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TADEÁŠ HÁJEK'S *DE CERVISIA*: A SIXTEENTH CENTURY TREATISE ON THE BREWING OF BEER WITH HOPS

HOLGER FUNK

The use of hops (*Humulus lupulus*) as an additive to beer is a practice that did not evolve until around 1000 AD. Due to its complexity, however, the technique was not scientifically described before the second half of the 17th century. A remarkable exception, apparently unknown to most brewing historians, is the detailed description by the Bohemian scholar, Tadeáš Hájek (c. 1525-1600), a celebrated physician and astronomer at the imperial court of Rudolf II in Prague. His description covers the whole brewing procedure in such technological accuracy that it allows direct comparisons to the corresponding steps in modern brewing. The present paper introduces Hájek's life and works and then focuses on the parts of his treatise that are particularly devoted to the step of adding the hops. The key paragraphs of the treatise are rendered in their original Latin, along with a translation.

Introduction: a 16th century controversy on the difference between ancient and modern beer

In 1552 the Flemish physician, Rembert Dodoens (Dodonaeus), one of the preeminent herbalists of the 16th century, published *De frugum historia* (*Enquiry into cereals*). Appended to the main text was a letter by the author to Jean Vischaven, a physician in Breda, entitled *Epistola de Zytho et Cerevisia*. In this letter Dodoens explained to his colleague why he was convinced that *Zythus*, the beer of the ancients, was by no means identical to *Cerevisia* or *Bera*, the modern kind of beer (for linguistic details on these designations, see below). It is not known whether Dodoens ever received a response from Vischaven, but in 1562 another colleague, Boudewijn Ronsse (Baudouin van Ronss, Balduinus Ronsseus), municipal physician in Gouda, felt obliged to react to Dodoens's letter. In it Ronsse vehemently contested Dodoens's opinion, maintaining that there was no basic difference between the old and modern kinds of beer. In a response to Ronsse, Dodoens reasserted his opinion, as in return did Ronsse in a final communication. All three letters were published posthumously in Ronsse's *Opuscula medica* from 1618.[1]

Dodoens had two main arguments for his insistence on the difference between ancient and modern beer. First, he pointed to the different methods of processing of barley, the basic component, and second, he highligthed the use of ingredients unknown in antiquity, such as hops. For him these two factors resulted in two substantially different beverages - a conclusion that was refuted persistently by his opponent, Ronsse. This is not the place to decide which opinion had more plausibility; instead I want to draw attention to some emblematic topics in the Dodoens-Ronsse controversy, which recur in nearly all 16th century discussions concerning the making of beer. Usually these debates started with (i) a reference to the ancient authorities (mainly Theophrastus, Dioscorides, Pliny and Galen), followed by (ii) a linguistic consideration on the different designations for beer and (iii) a debate about the supposed properties of beer in the wake of the predominant four-humours theory. Subsequently, there was (iv) a dispute about the medicinal benefits or drawbacks of beer and finally (v) a discussion on the great variety of local beer types. Of major importance, as indicated, was the role of hops in the brewing process, an additive generally accepted, but controversial as to its scope and effects.

This typical pattern of questions and arguments by the physician-herbalists can likewise be found in the works of less celebrated (and now all but forgotten) authors of the time such as Placotomus (1551),[2] Alexandrinus (1575),[3] Knaust (1575)[4] and Scot (1576).[5] Common to all these writings is the absence of any thorough information about the beer brewing process itself and the equipment involved, even though, at least in the case of Dodoens,[6] some knowledge seems to have been present. In general, much theory, padded with speculations and subjective assertions, prevailed. What was lacking, were solid empirical observations. Instead, the reader was fobbed off with remarks such as those made by Knaust: 'How the brewing and preparation is made, everybody knows', otherwise one could 'ask the brewers'.[7]

This was the situation when Hájek's treatise appeared in 1585. Just like the 16th century writers already mentioned he also dealt with the standard set of questions and arguments, emphasising, for example, (in chapter 2 and 12) the difference between ancient and modern beer. However, he went beyond them and was the first to expound in great detail the complex steps and technical apparatus needed during the production of beer. This new focus is the main reason to call his treatise unique.

Figure 1: Tadeáš Hájek, aged 35. Portrait from Hájek, T. (1562) Herbarz: ginak Bylinár. *Prague.*

Hájek: person and works

Tadeáš Hájek (old Czech spelling Hágek, Latin Hagecius) was one of the foremost scholars of the 16th century, who published prolifically in both Latin and in his native Czech language. There is no modern biography of Hájek, and for information about his life and publications we are obliged to depend on a variety of Czech sources which contain inaccuracies, blank assertions and persistent legends. The most reliable and well-documented accounts are by Smolík,[8] Vetter[9] and Drábek[10] and an overview of Hájek's writings is available from Urbánková and Horský.[11] There are also a few summaries in English and German.[12]

Hájek's date of birth is usually given as 1 December 1525. This is based on an article in a Czech encyclopaedia published over 100 years ago and has since become taken at face value.[13] However, this date is open to question because there are no contemporary documents to confirm it. What is certain is that he died on 1 September 1600, in Prague.

Hájek came from an old Prague family and studied at universities in Prague and Vienna. In 1552 he travelled to Italy and is said to have visited the renowned universities of Bologna and Milan. Whether he studied there, as is often claimed, remains uncertain because in the following year, 1553, he became professor of mathematics at the University of Prague. In 1558 he left the university, possibly due to the order of celibacy that was mandatory for professors. He published astrological calendars, observed and described comets and also devoted himself to geodetic studies. From 1566 to 1576 Hájek served in Vienna and various other places as the personal physician to Emperor Maximilian II before returning to Prague as court physician and scientific and political advisor to Rudolf II, Maximilian's son and successor as emperor. During this period, Hájek gained an international reputation as an astronomer, especially due to his studies of a supernova in the Cassiopeia constellation during 1572.[14] As a consequence of his astronomical studies he came to know the famous Danish scholar, Tycho Brahe, and in 1599 convinced the emperor to invite the Dane to Prague. The same happened a year later with respect to Johannes Kepler.

As Hájek was active in several scientific fields it is difficult to describe him by a single term. Because of his strong interest in occult subjects, he is often associated with alchemists who served Rudolf II at Prague Castle.[15] He was not concerned, however, with the transformation of base metals into gold and silver, the primary goal of the alchemists,[16] but supported the ancient doctrine of the four elementary states and can thus be connected to medical chemistry or iatrochemistry, that, in the 16th century, attempted to explain medical symptoms in terms of chemistry.[17] This interest in chemical processes is also evident in Hájek's beer book, especially in the chapter on fermentation.

