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Understanding Early Modern Beer: An Interdisciplinary Case-Study

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Abstract

Beer was a staple of early modern diets across northern Europe and the Atlantic World. While its profound social, economic, and cultural significance is well established, little is known about the nature and quality of the drink itself, particularly its nutritional characteristics. Until now, attempts to estimate calorie and alcohol content have been monodisciplinary in approach, involving either theoretical calculations based on grain content, or a rough approximation with modern equivalents. Using sixteenth-century Ireland as a case-study, this article describes an interdisciplinary approach to the problem of early modern beer. Exploiting a rich seam of unpublished archival material, the project recreates an early modern beer, using the most appropriate ingredients, equipment, and processes possible. Scientific analysis of the finished drink offers new perspectives on beer as a dietary staple. The project is a model for integrating practical or experimental approaches into mainstream historical study, and the practice of radical interdisciplinarity. It represents the most comprehensive effort to recreate an historic beer in any context to date, bringing together historians, experimental archaeologists, agronomists, microbiologists, brewing scientists, craftworkers, farmers, and maltsters to tackle problematic questions about the past.

Beer was a crucial part of diets in sixteenth-century Ireland, as it was in most of northern Europe. It fuelled manual labour and greased the wheels of social life from grand dining rooms down to raucous alehouses in towns and villages. This drink was in many ways comparable to its modern counterpart – it used hops, was lightly bitter, and was produced using similar processes – but it was also distinctive, employing pre-modern varieties of

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grains, brewed with heavy quantities of oats as well as barley, and reliant on less precise equipment. To understand more deeply beer's significance as an intoxicating and energy-providing foodstuff, it is vital to move beyond theoretical calculations and rough approximations with present-day equivalents. This can only be achieved by attempting to recreate an early modern beer, following the practices of past brewers, and employing the most accurate ingredients and technology possible.

This article describes the most comprehensive interdisciplinary investigation of historic beer carried out to this date. The experiment involved examining a range of sixteenth-century household accounts to select a representative example of beer for reproduction; identifying and sourcing appropriate cereals, and hops; malting and milling using period techniques; replicating contemporary technology using woodcut images, descriptions, and available archaeological evidence; measuring, mashing, and fermenting guided by descriptions of past processes; selecting, trialling, and growing a yeast inoculum for fermentation; and analysing the end-product to establish its detailed nutritional profile. While this approach represents the most detailed and systematic recorded effort to address the contribution of beer to historical diets, it is, of course, not intended to result in a definitive description of early modern beer. Though the basic practice was reasonably standard, pre-industrial brewing differed slightly according to the size and sophistication of the household or institution. The beer itself would have varied due to the drinkers' social status, from region to region, and throughout the year. So, this project offers a snapshot of the process and end-product based on a representative Irish case-study, from a large and high-ranking domestic residence. The aim was to establish parameters for the possible strength and nutritional value of early modern beers and develop a rigorous interdisciplinary approach that could be applied to other times and places. The findings are directly relevant to two major questions in the study of food and drink: how alcoholic was beer in the past and how much energy did it provide?

Historians have unequivocally established the centrality to early modern dietary consumption of ale and beer.¹ In the sixteenth century, the former term technically referred to un-hopped fermented malt liquor, while the latter indicated the hopped drink that became dominant in north-western Europe, though the terms were used interchangeably.² Drinking beer had many

¹ On the early modern period, see Craig Muldrew, *Food, energy and the creation of industriousness* (Cambridge, 2011) pp. 65–83; Richard Unger, *Beer in the middle ages and the Renaissance* (Philadelphia, PA, 2003), p. 103; Judith Bennett, *Ale, beer and brewers in England* (Oxford, 1996), pp. 77–97; David Gentilcore, *Food and health in early modern Europe: diet, medicine and society, 1450–1800* (London, 2015), pp. 157–80. For the late medieval period, see Philip Slavin, *Bread and ale for the brethren: the provisioning of Norwich Cathedral Priory, c. 1260–1536* (Hatfield, 2012); Barbara Harvey, *Living and dying in England* (Oxford, 1995).

