as a model. Hop fields around the Belgium villages of Poperinge and Aalst were created in the fifteenth century and across the Channel in Kent cultivation started just a century later. Hop gardens existed in early medieval Bavaria, but large-scale cultivation for the market cannot have commenced sooner than the last decades of the fifteenth century. In Hersbruck near Nuremberg the scale of cultivation was upgraded in the beginning of the eighteenth century and in the region of Tettnang in Württemberg hop culture started in the nineteenth century, the latter by planting hop slips of the Saaz cultivar. According to this line of development of commercial hop culture the region of Žatec has an outstanding position, which is of great significance for brewing history. Žatec is a monumental town with buildings and sites witnessing two beer revolutions. It is the heart of a region where the queen of hops has been grown for centuries. Since 1774 certificates were issued guaranteeing the origin of the shipments of hops, but certification was not executed systematically prior to the 1830s.⁴⁷ In the course of the nineteenth century a selection of districts belonging to the region producing Saaz was formed. Nowadays this region is defined in regulations of EUlaw.48

In the introduction the nineteenth century hop grower Schöffl was cited, who maintained that hops could be cultivated on any kind of soil. He was convinced that the quality of the hops was principally determined by its cultivar, not by the natural environment, the climate or the maintenance of the garden. A grower who wanted to produce high quality hops, ought to select slips of a fine race.⁴⁹ And in this respect Saaz hops were top of the bill.

References

 Schöffl, J. (1863) Der Saazer Hopfenbau, nach dreissigjährigen Erfahrungen und Beobachtungen. Saaz: Ritter von Schönfeld'schen Buchhandlung. pp.1-2, 6-14.
 Barth-Haas Group (2018) The Barth-Report: Hops 2017/2018. Nuremberg. p.14; International Hop Growers' Convention, Economic commission (IHGC, 2018) Summary Reports. Nuremburg. p.2.

3. Barth-Haas Group (2018) op. cit. p.18; Hop Growers Union of the Czech Republic (n.d.) 'Hop statistics: 2017 Crop'. Retrieved from www.czhops.cz; IHGC (2018) op. cit. p.6.

4. About breeding programmes for improvement of traditional hop cultivars and creation of hybrid varieties, Darby, P. (2012) 'The history of hop breeding and development', *Brewery History*. 121. pp.94-112.

5. Chmelarský Institut (2012) *Atlas of Czech hop varieties.* Žatec. Retrieved from www.czhops.cz; MoreBeer! (2 November 2015) 'The largest list of brewing hops'. Retrieved from www.morebeer.com/articles; Healey, J. (2018) *The hops list: 265 beer hop varieties from around the world*. Retrieved from www.hopslist.com.

6. Sometimes even four categories are discerned: fine aroma, aroma, bitter (dual-purpose) and high-alpha (very bitter) hops, Krofta, K. (2003) 'Comparison of quality parameters of Czech and foreign hop varieties', *Plant, Soil and Environment*. 49 (6) pp.261-268.

7. Krofta, K. (2003) op. cit.; Chmelarský Institut (2012) op. cit.

 Šuštar-Vozlic, J. & Javornik, B. (1999) 'Genetic relationships in cultivars of hop, Humulus lupulus L., determined by RAPD analysis', *Plant Breeding*. 118 (2) pp.175-181; Seefelder, S. Ehrmaier, H. Schweizer, G. & Seigner, E. (2000) 'Genetic diversity and phylogenetic relationships among accessions of hop, Humulus lupulus, as determined by amplified fragment length polymorphism fingerprinting compared with pedigree data', *Plant Breeding*. 119 (3) pp.257-263; Patzak, J. (2002) 'Characterization of Czech hop (Humulus lupulus L.) genotypes by molecular methods', *Rostlinná Výroba*. 48 (8) pp.343-350.

 Behre, K.-E. (1999) 'The history of beer additives in Europe - a review', *Vegetation History and Archaeobotany*.
 (8) pp.35-48; Meußdoerffer, F. & Zarnkow, M. (2014) *Das Bier: Eine Geschichte von Hopfen und Malz*. Munich: C.H. Beck. pp. 48-53.

10. Schönberger, C. & Kostelecky, T. (2011) 'The role of hops in brewing', *Journal of the Institute of Brewing*. 117 (3) pp.259-267.

11. Unger, R.W. (2004) *Beer in the Middle Ages and the Renaissance*. Philadelphia: University of Pennsylvania Press. pp.57-69; Meußdoerffer, F. & Zarnkow, M. (2014) op. cit. pp.49-50, 72-79.