Like many scholars of his time, Hájek was an avowed follower of Paracelsus and his doctrine of a causal relationship between the stars and people, plants, animals and minerals. His book on metoposcopy[18] was famous and much respected in his day. Being a mixture of physiognomy and chiromancy,[19] it proposed that you could tell someone's fortune by correlating the markings on the forehead to the classical planets. Hardly less esteemed were Hájek's studies of the influence of the stars on human diseases, an obsession of the so-called iatromathematics or iatromechanics.[20]

In botany, the stars likewise played a major role for Hájek, as he made clear in the preface of a herbal, entitled *Herbarz*, that he published in 1562:

> It would not be bad if everyone knew the influence that a herb has in itself through the power of astral radiation and if it were plucked and dug out according to that effect. For every plant, exactly as every human, is subject to a certain sign and star, from which the plant obtains its power.[21]

This herbal was a Czech translation of Matthiolus's *Commentarii in libros sex Pedacii Dioscoridis Anazarbei de materia medica* (1554), supplemented with descriptions based on the local Czech flora, thus making a great contribution to the development of a botanical terminology in the Czech language.[22]

Although there are good reasons for calling Hájek an astrologically-oriented Paracelsian, it is important to note that he insisted one should not follow any authority blindly; one should always use one's own reasoning.[23] He was an independent thinker and keen empirical observer, which becomes evident to the reader of his works, among which is his treatise on beer.

The treatise on beer

In the 16th century, botany was mainly considered an applied science; descriptions and illustrations of plants were primarily given for medical or nutritional purposes. In the herbals of that time, a typical 'chapter' about a plant had an introduction, in which its appearance and habitat were briefly described, so the plant could be found and identified. But the main focus lay in the following sections that detailed the uses and benefits of the plant. Hájek's beer treatise, too, was such a case of applied botany.

Hájek's was not the first book about beer. Meibom,[24] Tempír[25] and Unger[26] mention a few earlier works.[27] Hájek himself refers to the German physician Placotomus (Brettschneider),[28] whose work he got to know only after the completion of his own writing.[29] All these works are mainly centred on the time-honoured question of the four-humours theory (see below); whether beer had a 'cold' or 'warm' nature and what health benefits it possessed.[30] The question also interested Hájek (see the extensive chapter 12 *De viribus et facultatibus Cerevisiarum in genere*), but besides that he was the first to draw attention to the technological requirements of the whole process of beer production. This was not achieved again with the same detail and accuracy until much later when another two Bohemians, Fischer and Paupie, dealt separately with the subject (see below).[31]

Hájek's book was entitled *De cervisia, eiusque conficiendi ratione, natura, viribus et facultatibus opusculum* - 'A small work on beer, and its method of preparation, nature, powers and faculties'.[32] Most historical overviews on brewing and hops, even those written by Bohemian/Czech authors, for example Olbricht,[33] fail to include it and if he is mentioned, as by Teich,[34] it proves inadequate. *De cervisia* consists of 55 pages (wrongly numbered from page 49 onward) divided into 14 chapters (on the content of each chapter, see Basařová).[35] There are two useful Czech translations, although both are not free from deficiencies.[36]

Hájek had both general and personal reasons for writing the treatise. On the one level, he was reacting to a

Figure 2: Brewery ('Braxatorium'), from the frontispiece of Christoph Fischer, Pars prima, decas georgica X. *Prague 1679.*

significant increase in brewing that occurred in 16th century Bohemia. In 1517 brewing rights were extended from towns and monasteries to the nobility, many of whom erected breweries on their estates. Urban breweries, which produced better but more expensive barley beer, consequently suffered economically due to the increase in competition.[37] In his dedicatory letter, addressed to William of Rosenberg, the influential confidant of Emperor Rudolf II,[38] Hájek alludes to this situation with a pun when he states that 'we see more smoke rising from malt houses (*maltaria*) than from altars (*altaria*)'[39] - see Figure 2, showing a Bohemian brewery (*braxatorium*) together with a fish pond from the 17th century.

The personal reason for producing the treatise can be found in its dedicatory letter.[40] Hájek was asked for guidance on beer brewing by Julius Alexandrinus, his friend and colleague as an imperial personal physician, who was writing a book on health entitled *Salubrium sive de sanitate tuenda*.[41] Hájek was happy to help because the topic interested him,[42] and he immersed himself in the matter. He consulted maltsters and brewers, watching them at their work and making notes. However, Alexandrinus made little use of information Hájek provided.[43]

The use of hops in Hájek's times and the four-humours theory

When studying the history of beer, we should not only distinguish it from other alcoholic beverages but also recognize that there are different kinds of beer. Of all fermented beverages only beer contains malt sugar derived from cereal starch.[44] Consequently, beer has been defined as any sort of maltose-based alcoholic beverage.[45] Regarding the different kinds of beer, it was not before AD 1000 that hops were used on a larger scale for brewing, which significantly distinguishes the ancient cerevisia from the beverage we know today.[46] Beer in the modern sense can be defined as a fermented aqueous beverage based on starch and flavoured by hops.[47]

A great variety of herbs were added to beer in ancient times, but not hops. Neither Egyptian nor Babylonian beers contained hops[48] and there is no evidence of their use by Greeks and Romans until the 6th century AD.[49]

After hops first appeared in the herbal of Hildegard von Bingen's 12th century, *Liber de plantis*, their basic properties were much discussed, but with contradictory attributions. While hops were commonly regarded as 'warm and dry in the second degree',[50] they were rated in other herbals as 'cold and dry in the first degree', as in the *Herbarius*[51] and by Brunfels.[52] It was also the case that the same authority was quoted, but for contrary attributes: according to *Ortus sanitatis*[53] the famous Persian physician Mesue (c.777-857) considered hops 'warm and dry in the second degree', while another work claimed that he described hops as 'cold in the first degree'.[54] Although there was little consensus on the use of hops in detail,[55] their healthy powers were generally acknowledged throughout medieval times - *Ortus sanitatis*[56] recommended even wine to be cooked and drunk with hops. Hájek himself[57] considered hops as 'warm and dry in the second degree', producing positive effects such as moderating the harmful properties of the wort, allowing it to keep for longer and being laxative, detergent and diuretic in its medicinal effects.[58]

Based on linguistic analyses,[59] it has been inferred that the use of hops, although not necessarily for flavouring beer, came to Europe from the Caucasus or the Ural-

Altaic region at around the beginning of the Christian Era.[60] Hops were known in present-day France since at least the 9th century,[61] perhaps earlier,[62] but it is the second half of the 11th century which is usually recognized as the time when they started to be commonly used for brewing beer and a 'new era' of brewing began.[63] From the 13th century onward, hops slowly replaced rosemary, yarrow, coriander and bog myrtle as the most common beer additives.[64]

In Bohemia, the first written evidence of beer with hops (*chmel* in Czech) dates from 1088[65] and, by the 12th century, they were widely cultivated in the region.[66] Hops were also exported from Bohemia as early as 1101.[67] They had to be cultivated because it was believed that the wild plant lacked the preservative properties of the cultivars.[68] In Hájek's times, hops were grown in Bohemia as they are today, with poles arranged in rows, while in England, for instance, the poles were stuck in small mounds - see Figs.3, 4 and 5.

Figure 3: Tripartite vedoute of the town of Klatovy and vicinity in the district of Plzeň (Pilsen) (end of the right part cut off). In the foreground extensive hop gardens can be seen. Drawing from Jan Willenberg (1571-1613), reproduced in Podlaha, A. and Zahradník, I. (1901) Jana Willenbergera pohledy na města, hrady a památné stavby Království Českého z počátku XVII. století. *Prague.*

Figure 4: Detailed view from figure 3 showing the poles and trellises for growing hops.