² For example, when the proctor of Christ Church, Dublin, brewed 'ale' for his masons, he always used hops, as described in Raymond Gillespie, ed., *The proctor's accounts of Peter Lewis, 1564–1565* (Dublin, 1996). On the linguistic confusion, see Pamela Sambrook, *Country house brewing in England, 1500–1900* (London, 1996), pp. 109–11.

functions. It played a vital role in the social lubrication of communities, in processes of identity formation and the performance of ‘good fellowship’.³ Fermented drinks also possessed immense nutritional significance. In this period, ‘food’ and ‘drink’ were not distinguished as they are today but were grouped as comestibles that nourished the body. In contemporary dietetic understanding, beer was thought to benefit the constitution, serving to balance the humors, facilitate digestion, and quench thirst. Hopped beer in particular had ‘manifold force and efficacy’, cleaning the blood of corrupt humors and preventing digestive obstructions.⁴ Beer was believed to be especially suitable for sustaining hard work, and was a common entitlement for labourers.⁵ The proctor of Christ Church, Dublin, Peter Lewis, brewed every ten days for the masons employed on building works at the cathedral in 1565. Hopped ‘ale’ was provided several times a day and requested by the workmen when tasks were commenced and completed.⁶ Supplying acceptable beer was a constant preoccupation in domestic and military institutions. In 1597, the Irish lord chancellor wrote to Sir Robert Cecil asking for malt to be sent to the English garrisons in Ireland, as beer would ‘greatly comfort the soldiers and prevent a lamentable weakness they fall into daily for want of drink, being driven only to live upon water, which in reason cannot be but one principal cause of so great a diminution of the army, as happeneth daily by sickness, death, and running away’.⁷

Though they inevitably varied, levels of consumption could be remarkably high by today’s standards. In 1574, the lord deputy’s household at Dublin Castle consumed 479.25 hogsheads or 207,684 pints of beer across the year. While the household’s records do not reveal how this drink was distributed, the volume was equivalent to 6 to 10 pints per day for each ordinary member of staff.⁸

³ For examples of this rich historiography, see Mark Hailwood, *Alehouses and good fellowship in early modern England* (Woodbridge, 2014); Mark Hailwood, ‘Broadside ballads and occupational identity in early modern England’, *Huntington Library Quarterly*, 79 (2016), pp. 187–200; B. Kümin, ‘Useful to have, but difficult to govern: inns and taverns in early modern Bern and Vaud’, *Journal of Early Modern History*, 3 (1999), 153–75; Angela McShane, ‘Drink, song, and politics in early modern England’, *Popular Music*, 35 (2016), 166–90; A. L. Martin, *Alcohol, sex, and gender in late medieval and early modern Europe* (Basingstoke, 2001), pp. 62–6; Alexandra Shepard ‘“Swil-bols and tos-pots”: drink culture and male bonding in England, c. 1560–1640’, in Laura Gowing, Michael Hunter, and Miri Rubin, eds., *Love, friendship and faith in Europe, 1300–1800* (Basingstoke, 2005), pp. 110–30.

⁴ Tobias Venner, *Via recta ad vitam longam* (London, 1620), pp. 38–42. See also James Hart, *The diet of the diseased* (London, 1633), p. 127. On beer and dietary opinions, see Gentilcore, *Food and health*, p. 157.

⁵ Muldrew, *Food*, p. 67. This was recommended in Venner, *Via recta*, pp. 39–42; Hart, *Diet of the diseased*, p. 127.

⁶ For example, see Gillespie, ed., *Proctor’s accounts*, pp. 26, 35, 41, 45, 83, 98, 103.

⁷ Ernest George Atkinson, ed., *Calendar of state Ireland, 1596–1597* (London, 1893), pp. 362–89. *British History Online*, www.british-history.ac.uk/cal-state-papers/ireland/1596-7/pp362-389 (accessed 22 Sept. 2022).