12. Von Blanckenburg, C. (2001) *Die Hanse und ihr Bier: Brauwesen und Bierhandel im hansischen Verkehrsgebiet.* Cologne: Böhlau Verlag, pp.196-204.

13. Behre, K.-E. (1999) op. cit. pp.38-41.

14. Ehrenbacher, R. (1915) Die Geschichte des Fränkischen Hopfenbaues nebst einer Betrachtung der Entwicklung und Organisation des Nürnberger Hopfenmarktes. Friedrich-Alexanders-Universität Erlangen. pp.18-19. A cunning short history of the Saaz hop region gives Barth, H.J., Klinke, C. & Schmidt, C. (1994) *Der Grosse Hopfenatlas: Geschichte und Geographie einer Kulturpflanze*. Nuremberg: Firma Joh. Barth & Sohn. pp.199-215.

15. Olbricht, F. (1835) *Böhmens Hopfenbau und -handel*. Prague: J.S. Calve'sche Buchhandlung. pp.5-6; Ehrenbacher, R. (1915) op. cit. p.18.

16. Matthaeus, A. (1698-1710) *Veteris aevi analecta*. 10 volumes. Leiden. Volume III pp.260-261; Olbricht, F. (1835) op. cit. p.4; Unger, R.W. (2004) op. cit. p.59.

Ehrenbacher, R. (1915) op. cit. p.19; Mach, V. & Valeš,
 V. (2017) Žatec. Mesto Žatec. pp.159-160; Vanícek, J.,
 Bažant, P. & Valeš, V. (2018) Památky pestování a zpracování chmele a výroby piva v Žatci. Žatec: Huml & Vanícek. p.35.

18. Parízková, J. & Vlkova, M. (2013) 'Beer in the Czech Republic' in: Schiefenhövel, W. & Macbeth, H. (eds.) *Liquid bread. Beer and brewing in cross-cultural perspective*. New York/Oxford: Berghahn. pp.101-109 (102); Mach, V. & Valeš, V. (2017) op. cit. p.159; Vanícek, J., Bažant, P. & Valeš, V. (2018) op. cit. pp.24, 35.

19. Irsigler, F. (1996) "Ind machden alle lants beirs voll". Zur Diffusion des Hopfenbierkonsums im westlichen Hanseraum' in: Wiegelmann, G. & Mohrmann, R.-E. (eds.) *Nahrung und Tischkultur im Hanseraum*. Beiträge zur Volkskultur in Nordwestdeutschland 91. Münster/ New York: Waxmann. pp.377-397 (380-386); Von Blanckenburg, C. (2001) op. cit. pp.37-57, 196-204.

 Neddermeyer, F.H. (1832) *Topographie der freien und Hansestadt Hamburg*. Hamburg: Hoffmann & Campe. p.254.
 Olbricht, F. (1835) op. cit. p.35; Ehrenbacher, R. (1915) op. cit. pp.22-24; Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. p.119.

22. Ehrenbacher, R. (1915) op. cit. pp.31-33; Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. pp.115-117.

23. Irsigler, F. (1996) op. cit. pp.386-392; Unger, R.W. (2004) op. cit. pp.74-88.

24. Papin, K. (2004) 'De hophandel tijdens de middeleeuwen in Noord- en Midden-Europa (13de-16de eeuw)', *Handelingen der maatschappij voor geschiedenis en oudheidkunde te Gent.* Nieuwe Reeks 58. pp.105-146 (118-125). ['The hop trade in the Middle Ages in northern and central Europe (13th-16th century)']; Unger, R.W. (2004) op. cit. pp.89-96.

25. Luu, L.B. (2002) 'Dutch and their beer brewing in England 1400-1700' in Kershen, A.J. (ed.) *Food in the migrant experience*. Aldershot: Ashgate. pp.101-133; Unger, R.W. (2004) op. cit. pp.97-103.

26. Barth, H.J., Klinke, C. & Schmidt, C. (1994) op.cit. pp.219-243; Papin, K. (2004) op. cit. pp.131-137.

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27. Olbricht, F. (1835) op. cit. pp.14-15, 18; Von Blanckenburg, C. (2001) op. cit. pp.317-347; Volkers, K. & Kik, C. (2016) 'Nieuwe hoop voor de Nederhop? Ondergang en opleving van de hopteelt in Nederland', *Tijdschrift voor historische geografie*. 1 (3) pp.147-163 (151-155). ['Good hope for "Netherhops"? Downfall and revival of hop culture in the Netherlands'].