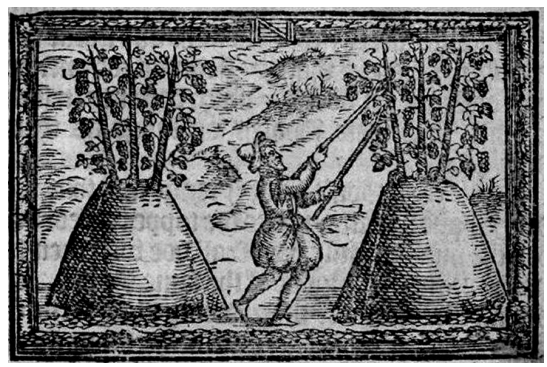

Figure 5: Hop garden, from Scot, R. (1576) A perfite platforme of a hoppe garden. *London, p.31.*

Although hops are not particular about the soil in which they grow, their cultivation cannot occur anywhere (see for instance Neve[69] and Whitehead[70] for problems in England); however in most parts of Bohemia their cultivation was easy. The area around Žatec (formerly known under its German name Saaz) in the north-west is still especially famous for its hops[71] and the beer from this area (*Zacensis*) was already praised by Hájek.[72]

Hájek's description of adding hops and the Renaissance herbal tradition

The brewing process can roughly be divided into five main steps:[73]

1) malting: inducing germination of the grain (barley, wheat)
2) mashing: soaking and heating the cracked grain
3) lautering: separating (rinsing off) the solids of the mash to extract an intermediate product, the wort
4) hopping: adding hop flowers (cones) to the wort and boiling the mixture
5) fermenting: starting fermentation by adding yeast (in Hájek's time, lees - *faeces*, *sedimentum*), thereby converting the sugar in alcohol

All these steps are described in detail by Hájek. Malting is described in chapter 3, mashing and lautering in chapter 4,[74] adding hops in chapters 5, 6 and 9 and, finally, fermenting in chapter 10, where top-fermented wheat beer in particular is analyzed.

Hájek provided the first ever account of the entire brewing process. The only earlier text known is a fragment in Greek (contained in a manuscript by the alchemist Zosimus of Panopolis (4th century BC), but of an earlier origin) about the making of *zythus* (the Egyptian beer) entitled Περὶ ζύθων ποιήσεως[75] Step 4, concerning the addition of hops, was not, of course, part of that ancient recipe. A brief German text, entitled *Wie man ein Bier brawet*, by Knaust[76] did mention the introduction of hops, but though the basic steps of malting, mashing and fermenting are clearly recognizable, really instructive details are missing.

The following discussion focuses on step 4 of the brewing process, the boiling of the wort with hops, but first contemporary knowledge about hops and beer, derived from early herbals, will be summarized in order to highlight Hájek's significance.

Although hops had been in use for making beer for several centuries, the fact only gradually made its way into herbals. The printed editions of the most popular herbals of the 15th century, *Macer floridus*[77] and *Circa instans*[78], omitted any mention of the plant. Even when hops were referred to in books of the time - for example, in Simon Januensis's extensive *Clavis sanationis*,[79] Konrad von Megenberg's *Das puech der natur*,[80] *Herbarius*[81] or *Ortus sanitatis*[82] - it is not in the context of beer production.[83] In the early 16th century the use of hops for brewing begins to be mentioned occasionally;[84] Brunfels[85] and Brunschwig,[86] followed by Dorsten,[87] Fuchs[88] and Dodonaeus[89] state that this occurs.

The first printed Czech herbal by Jan Černý, which was published in 1517,[90] fails to mention the use of hops in brewing beer, but in Hájek's own work on the subject,[91] which appeared some 45 years later, (see Fig. 6) they are said to be 'commonly known, for it is needed for beer' ('známý wssem / neb ho k Piwu potrebugij'). In all the herbals just referred to hops are mentioned in the context of their medical benefits. When Brunschwig,[92] as Hájek later on, remarked that the use of hops for making beer was 'gemenlich wol bekant' ('commonly well known'), it may well have been true for physicians and brewers, but it was not elaborated upon by herbalists, nor were any technical details considered.

At the beginning of his treatise, Hájek states that *cerevisia* 'is artfully prepared by grain and hops' (*frumento et lupulo artificiose conficitur*).[93] The addition of hops is then described in chapter 5.[94] The original Latin text of this chapter is provided below, together with my translation.

Hájek's complex description with its bewildering variety of vessels (altogether seven types with twelve different designations) can again be reduced to five steps:

*Figure 6: Hops (*Chmel*) in Tadeáš Hájek,* Herbarz: ginak Bylinár. *Prague, p.386.*

De additione lupuli, qui dat formam Cerevisiae

Hactenus de absoluta cremoris polentacei praeparatione dictum esto: restat, ut reliquam partem persequamur, quae consistit in additione lupuli et Cervisiae fermentatione. Excocto igitur cremore, eoque omni in cupam illam transfuso, aperto cupae epistomio, aliqua eius quantitas defluere permittitur in subiectum alveum, indeque rursus immittitur in ahenum: in quod iniiciuntur duo chori florum lupi salictarii,[95] ac lento igne friguntur ad consumptionem fere infusi cremoris. Hic vero iterum vigilantem decet esse Zythepsam, ut lupulum rite frigat, et non adurat; unde deinceps vel amaresceret Cervisia, vel fumum empyreumaque redoleret. Deinde in illum lupulum frigatum, in ahenoque relictum, per adhibitum canalem tantum cremoris imponitur, quantum ahenum capere potest: permittiturque, ut aliquandiu effervescat, donec omnis lupuli vis et facultas in ipsum cremorem fuerit translata.

On adding hops which give beer its shape

So much shall be said about the entire preparation of the malt juice[96] (= wort); still lacking is to consider the remaining part, which concerns adding hops and fermenting the beer. Now, when the juice is completely cooked and all of it poured into that tun, the bung of the tun is opened and a certain quantity of the juice is allowed to flow off into an underlying tub, and from there it is run back to the brazen cauldron, into which two *chori*[97] of hops flowers are thrown and roasted at a low heat until the juice that was poured in is almost consumed. Here the brewer[98] must indeed be attentive again to roast the hops properly and not scorch them, by which the beer would then get a bitter taste or smell of smoke and charring. Then to that roasted hops, which is left in the cauldron, by means of a pipe as much of the juice is added as the cauldron can hold. It is left to bubble up for some time, until finally the whole force and effect of hops is transferred into the juice itself.

Quod reliquum est Cremoris in cado, seu cupa, id omne per saepe nominatum epistomium cadi demittitur in subiectum alveum, ex eoque rursus transfunditur in alios cados. Quod dum fit, interea Zythepsa insilit in dictu cadum cremore iam vacuum, ac quisquilias polentaceas in eo relictas spatha lignea subruit et invertit: inde mox cremorem lupulaceum ex aheno seu caldario scaphis auferri, et per calathos seu corbes colatorios in reliquos cados seu tinas, in quas cremor polentaceus distributus fuit, transfundi et percolari mandat. Cavendum autem hic est diligentissime, quando cremor ille plures tinas seu dolia diffunditur, ne in eisdem perfrigescat emoriaturque: quod potissimum hyberne tempore accidere consuevit. Quare tempestive omnis ille cremor in unum cadum colligi consuevit: aut, siquidem aestivum tempus est, in varios cados diffunditur, asservaturque aliquantulo spacio temporis, donec refrixerit.