⁸ Household accounts of Sir William Fitzwilliam, 1574: Northamptonshire Record Office (NRO), Fitzwilliam Manuscripts (Irish), MS 51. In 1574, the median number of messes served each day was twenty-eight, which over the course of two meals equates to fifty-six diners. They could have each consumed 10.16 pints of the total daily beer consumption. Taking a higher estimate

Those doing hard labour sometimes drank even more. Based on the proctor's accounts, the skilled masons at Christ Church may have consumed 10.5 to 12 pints daily, rising to as much as 15.5 pints during onerous tasks.⁹ Significantly, both institutions spent more money on the provision of beer than they did on bread.¹⁰ These figures are in line with those established for other regions. Richard Unger proposed an average consumption across Europe of 528 pints per person each year but reckoned this could rise to 2,569 pints in certain contexts, such as aristocratic residences or communities of craftspeople. That is 7 pints a day.¹¹ In his detailed study of food and energy in seventeenth- and eighteenth-century England, Craig Muldrew calculated that the typical intake at a farming household or house of correction was around 4 pints a day for men, and 2 for women. In cases of hard labour, over a gallon could be provided.¹² Anecdotal evidence suggests that consumption was occasionally higher.¹³ These numbers all refer to occupational or domestic drinking, for which the best evidence is available. The amounts consumed for recreation were no doubt considerable too.¹⁴

Given this substantial consumption, it is unsurprising that historians have gone to great lengths to understand beer's characteristics. There have been two main areas of focus. The first is the amount of energy that various occupations, including monks, sailors, and labourers, derived from their daily allocations of drink. This issue is important for wider historiographical themes. Scholars have estimated the number of calories in early modern drink as part of considering how well people were nourished, a question that has implications for our understanding of major processes like proto-industrialization, agricultural improvement, and military expansionism.¹⁵ For a period when people were regularly drinking several pints a day, the accuracy of those estimates is therefore of vital concern. The energy content of beer is largely determined by the second point of interest – the volume of alcohol that it contains. In both popular and academic writing, there is a long-standing notion that pre-industrial beer, particularly that produced for everyday consumption, was relatively weak.¹⁶ This is at odds with anxieties about levels of inebriation

of 100 diners, to account for the wider payroll and food consumed elsewhere in the household, average per person consumption stands at 5.69 pints.

⁹ See, for example, Gillespie, ed., *Proctor's accounts*, p. 50.

¹⁰ *Ibid.*, p. 60; NRO, Fitzwilliam Manuscripts (Irish), MS 56. In 1574, for example, the Fitzwilliams spent £108 9s 10d on bread wheat and £173 8s 5d on the ingredients for beer.

¹¹ Unger, *Beer*, pp. 126–42.

¹² Muldrew, *Food*, pp. 70–1. For further estimates, see A. L. Martin, *Alcohol, violence and disorder in traditional Europe* (Kirksville, MO, 2009), pp. 61–72; J. A. String and D. H. Buss, 'Three centuries of alcohol in the British diet', *Nature*, 270 (1977), pp. 567–72.

¹³ Muldrew, *Food*, p. 70; Andrew Campbell, *The Book of Beer* (London, 1956), p. 111.

¹⁴ Muldrew, *Food*, p. 72.

¹⁵ Slavín, *Bread and ale*; Harvey, *Living and dying*; Patrick W. Hayes et al., 'European naval diets in the sixteenth century: a quantitative method for comparative and nutritional analysis', *Historical Methods*, 52 (2019), pp. 195–212; Muldrew, *Food*.