28. Tests on genetic relationships between hop races only included foreign and hybrid varieties from Belgium, Šuštar-Vozlic, J. & Javornik, B. (1999) op. cit.; Seefelder, S. Ehrmaier, H. Schweizer, G. & Seigner, E. (2000) op. cit.

29. Mulder, R. (2018) 'De verloren hopsoorten van België'. Retrieved from http://verlorenbieren.nl. ['Lost hop cultivars from Belgium']. 6 June.

30. Hackel-Stehr, K. (1987) Das Brauwesen in Bayern vom 14. bis 16. Jahrhundert, insbesondere die Entstehung und Entwicklung des Reinheitsgebotes (1516). Technischen Universität Berlin. pp.202-203, 367-371.

31. Ehrenbacher, R. (1915) op. cit. pp.2-3; Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. pp.93-98; Meußdoerffer, F. & Zarnkow, M. (2014) op. cit. p.84.

32. Ehrenbacher R. (1915) op. cit. pp.27, 34-35, 37, 39-42, 49, 138, 140; Hackel-Stehr, K. (1987) op. cit. pp.48-51, 82, 85-89, 167-168, 177, 180, 182, 203, 267, 272; Meußdoerffer, F. & Zarnkow, M. (2014) op. cit. pp.84-86. Hackel-Stehr assumes that Bohemian beer was of the bottom fermented kind. Meußdoerffer and Zarnkow state that until the nineteenth century Bohemian brewers used top fermentation. To some extent they all are right. Bottom fermentation by Bohemian brewers is witnessed from the fifteenth century, but this method was gradually abandoned and had nearly died out at the beginning of the nineteenth century, Rail, E. (2012) 'On the founding of Pilsner Urquell', *Brewery History*. 149. pp.20-29.

33. Olbricht, F. (1835) op. cit. p.17.

34. Ehrenbacher, R. (1915) op. cit. pp.38-42. More about the strive for levelling the quality of Saaz hops in Barth, H.J.,

Klinke, C. & Schmidt, C. (1994) op. cit. p.211.

35. Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. pp.119-121.

36. Ehrenbacher, R. (1915) op. cit. pp.54-62, 66; Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. p.211.

37. Olbricht, F. (1835) op. cit. pp.8, 16-25, 36, 91-92.
38. Hops from the 'Saaz-family' have a comparable content of alpha- and beta-acids, but the oils contain more myrcene and farnesene, Patzak, J. (2002) op. cit. For further comparison in DNA: Šuštar-Vozlic, J. & Javornik, B. (1999) op. cit.; Seefelder, S. Ehrmaier, H. Schweizer, G. & Seigner, E. (2000) op. cit.

39. Olbricht, F. (1835) op. cit. pp.9, 14, 16-18, 25, 38, 90;
Ehrenbacher, R. (1915) op. cit. pp.9-14; Barth, H.J., Klinke,
C. & Schmidt, C. (1994) op. cit. pp. 111-113.

40. Rail, E. (2012) op. cit.

41. Poelmans, E. & Swinnen, J.F.M. (2011) 'A brief economic history of beer' in: J.F.M. Swinnen (ed.) *The economics of beer*. Oxford University Press. pp. 3-28 (13-26); Meußdoerffer, F. & Zarnkow, M. (2014) op. cit. pp.113-124.

42. Ehrenbacher, R. (1915) op. cit. pp.138, 140; Teich, M. (2000) *Bier, Wissenschaft und Wirtschaft in Deutschland 1800-1914*. Ein Beitrag zur Deutschen

Industrialisierungsgeschichte. Vienna: Böhlau. pp.166-167. 43. Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. pp.169, 215, 315-317.

44. About the high quality of Saaz aroma hops in past centuries: Barth, H.J., Klinke, C. & Schmidt, C. (1994) op. cit. pp.199-203, 211, 214-215.

45. Valeš, V. (2017) 'Kryštof Semš left a significant mark on the history of Czech hop growing', *Czech Hops Magazine*. p.51. Retrieved from www.czhops.cz.

46. http://www.zateckychmel.eu.

47. Mach, V. & Valeš, V. (2017) op. cit. p.161.

48. http://www.zateckychmel.eu/cadastral.html.

49. Schöffl, J. (1863) op. cit. pp.6-9.

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