All of the remainder of the juice in the vat or tun is discharged, through the bung of the vat often mentioned before, in the underlying tub and transferred out of it again in other vats. While this happens, the brewer jumps in the aforementioned vat which is already free from sap, and digs up and turns the malt remainders that are left in it with a wooden scoop. A little later, he lets the hop juice be taken out of the cauldron or thermal vessel using buckets and poured and sieved by means of baskets or filter basket into the remaining vats and vessels, into which the malt juice was distributed. Here you must, however, be extremely careful to prevent the juice from freezing and dying in them when it is poured into the many vessels or barrels, which usually happens most likely in winter. Therefore, the whole juice is usually collected in due time in a single vat or, in the summertime, cast into various vats and stored for some time, until it has cooled down.

1. A portion of the wort is drained into a tub underneath a tun.
2. From there it is fed back into a cauldron and a variable amount (*chori*) of hops is added.[99]
3. This mixture is simmered until the wort is nearly consumed.
4. The main part of the wort is added to the remaining hops and boiled again.
5. The brew is carefully cooled, depending on the season.

In any case, Hájek's description reveals that significantly more devices were required for brewing than depicted in a contemporary German woodcut (Fig. 7).

Figure 7: 'Der Bierbreuwer' ('The beer brewer'), woodcut from Jost Amman in Hans Sachs (1568) Eygentliche Beschreibung aller Stände auff Erden. *Frankfurt. The doggerel below the image reads: From barley I cook good beer / thick, sweet and also in a bitter manner / in a large and wide brew kettle / Into it I then throw the hops / and let the decoction cool down properly in vats / With this I fill the barrels / which are well bound and sealed with pitch / then the hop brew ferments and is prepared.*

In chapter 9 Hájek describes the reasons for adding hops. He says: 'The hop is something that gives beer its shape and not only ensures that it is beer, but rather that it is a good beer, durable and healthy for the drinker'.[100] For Hájek, health meant (according to the benefits enumerated in his *Herbarz*)[101] that flatulence induced by the wort was attenuated by hops and obstructions of the bowels were dissolved. Besides improving the taste and aroma, hops were especially appreciated for increasing the longevity of beer. A contemporary English source stated that beer made with hops would keep for a month, while unhopped ale had to be drunk within two weeks.[102]

Hájek noticed the effects hops had on beer, but was unable to know the physiological reasons why. The bitterness of hops is due to the production of resins containing alpha-acids or humulones and beta-acids or lupulones in female inflorescence. The resin, observable as fine yellow powder, is produced by so-called lupulin glands (discovered by Ives in 1820, who also coined the term),[103] at the base of the bracts, deep within the hop cone (arrowed in Fig. 8). These glands are unique to *Humulus*.[104] The resins together with some oils from the cones are responsible for the sterilizing, preservative and aromatic effects of hops.[105] The characteristic bitterness of beer depends, in turn, on the hop variety.

Reception and new approaches

There is some evidence that Hájek's treatise was both read and put into practice in central Europe. Alsted,[106] for example, reprinted in his encyclopaedia of science Hájek's treatise in its entirety, managing to compress it to occupy surprisingly just seven pages. Schoockius,[107] in his *Liber de cervisia*, likewise draws extensively on Hájek.

In his treatise, Hájek mentions English ale (*alla*), which was made without hops and therefore, in his eyes, was less commendable.[108] This did not go unnoticed in England. An early 20th century British auction catalogue[109] listed a copy of Hájek's work, to which a twelve page manuscript of the same era 'in a contemporary English hand', containing recipes for making beer, had been added. This is most likely the earliest evidence of Hájek's far-reaching reception.[110]

These are positive testimonies of the reception of Hájek's work abroad, but in his Bohemian home country the situation was different. Incredibly enough, there

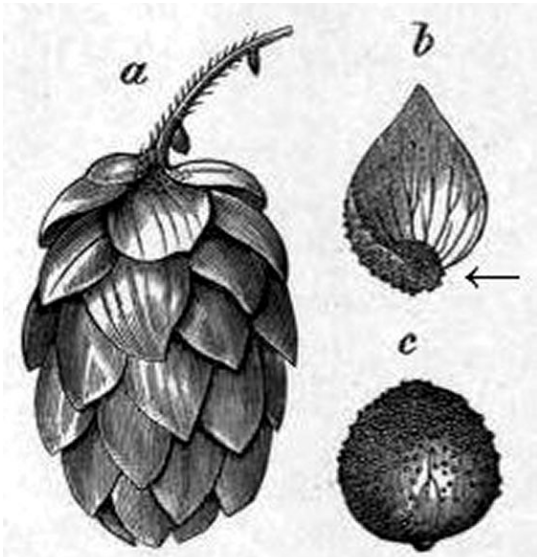

FIG. 72.—Hop. *a*, strobile of the Hop, natural size. *b*, bract enfolding at its base a small fruit, and showing lupulin glands, natural size. *c*, fruit magnified, showing lupulin glands. (Tschirch.)

Figure 8. Hop cone, from Greenish, H.G. (1920) A text book of materia medica. *London, p.128. See also the illustration in Briggs, D.E., Hough, J.S., Stevens, R. and Young, T.W. (1982)* Malting and brewing science. Hopped wort and beer. *Volume 2. New York, p.393.*

is - as to my knowledge - no evidence of any response whatsoever. There are two obvious instances where a reference to Hájek could have been expected, but this did not occur. First, almost a century after the publication of *De cervisia*, Hájek's compatriot Christoph Fischer (Czech spelling Krištof Fisser or Fišer, 1611-1680), a Jesuit and excellent economist, described meticulously the process of beer brewing, including the establishment of a hop garden (*lupuletum*).[111] Hájek's treatise, for whatever reason, is mentioned nowhere.

Second, another century later, Franz Andreas Paupie (in Czech František Ondřej Poupě, 1753-1805), another compatriot of Hájek, published an extensive work on brewing in three parts (1794, second edition posthumously 1820-1821) that surpassed most scholarly examinations of beer making.[112] Among others, Paupie acquired enduring renown for employing the thermometer as well as the hydrometer as standard tools in the brewery.[113] Yet, he also fails to mention Hájek's treatise.

In conclusion, it appears that despite the original nature of Hájek's work its significance has slipped from view. More attention has been given to either the earliest mention of hops or to the date when they were first added to the beverage we now call beer - the specific process of hopping beer has been somewhat overlooked. The purpose of this article is to go some way to restoring Hájek's reputation as one of the first, if not the first, scholars to desribe, in a technical manner, one of the most important innovations in brewing.

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3. Alexandrinus, J. (1575) *Salubrium sive de sanitate tuenda, libri triginta tres*. Cologne.

4. Knaust, H. (1575) *Fünff Bücher Von der Göttlichen und Edlen Gabe der Philosophischen, hochthewren und wunderbaren Kunst, Bier zu brawen*. Erfurt.

5. Scot, R. (1576) *A perfite platforme of a hoppe garden and necessarie instructions for the making and mayntenaunce thereof*. London.

6. Indicated by remarks on malt (*maltum*), wort (*polenta*)

and lees (*feces*), see also Dodoens's great herbals (1554) *Cruijdeboeck*. Antwerp. pp.435-436 and (1583) *Stirpium historiae pemptades sex sive libri XXX*. Antwerp. pp.495-496.