¹⁶ For popular examples, see 'What was the drink of choice in medieval Europe', *Slate*, 21 May 2013, <https://slate.com/human-interest/2013/05/medieval-europe-why-was-water-the-most-popular-drink.html> (accessed 12 Dec. 2022); Alex Delany, 'What is table beer, the beer we've been seeing

throughout contemporary society, worries that grew in volume over the sixteenth century in line with attempts to reform plebeian manners. On the one hand, dietary writers linked beer to industriousness and suggested a degree of intoxication was acceptable.¹⁷ On the other, ‘purposeful’ drinking to get drunk was seen as a mark of wastefulness and incivility. As Phil Withington has argued, this dialectic between ‘prodigality and reformation’ and ‘intoxication and industriousness’ was a ‘defining feature’ of early modern society.¹⁸ Understanding the kinds of drink provided in institutional settings, whether religious or secular, is an important first step in understanding the effect of ‘quasi-sanctioned’ inebriation.¹⁹ It sheds light not just on issues of health and stamina, but also on governance, sociability, and morality.

So far, however, attempts to examine those two key aspects of early modern beer have been limited by their paper-based approach. Some studies have calculated the beverage’s nutritional value based on quantitative analysis of documentary evidence, estimating the energy and alcohol content based on the number of the calories in the amount of malt used per gallon of beer produced. For example, using this method, Craig Muldrew suggested that ordinary table beer contained about 400 kCal per pint, a high figure compared to present-day drinks, which supported his central thesis about the well-nourished workers of early modern England.²⁰ Such calculations tend to be based on recipes in household guides, rather than on records of brewing in practice. References to the production process are theoretical, anecdotal, and unclear on critical issues such as the efficacy of pre-modern yeast. Other scholars, acknowledging the challenges of quantification, have simply substituted modern equivalents. To work out the energy intake of medieval monks at Westminster, Barbara Harvey assumed that what they drank was much like ‘present day pale ale’.²¹ Likewise, a recent analysis of European naval diets in the sixteenth century used an average of five modern bitters with an alcohol content of less than 4 per cent to create an estimate of 142 kCal.²² Though the gap between this number and Muldrew’s is striking, this experiment does not seek to establish a definitive alternative benchmark, but to challenge assumptions about early forms of brewing and indicate the direction in which existing estimates should be revised.

everywhere?’, *Bon Appetit*, 28 Aug. 2017, www.bonappetit.com/story/what-is-table-beer (accessed 12 Dec. 2022). Academic examples include Alison Sim, *The Tudor housewife* (Stroud, 1998), p. 75; Paul Lloyd, *Food and identity in England, 1540–1640* (London, 2015), p. 56.

¹⁷ Louise Hill Curth and Tanya M. Cassidy, ‘“Health, strength and happiness”: medical constructions of wine and beer in early modern England’, in Adam Smyth, ed., *A pleasing sinne: drink and conviviality in seventeenth-century England* (Cambridge, 2004), pp. 143–61. See also Jennifer Richards, ‘Health, intoxication, and civil conversation in Renaissance England’, *Past & Present*, 222, issue supplement 9 (2014), p. 178.

¹⁸ Phil Withington, ‘Intoxicants and society in early modern England’, *Historical Journal*, 54 (2011), p. 657. See also Phil Withington, ‘Introduction – cultures of intoxication’, *Past & Present*, 222, issue supplement 9 (2014), pp. 9–33.

¹⁹ On the concept of immanent intoxication, see Withington, ‘Intoxicants and society’, p. 651.

²⁰ Muldrew, *Food*, pp. 74–83. See also Slavin, *Bread and ale*, pp. 161–4.

²¹ Harvey, *Living and dying*, p. 58.

²² Hayes et al., ‘European naval diets’, p. 207.