7. Knaust, H. (1575) op. cit. first book.

8. Smolík, J. (1864) *Mathematikové v Čechách od založení university Pražské až do počátku tohoto století*. Prague. pp.57-77.

9. Vetter, Q. (1926) 'Tadeáš Hájek z Hájku', *Říše hvězd*. 6. pp.169-185.

10. Drábek, P. (ed.) (2000) *Tadeáš Hájek z Hájku. K 400. výročí úmrtí*. Prague.

11. Urbánková, E. and Horský, Z. (1975) *Tadeáš Hájek z Hájku 1525-1600 a jeho doba*. Prague.

12. Pelcl, F.M. (1777) *Abbildungen böhmischer und mährischer Gelehrten und Künstler, nebst kurzen Nachrichten von ihren Leben und Werken. Dritter Theil*. Prague. pp.35-46; Maiwald, V. (1904) *Geschichte der Botanik in Böhmen*. Vienna. pp.21-23; Hellman, C.D. (1994) *The comet of 1577*. New York. pp.184-193.

13. Láska, V. (1896) 'Hájek z Hájku' in *Ottův slovník naučný*. Volume 10. Prague. pp.754-775.

14. Hellman, C.D. (1994) op. cit.

15. Zachar, O. (1913) 'Rudolf II. a alchymisté'. *Časopis musea království českého*. 87. pp.148-155, 243-257; Evans, R.J.W. (1973) *Rudolf II and his world. A study in intellectual history, 1576-1612*. Oxford. pp.203-204.

16. Hájek, T. (1596) *Actio medica Thaddaei ab Hayck adversus Philippum Fanchelium Belgam, incolam Budvicensem, medicastrum et Pseudoparacelsistam*. Amberg. p.20. 'So far I have not seen any of these alchemists, who would have had the true fifth essence of gold and would have come forward with the promised miracles'. (*Neque enim huc usque quenquam vidi ex istis Chymicis, qui veram illam Q[intam] essentiam auri habuerit et miracula, quae praedicantur, cum ea praestiterit*.).

17. Kopp, H. (1843) *Geschichte der Chemie*. Volume 1. Braunschweig. pp.84-92. Kopp, H. (1844) *Geschichte der Chemie*. Volume 2. Braunschweig. p.158.

18. Hájek, T. (1584) *Aphorismorum metoposcopicorum libellus unus*. Second edition. Frankfurt.

19. Müller-Jahncke, W.-D. (1982) 'Zum Prioritätenstreit um die Metoposkopie: Hájek contra Cardano'. *Sudhoffs Archiv*. 66. pp.79-84.

20. Müller-Jahncke, W.-D. (1981) 'Der Höhepunkt der Iatromathematik'. *Berichte zur Wissenschaftsgeschichte*. 4. pp.41-50; Lindemann, M. (1999) *Medicine and society in early modern Europe*. Cambridge. pp.79-84; Sudhoff, K. (1902) *Iatromathematiker vornehmlich im 15. und 16. Jahrhundert*. Breslau. p.68.

21. Hájek, T. (1562) *Herbarz: ginak Bylinár, welmi užitecny, a figůrami pieknymi y zřetedlnymi*. Prague; quotation from the unpaginated preface (předmluwa). (All translations are by the present author.) This so-called 'astrological botany' was widespread in the 15th and 16th century. Arber, A. (1986) *Herbals: their origin and evolution. A chapter in the history of botany 1470 - 1670*. Third edition. Cambridge. pp.256-263.

22. Větvička, V. (2000) 'Tadeáš Hájek z Hájku jako botanik', in Drábek, P. (ed.) *Tadeáš Hájek z Hájku. K 400. výročí úmrtí*. Prague. pp 95-102; Hendrych, R. (1976) 'Tadeáš Hájek z Hájku jako botanik', in Bouška, J. (ed.) *Tadeáš Hájek z Hájku (1526-1600)*. Prague. pp 13-18.

23. Hájek, T. (1596) op. cit. 'Meanwhile, with us the truth should be more important than the authority' (*Nobis interea veritas authoritate sit potior*) p.18. The same was proclaimed in Hájek, T. (1566) Praefatio, pp.[28]-[37] (unpaginated) in Landavus, A. (ed.) *Laurentii Grylli de sapore dulci & amaro libri duo*. Prague.

24. Meibom, J.H. (1668) *De cervisiis potibusque et ebriaminibus extra vinum aliis commentarius*. Helmstedt. Preface to the reader.

25. Tempír, Z. (2000) 'Pěstování chmele do 16. století a Tadeáš Hájek', in Drábek, P. (ed.) *Tadeáš Hájek z Hájku. K 400. výročí úmrtí*. Prague. pp.67-78.

26. Unger, R.W. (2004) *Beer in the Middle Ages and the Renaissance*. Philadelphia. p.144.

27. My attempts to find these works failed. It seems they are quoted on the basis of second-hand information (indicated by inaccuracies such as spellings like 'Hagesius').

28. Hájek, T. (1585) *De cervisia, eiusque conficiendi ratione, natura, viribus et facultatibus opusculum*. Frankfurt. p.7.

29. Placotomus, J. (1551) 'De natura et viribus cerevisiarum et mulsarum opusculum', in *De tuenda bona valetudine libellus Eobani Hessi*. Frankfurt. pp.66v-101v.

30. According to the ancient (Hippocratic/Galenic) four-humours theory each body or substance (animal, vegetable, inorganic) has the basic properties or qualities 'warm' (*calidus*), 'cold' (*frigidus*), 'dry' (*siccus*) and 'moist' (*humidus*) which affect the corresponding fluids (*humores*) in the human body (thus a phrase like 'a given substance is cold and moist' means that it has cold and moist effects on the human body). The balance (or imbalance) of these properties determines the specific 'temperament' (*temperamentum*, literally 'mixture') of the individual substance.
The medicinal or dietary effects of these four qualities furthermore were divided in ascending order into four degrees of intensity, from 1 (mildly) to 4 (vehemently) (Harig, G. (1974) *Bestimmung der Intensität im medizinischen System*

Galens. Berlin; Scully, T. (1995) 'Tempering medieval food', in Adamson, M.W. (ed.) *Food in the Middle Ages*. Westport, Connecticut.pp.3-23). Besides these so-called primary qualities secondary qualities as tastes (*dynameis*, e.g. sweetness, bitterness) and medicinal effects (*virtus*, e.g. astringent, cleansing) were considered. On the four-humours theory in antiquity, see Nutton, V. (1993) 'Humoralism', in Bynum, W.F. and Porter, R. (eds.) *Companion encyclopedia of the history of medicine*. Volume 1. London, New York. pp 281-291 and Scarborough, J. (1984) 'Early Byzantine pharmacology'. *Dumbarton Oaks papers*. 38. pp.213-232, in the Renaissance Harig, G. (1966) 'Leonhart Fuchs und die theoretische Pharmakologie der Antike'. *Zeitschrift für Geschichte der Wissenschaften, Technik und Medizin*. 3. pp.74-104, and on beer in particular Nelson, M. (2005) *The barbarian's beverage. A history of beer in ancient Europe*. London. pp.33-34 and Nelson, M. (2011) 'Beer: Necessity or luxury?', *Avista forum journal*. 21. pp.73-85. This doctrine remained predominant well into the 17th century (see Harig, G. (1974) op. cit. pp.201-203). Its weak point was the lack of an objective frame of reference for the supposed qualities, thus giving rise to fruitless (because undecidable) discussions as the examples below concerning beer demonstrate.

31. Fischer, C. (1679) 'De braxatorio', in *Pars prima, decas georgica X. Prinicpalium operarum oeconomiae suburbanae*. Prague. pp.71-98; Paupie, F.A. (1794) *Die Kunst des Bierbrauens, physisch - chemisch - ökonomisch beschrieben*. 3 parts. Prague.

32. There were three common spellings: *Cervesia*, *Cervisia* and *Cerevisia*, see Cornish, F.W. (ed.) (1898) Cervesia, cervisia, cerevisia, in *A concise dictionary of Greek and Roman antiquities*. London. p.157; Hájek used alternately *Cerevisia* and *Cervisia*. The word is of Celtic origin and not derived from 'Ceres', the name in Latin of the goddess of grain, as Hájek states (Hájek, T. (1585) op. cit. p.15). The original Celtic word is composed of two parts, which can approximately be rendered as 'ceir' and 'uisg', meaning 'wax' or 'honeycomb' and 'water'. The Celts used this word first for an alcoholic drink that was produced from honey and kept it later on for beverages that contained mainly fermented cereals, see Arnold, J.P. (1911) *Origin and history of beer and brewing. From prehistoric times to the beginning of brewing science and technology*. Cleveland. pp.142-148. The Romans then adopted and Latinized the Celtic term.

33. Olbricht, F. (1835) *Böhmens Hopfenbau und Handel*. Prague.

34. Teich, M. (2005) 'A chapter in the history of transfer of information on attenuation'. *Brewery History*. 121. pp.40-46.

35. Basařová, G. (2000) 'Přínos Tadeáše Hájka z Hájku českému a světovému pivovarnictví', in Drábek, P. (ed.) *Tadeáš Hájek z Hájku. K 400. výročí úmrtí*. Prague. pp.79-92; Basarová, G. (2004) 'Der Beitrag des böhmischen Professors Tadeás Hájek aus Hájek (Thaddeus Hagecius ab Hayck) zum Brauwesen des 16. Jahrhunderts'. *Gesellschaft für Geschichte des Brauwesens*. pp.116-132.

36. Nademlejnský, K. (translator) (1884) 'O pivě a jeho výrobě, povaze, silách a vlastnostech'. *Pivovarské listy*. 2. pp.8-11, 27-29, 39-44, 59-60, 91-95, 189-192, 241-242, 257-264; Bartuch, R. (translator) (1878) 'O pivě a způsobách jeho přípravy, jeho podstatě, silách a účincích'. *Kvas*. 6. pp.100-103, 122-125. 141-143, 163-164, 255-257, 295-297, 366-367, 424-425, 477-480, 499-500, 518-520.

37. Janáček, J. (1959) *Pivovarnictví v českých královských městech v 16. století*. Prague and Basařová, G., Hlaváček, I., Basař, P. and Hlaváček, J. (2011) *České pivo*. Prague. pp.23-40.

38. Pánek, J. (2011) *Vilém z Rožmberka. Politik smíru*. Prague. pp.368-424.

39. Hájek, T. (1585) op. cit. p.5.

40. ibid. p.6.

41. Alexandrinus, J. (1575) *Salubrium sive de sanitate tuenda, libri triginta tres*. Cologne. On Alexandrinus (1506-1590), see Khautz, F.C.F von (1755) *Versuch einer Geschichte der Oesterreichischen Gelehrten*. Frankfurt & Leipzig. pp.204-228.

42. Hájek's mother, Kateřina, had twice married wealthy Prague brewers.

43. See Alexandrinus, J. (1575) op. cit. pp.403-405, section *De cervisia*.

44. Behre, K.-E. (1998) 'Zur Geschichte des Bieres und der Bierwürzen in Mitteleuropa', in Both, F. (ed.) *Gerstensaft und Hirsebier - 5000 Jahre Biergenuß*. Oldenburg. pp.49-88.

45. Nelson, M. (2005) op. cit. p.4; Arnold, J.P. (1911) op. cit. pp.41-42.

46. Pietzcker, C.F. (1835) *De cerevisia*. Berlin. pp.8-9.

47. De Keukeleire, D. (2000) 'Fundamentals of beer and hop chemistry'. *Química nova*. 23. pp.108-112.

48. Steiger, A. (1954) 'Vom Hopfen' in Meier, F.M. (ed.) *Westöstliche Abhandlungen*. Wiesbaden. pp.87-106; Stika, H.-P (1998) 'Prähistorische Biere: Archäobotanische Funde und Experimente zum Nachbrauen', in Both, F. (ed.), *Gerstensaft und Hirsebier - 5000 Jahre Biergenuß*. Oldenburg. pp.39-47; Wartke, R.-B. (1998) 'Bier in den altvorderasiatischen Hochkulturen', pp 91-108 ibid. The term 'hops' commonly refers to *Humulus lupulus*, for other *Humulus* species than *lupulus*, see Briggs et al. (1982), op. cit. (figure 8) p.390.

49. Renner, S.S., Scarborough, J., Schaefer, H., Paris, H.S.

and Janick, J. (2008) 'Dioscorides's *bruonia melaina* is *Bryonia alba*, not *Tamus communis*, and an illustration labeled *bruonia melaina* in the *Codex Vindobonensis* is *Humulus lupulus* not *Bryonia dioica*', in Pitrat, M. (ed.) *Cucurbitaceae 2008. Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae*. Avignon. pp.273-280; Hünemörder, C. (1998) 'Hopfen', in Cancik, H. and Schneider, M. (eds.) *Der Neue Pauly. Enzyklopädie der Antike*. Volume 5. Stuttgart. pp.713-714; Tresenreuter, J.U.C. (1759) *Wirthschafftliche und rechtliche Abhandlung von dem Hopfen. Nebst Johann Heumanns, öffentlichen Lehrers der Rechte bey der hohen Schule zu Altdorff, historischem Vorbericht von der Kräuter-Kenntnus der alten Teutschen, wie auch desselben Ubersetzung der vom Herrn R. Bradley, Lehrer der Kräuter-Wissenschafft bey der Universität zu Cambridge, in Englischer Sprache herausgegebenen Abhandlung von dem Reichthum eines Hopfgartens*. Nuremberg. pp.1-3; already Placotomus, J. (1551) op.cit. p.90r.

Ancient descriptions from Theophrastus, Dioscorides and Plinius that are often associated with hops refer to different kinds of climbing plants and are not related to beer (Beckmann, J. (1805) 'Hopfen', in *Beyträge zur Geschichte der Erfindungen*. Volume 5. Leipzig. pp.209-210). In detail these are σμῖλαξ (or μῖλαξ) (Theophrastus, *Historia plantarum* 3.18.11 or Dioscorides, *De materia medica* 1.143 (Wellmann)), today identified as *Smilax aspera* (rough bindweed) or as *Convolvulus sepium* (larger bindweed); βρύον (Dioscorides, 1.20 (Wellmann)), identified as *Evernia* genus (lichens); βρυωνία (4.182 and 4.183 (Wellmann)), identified as *Bryonia dioica* Jacq. (red bryony) and *Bryonia alba* (white bryony or wild hop) (see Renner, S.S. et al. (2008) op.cit.); and Wilson (1975) 'Plant remains from the Graveney boat and the early history of Humulus lupulus L. in W. Europe', *New phytologist*. 75. pp.627-648); *Lupus salictarius* (Plinius, *Naturalis historia* 21.50.86), commonly identified as hops, is in fact not clearly recognizable, see Jones, W.H.S. (translator) (1956) Index of plants, in *Pliny: Natural history*. Volume VII, books 24-27. London, p.518.