As historians themselves acknowledge, those previous approaches are restricted by their monodisciplinarity.²³ Malting, milling, and brewing equipment, beer-making techniques, and most importantly the grain itself were markedly different in the sixteenth and seventeenth centuries. The implications for these differences can only be fully assessed through a systematic, interdisciplinary reconstruction and analysis of each stage in the brewing process. The idea of reconstruction is clearly not new. Cooking old recipes, along with baking, brewing, and even making cheese, are typical parts of the interpretation at living museums, presenting visitors with a tangible connection to the past.²⁴ Such activities have also been employed in historical research. This has been connected to the increased attention scholars of food history, like those from other fields, have started to place in the last two decades on the material basis of their subject. This has involved consideration of the physical objects associated with food preparation and consumption, as well as the embodied and sensory experiences of cooking and eating.²⁵ The present study shares these concerns, as it illuminates the implicit knowledge and developed skill required for brewing. But it also draws on the entrepreneurial spirit of experimental archaeology, in which researchers use practical recreations to fill in the holes and explain unanswered questions posed by the material remains.²⁶ As a result, while this article primarily offers insight into what early modern beer was actually like, it reflects too on how historians can carry out interdisciplinary research that buries deep into the *stuff* of the food that they study.

I

Residences and institutions invested a large amount of time and resources in brewing and its related processes. This expenditure could leave a detailed written record. Numerous household accounts were examined for this experiment. The most detailed evidence for beer made in Ireland are the household accounts of Lord Deputy William Fitzwilliam at Dublin Castle, which date to

²³ Several historians have noted the need to replicate historical beer. For example, Muldrew, *Food*, p. 74; Hayes et al., 'European naval diets', p. 197. Slavin noted the problem of trying to assess calorific and alcohol strength from records alone, in Slavin, *Bread and ale*, p. 161.

²⁴ A good example in the UK is the Weald and Downland Living Museum in West Sussex which hosted this experiment. In the USA, such museums include Colonial Williamsburg in Virginia and the brewery at Carillon Historical Park in Dayton, Ohio.

²⁵ On material culture, see Melissa Calaresu, 'Introduction: the material worlds of food in early modern Europe', *Journal of Early Modern History*, 24 (2020), pp. 1–16. On embodied experiences, see Emma-Jayne Abbots, 'Introducing a special issue on food stuffs: materialities, meanings, and embodied encounters', *Gastronomica*, 16 (2016), pp. 1–4. For a study in this latter vein involving making marmalade, see Lucy Havard, "'Almost to candy height": knowledge-making in the early modern kitchen, 1700–1850', *Cultural and Social History*, 19 (2022), pp. 119–39.

²⁶ For a recent application of this approach to food, see G. Tsai et al., 'Bay salt in seventeenth-century meat preservation: how ethnomicrobiology and experimental archaeology help us understand historical tastes', *BJHS Themes*, 7 (2020), pp. 63–93.

several years in the 1570s and 1590s.²⁷ The castle was a major military and residential complex, the home of successive lords deputy, the queen's representatives in Ireland. It housed 100 staff of varied status and welcomed numerous guests and messengers. The Fitzwilliam records provide remarkable detail about the beer with which all these people were provided and how it was made over the annual brewing cycle. The buttery accounts from 1574 (see, for example, [Figure 1](#)) are especially rich, listing for each brew the quantities of malt and hops used along with the volumes of beer produced. It is helpful that the grain is quantified using the English statute bushel, rather than the variable, regional alternatives.²⁸ Importantly, these are not recipes like those in manuscript or print collections, which we can never be sure were actually followed. Instead, they are records of production in a specific institution, at a given moment in time, making them highly suitable to guide experimental reproduction.

The beer in these accounts was graded with the nomenclature typical of the period. Historians generally identify three main strengths of beer in accounts and brewing instructions: 'strong beer', perhaps with a particular seasonal association like 'October' or 'March'; 'ordinary' or 'household' beer; and 'small' beer. Within these categories, there was variation in quality and strength, and a tendency for types to overlap.²⁹ Names also varied over time. While such issues make estimating the relative amounts of each type produced difficult, there are indications that ordinary beer was the most consumed overall, particularly by the working classes.³⁰ This is confirmed by the Irish accounts. At Dublin Castle, household production focused on two kinds, strong and ordinary, of which far more was drunk of the latter. In the yearly account for 1574, only 13 per cent of beer consumed was strong. Other years showed similar values.³¹ Furthermore, when Fitzwilliam was away from the castle on 'journeys', the proportion of strong beer produced fell. Further sources underline the suggestion that the ordinary beer was destined for servants and labourers, the majority of the household. A 1580