50. Bingen, H. von (1855) 'Physica. Liber de plantis', in Migne, J.-P. (ed.) *Patrologia Latina*. Volume 197. Paris. pp.1126-1210; Megenberg, K. von (1475) *Das puech der natur*. Augsburg; Placotomus, J. (1551) op.cit. p.90r.; Knaust, H. (1575) op. cit; and still Fischer, C. (1679) op.cit. p.71.

But also 'warm and dry in the first degree' (Anonymous (1491) *Tractatus de virtutibus herbarum*. Venice. p.78) or 'warm and dry in the third degree' (Anonymous (1484) *Herbarius*. Speyer. p.78).

51. Anonymous (1484) *Herbarius*. Mainz. chapter 78.

52. Brunfels, O. (1530) *Herbarum vivae eicones*. Strasburg. Appendix. See also Nelson, M. (2012) op. cit. p.82, note 59 for more herbalists.

53. Anonymous (1485) *Ortus sanitatis, auf teutsch ein gart der gesuntheit*. Mainz. chapter 215.

54. Mesue, J. (1550) *De re medica libri tres*. Lyon. p.80.

55. While Bingen, H. von (1855) op.cit. p.1153 stated that hop increases melancholy (*melancoliam in homine crescere facit*), the Anonymous (1485) op. cit. chapter 215 asserted the exact opposite: hop '*trybet vß die melancoly*' ('drives out melancholy').

56. Anonymous (1485) op. cit. chapter 215.

57. Hájek, T. (1585) op. cit. pp.31, 45.

58. According to Culpeper, N. (1652) *The English physitian, or An astrologo-physical discourse of the vulgar herbs of this nation*. London. p.66 the virtues of hops are 'to open Obstructions of the Liver and Spleen, to clens the Blood, to loosen the Belly, to clens the Reins from Gravel, and provoke Urine'. For a modern survey, see Grieve, M. (1971) *A modern herbal*. Volume 1. New York. p.414. 'Hops have tonic, nervine, diuretic and anodyne properties. Their volatile oil produces sedative and soporific effects, and the Lupamaric acid or bitter principle is stomachic and tonic. For this reason Hops improve the appetite and promote sleep'.

59. Huber, E. (1927) 'Die Völker unter babylonischem Kultureinfluß. Auftreten des gehopften Bieres', in Schulze-Besse, H. (ed.) *Bier und Bierbereitung bei den Völkern der Urzeit*. Volume 2. Berlin. pp.56-57; Unger, R.W. (2004) op. cit. p.53.

60. Already Linnaeus, C. (1769) *Amoenitates academicae*. Volume 7. Stockholm. p.452 suggested that hops came to Western Europe during the Migration Period.

61. Nelson, M. (2005) op. cit. pp.105-110, 165-166; Unger, R.W. (2004) op. cit. pp.52-106; Beckmann, J.H. (1805) op. cit. p.215.

62. Behre, K.-E. (1998) op. cit.; Nelson, M. (2014) 'The geography of beer in Europe from 1000 BC to AD 1000', in Patterson, M. and Hoalst-Pullen, N. (eds.) *The geography of beer*. Dordrecht. pp 9-21.

63. Becker, J.H. (1822) 'Bier', in *Versuch einer allgemeinen und besondern Nahrungsmittelkunde*. Volume 2. Stendal. pp.108-182.

64. Moir, M. (2000) 'Hops - A millennium review'. *Journal of the American Society of Brewing Chemists*. 58. pp.131-146; Tempír, Z. (2000) op. cit.; Behre, K.-E. (1999) 'The history of beer additives in Europe - A review'. *Vegetation history and archaeobotany*. 8. pp.35-48.

65. Arnold, J.P. (1911) op. cit. p.233; Janyšková, I. (2001) 'Poznámky k staroslověnskému pivo'. *Slavia*. 70. pp.361-363.

66. Basařová, G. et al. (2011) op. cit. pp.49-60.

67. Basařová, G. (2000) op. cit.; Neve, R.A. (1991) *Hops*. London.; Meußdoerffer, F. and Zarnkow, M. (2014) *Das Bier: Eine Geschichte von Hopfen und Malz*. Munich. p.50.

68. Fischer, C. (1679) op. cit. p.91.

69. Neve, R.A. (1991) op.cit. p.59.

70. Whitehead, C. (1893) *Hop cultivation*. London. p.6.

71. Barth, H.J., Klinke, C. and Schmidt, C. (1994) *The hop atlas. The history and geography of the cultivated plant*. Nuremberg. pp.208-215.

72. Hájek, T. (1585) op. cit. pp.38, 47. Today, the hop from this town is internationally protected by the designation 'Žatecký chmel' (Boulton, C. (2013) *Encyclopaedia of brewing*. Chichester. p.704; Rybáček, V. (1991) *Hop production*. Amsterdam. pp.70-77). A local cultivar is 'Žatecký červeňák' or 'poloraný červeňák' ('semi-early red bine'), which is used for lager-type beers like Plzeňský Prazdroj (pilsener) or Budějovický Budvar (budweiser).

73. Esslinger, H.M. (ed.) (2009) *Handbook of brewing. Processes, technology, markets*. Weinheim; Narziss, L. (1992) *Die Bierbrauerei. Die Technologie der Würzebereitung*. Volume 2. Stuttgart.

74. Hájek describes the so-called three-mash method or 'Dreimaischverfahren', see Narziss, L. (1992) op. cit. pp.164-168.

75. See Nelson, M. (2005) op. cit. pp.23-24; the text is available from Gruner, C.G. (ed.) (1814) *Zosimi Panopolitani de Zythorum confectione fragmentum, nunc primum Graece et Latine editum*. Sulzbach, translations are provided by Nelson, M. (2005) op. cit. p.127 and by Irby-Massie, G.L. and Keyser, P.T. (2002) *Greek science of the Hellenistic era. A sourcebook*. London & New York. p.251.

76. Knaust, H. (1575) op. cit. no pagination.

77. Odo Magdunensis (1477) *De viribus herbarum* ('Macer floridus'). Naples.

78. Matthaeus Platearius (1497) *Liber de simplici medicina* ('Circa instans'). Venice.

79. Simon Januensis (1473) *Synonyma medicinae sive Clavis sanationis*. Milan.

80. Megenberg, K. von (1475) op. cit.

81. Anonymous (1484) *Herbarius*. Mainz. p.78.

82. Anonymous (1485) op. cit. p.215.

83. Simon Januensis (1473) op. cit. mentions hops, adding that the Gauls and Germans (Teutons) 'put its flower into mead' (*cuius florem in medone ponunt*).

84. For instance in Brunschwig, H. (1500) *Liber de arte distillandi. de Simplicibus*. Strasburg. 60v. Von hopffen wasser: 'byer' or in the *Grete herbal* (Anonymous (1526) *The grete herball*. London.) Hoppes: 'dowble beare' - that is, twice-brewed beer.

85. Brunfels, O. (1531) *Novi herbarii tomus II*. Strasburg. p.191.

86. Brunschwig, H. (1531) *Das neüwe Distilier buoch Der rechten kunst*. Strasburg. chapter 8.

87. Dorsten, T. (1540) *Botanicon*. Frankfurt. 152v.

88. Fuchs, L. (1542) *De historia stirpium commentarii insignes*. Basle. p.165.

89. Dodonaeus, R. (1583) *Stirpium historiae pemptades sex sive libri XXX*. Antwerp. pp.495-496.

90. Černý, J. (1517) *Knieha lekarska kteraz slowe herbarz: aneb zelinarz: welmi vziteczna: z mnohych knieh latinskych. y zskutecznych praczij wybrana: poczina se sstiastnie*. Nuremberg. 19r-19v on *chmel*.

91. Hájek, T. (1562) op. cit. 385v on *chmel*.

92. Brunschwig, H. (1500) op. cit. 60v.

93. Hájek, T. (1585) op. cit. p.14.

94. ibid. pp.27-29.

95. The Plinian designation *Lupus salictarius* was adopted by Hájek (ibid. p.17), but mainly he referred to hops as *lupulus*.

96. Hájek's terminus technicus for wort is *cremor polentaceus* or simply *cremor*. *Cremor* means thick juice, broth, and *polenta* (barley-meal) is Hájek's term for malt (ibid. p.22), adopted from Pliny, *Naturalis historia* 18.14.72 (see Anonymous (1750) *ΟΙΝΟΣ ΚΡΙΘΙΝΟΣ. A dissertation concerning the origin and antiquity of barley wine*. Oxford. p.25). The wort is, as described adequately by Hájek ((1585) op. cit. p.26), a 'glutinous and viscous substance' (*substantia lenta et viscida*).

97. *Chorus* was an old German measure of capacity for grains of varying content. It remains unclear which capacity is meant here, Nademlejnský, K. (1884) op. cit. p.92) translated the term by 'handful', Bartuch, R. (1878) op. cit. p.295) by 'quarter' (of what?).

98. *Zythepsa* is Hájek's term for beer brewer, from ζύθος (or ζῦθος/ζῦτος), the most common Greek term for (Egyptian) beer (Nelson, M. (2001) 'ξυτουργεων: a scholarly ghost word'. *Mnemosyne*. 54. pp.721-723.), and πέπτω (ripen, ferment). Hájek's other term is *Cervisarius*. Another Latin term, but not used by Hájek, was *braxator* (Latinized from German 'Brauer').

99. As Muspratt, S. (1860) 'Beer', in *Chemistry, theoretical, practical, and analytical. As applied and relating to the arts and manufactures. Volume 1*. London. pp.236-285) put it: 'The quantity of hops added to the wort is dependent upon the quality of the product and the strength of the worts, and also upon the length of time they are to be retained, or the climate they have to endure. The quality of the flowers has also an

influence upon the proportion required to communicate the requisite properties to the liquor'. p.265.

100. Hájek, T. (1585) op. cit. p.31.

101. Hájek, T. (1562) op. cit. p.385v on hops.

102. Scot, R. (1576) op. cit. p.6; Knaust, H. (1575) op. cit. and independently Fischer, C. (1679) op. cit. p.91 remarked that hops have the same preserving effect in beverages as has salt in food: *Idem facit lupulus in potu, quod sal in cibo, rebusque aliis, quae diuturnam asservationem petunt*.

103. Ives's discovery of the lupulin glands from 1820 remained without consequences for a long time, not until the end of the 19th century, German researchers could provide more clarity (Teich, M. (2000) *Bier, Wissenschaft und Wirtschaft in Deutschland 1800-1914*. Wien. pp.163-164.

104. Since hops were expensive and extraction of the 'bittering' agents often failed, bitter substances from some other plants were used as surrogates, preferably *Menyanthes trifoliata* (bog-bean or buckbean) - see Becker, J.H. (1822) op. cit. pp.132-133; Artus, W. (1843) *Leicht fassliche Anleitung zur Auffindung der Mineralgifte. Ein Leitfaden bey gerichtlich-chemischen Untersuchungen, zum Gebrauche für Aerzte und Apotheker, nebst einem Anhange über Prüfung des Weines, Essigs und Bieres*. Leipzig. p.237. These surrogates should be distinguished from the numerous herbs that were used deliberately instead of hops. However, even today, they usually are lumped together indiscriminately (for example by Behre, K.-E. (1999) op. cit.).

105. Boulton, C. (2013) op. cit. p.319; Shellhammer, T. (2011) 'Lupulin', in Oliver, G. (ed.) *The Oxford companion to beer*. Oxford. p.556; De Keukeleire, D. (2000) op. cit.; Neve, R.A. (1991) op.cit. pp.33-34.

106. Alsted, J.H. (1649) 'Zytheptica', in *Scientiarum omnium encyclopaedia*. Volume 3. Lyon. pp.660-666.

107. Schoockius, M. (1661) *Liber de cervisia*. Groningen. p.303-307.

108. Hájek, T. (1585) op. cit. p.51.

109. Sotheran, H. (1918) *Catalogue of rare and standard books on exact and applied science*. London. p.196.

110. Another work from England, Worth, W.Y. (1692) *Cerevisiarii comes, or, The new and true art of brewing*. London. has just some meagre remarks concerning the addition of hops (p.53) and was unaware of Hájek, as was Tyron (1690) A new art of brewing beer, ale, and other sorts of liquors. London.

111. Fischer, C. (1679) op. cit. There exists also Czech (Fisser, K. (1706) 'O piwováru', in *Knihy hospodárské*. Prague. pp.58-80) and German (Fischer, C. (1719) 'Von dem Brau-Wesen', in *Fleißiges Herren-Auge, oder Kluger und wohl-abgerichteter Hauß-Halter*. Nuremberg. pp.79-109) translations.

112. Paupie, F.A. (1794) *Die Kunst des Bierbrauens, physisch - chemisch - ökonomisch beschrieben. 3 parts*. Prague; (1820) *Die Kunst des Bierbrauens, physisch - chemisch - ökonomisch beschrieben*. Second edition. Parts 1 and 2. Prague; (1821) Die Kunst des Bierbrauens, physisch - chemisch - ökonomisch beschrieben. Second edition. Part 3. Prague. Paupie was born in a small town in central Bohemia. He was introduced early to making beer and was trained by his brother, who was a professional brewer, before going on to work in several Bohemian breweries where he refined his knowledge (for biographical details, see Bělohoubek, A. (1878) *Život a působení Františka Ondřeje Poupěte*. Prague). Today Paupie is esteemed in his home country as a great reformer in the history of brewing.Comparable to Paupie's life and achievements is only the Bavarian brewing expert Benno Scharl (1741-1812) with his *Beschreibung der Braunbier-Brauerey im Königreiche Baiern* (posthumously 1814, including a biography). Regarding hops, however, Scharl had little to say.

113. Basařová, G. et al. (2011) op. cit. pp.66-68.; Teich, M. (2005) op. cit.