²⁷ Household accounts of Sir William Fitzwilliam: NRO, Fitzwilliam Manuscripts (Irish), MSS 30, 31, 50, 51, 56. The other accounts examined include household accounts for Ireland of Sir Henry Sidney, 1558–9: Kent History and Library Centre, De L'Isle Manuscripts, U1475/O25/2; Gillespie, ed., *Proctor's accounts*; indenture between a Dublin brewer and Trinity College, October 1598: Trinity College Dublin Archives, MUN/P/1/35; account and recipe book of Edward Pierce, steward to Thomas Hackett, bishop of Down and Connor, 1674–7: Public Record Office of Northern Ireland (PRONI), D2056/1.

²⁸ W. Pinkerton, 'Lord deputy of Ireland's household expenses (circa, 1580)', *Ulster Journal of Archaeology*, first ser., 8 (1860), pp. 27–34.

²⁹ Muldrew, *Food*, pp. 73–4; Sambrook, *Country house brewing*, p. 111.

³⁰ Muldrew, *Food*, pp. 77–8.

³¹ NRO, Fitzwilliam Manuscripts (Irish), MS 51. Similarly, in the eighteen months to October 1591, the household produced 116 hogsheads of 'strong beer' (12.1 per cent) and 840 hogsheads (87.9 per cent) of 'ordinary beer'. See NRO, Fitzwilliam Manuscripts (Irish), MSS 30, 31. For similar status-related allocation of beers at Trinity College, with 'good' and 'strong' beer reserved for provost and fellows, see John William Stubbs, *The history of the University of Dublin, from its foundation to the end of the eighteenth century* (Dublin, 1889) pp. 26, 41. On the hierarchical distribution of ales in medieval institutions, see Slavin, *Bread and ale*, p. 160.

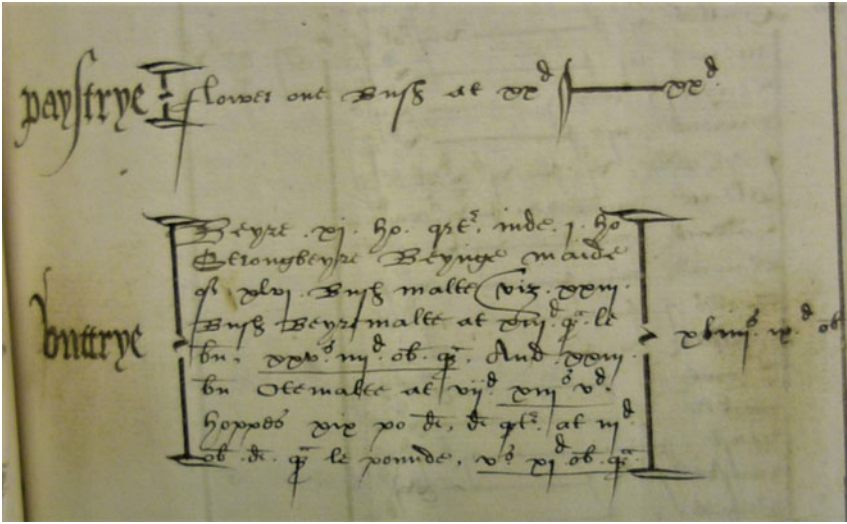


Figure 1. Sample entry from buttery account, Fitzwilliam household, week ending 13 March 1574. Source: NRO, Fitzwilliam Manuscripts (Irish), MS 51. Reproduced with permission of Sir Philip Naylor-Leyland Bt and Milton (Peterborough) Estates Company.

estimate of annual expenses under one of Fitzwilliam's successors distinguished beers in hierarchical terms. Beer malt was recorded for '6 good brewings of beer onlie for his lordship', with malt recorded separately for a further 36 brewings 'for the household'.³² Conversely, small beer is not identified in any of the Irish accounts examined. As elsewhere, it was likely considered unsuitable for working adults, being 'injurious to health' on grounds of its thinness and weakness.³³

Ordinary beer was brewed in two different ways. Either different types of beer could be made at once: hot water was poured on the malt twice or even three times, with the first wort being used to make the strongest beer and the last the weakest.³⁴ Or ordinary beer was brewed 'entire', blending all the washes of grain from one charge of malt. This method of brewing 'every kind of malt-liquor separate' had advantages in taste and quality. (Strong beer could be made in a similar fashion but with additional malt.)³⁵ The latter option may have been more common in summer months when brewing was complicated by the heat, which made it difficult to control the fermentation

³² Pinkerton, 'Lord deputy of Ireland's household expenses'.

³³ Thomas Tryon, *A new art of brewing beer* (London, 1691), pp. 21–2; Randal Holme, *The academy of armory* (Chester, 1688), Book III, p. 104; Sambrook, *Country house brewing*, p. 120; Muldrew, *Food*, p. 79.

³⁴ Sambrook, *Country house brewing*, pp. 89–104; Muldrew, *Food*, p. 73.

³⁵ George Watkins, *The complete English brewer* (London, 1773), p. 66. On this method, see Muldrew, *Food*, p. 75; Sambrook, *Country house brewing*, p. 120. Tryon noted that the best table beer was made by mixing the first and second worts equally together, in Tryon, *New art*, p. 22.

of stronger brews.³⁶ This seasonality is conspicuous in the accounts for Dublin Castle, where entire ordinary beers were produced predominantly between May and October.³⁷

At the lord deputy's residence, the amount of malt used to produce each gallon of beer was consistent throughout the year. The brewers generally achieved 13.5 gallons of ordinary drink from every bushel of grain. In terms of strength, this is towards the middle of the scale for similar ales and beers outlined in recipes or produced in English households around this time.³⁸ In Richard Arnold's *Customs of London* (1502), the oldest brewing instructions for beer in England currently known, 1 bushel of malt makes 19.2 gallons.³⁹ In William Harrison's *Description of England* (1577), the same quantity of malt yielded 18 gallons of a 'good beer for poor men'.⁴⁰ At the other end of the range, the household of Dame Alice de Bryene yielded just 7 gallons of ale.⁴¹ These comparisons suggest that the usual Dublin Castle drink, neither exceptionally strong nor weak, is a good representation of the 'stronger middle beer' that was most consumed by workers in this period.⁴²

Where the beer in the Irish accounts may be somewhat distinctive is in the type of malt used. Specifically, Irish beers contained a high proportion of oat malt in relation to barley. This would have affected the flavour, nutritional content, and the alcohol level of the resulting drink.⁴³ In the Fitzwilliam household between January 1574 and October 1575, the total volume of malt in each of the ninety-one brewings was equally divided between barley and oats.⁴⁴ Other Irish institutions brewed with even higher shares, and, occasionally, entirely with oat malt.⁴⁵ Growing well in marginal soils and cool, damp climates, oats were one of the main cereal crops in early modern Ireland.

³⁶ Sambrook, *Country house brewing*, p. 120.

³⁷ NRO, Fitzwilliam Manuscripts (Irish), MS 51.

³⁸ For the sake of comparison, if we apply Muldrew's calculations, the Dublin Castle ordinary beer was produced with 2.76 lb of malt per gallon. The scale assumed for middle beers is 2.7 lb to 4 lb of malt per gallon, which places this example at the lower end of the scale in terms of strength. See Muldrew, *Food*, p. 80.

³⁹ Richard Arnold, *The customs of London, otherwise called Arnold's chronicle*, ed. F. Douce (London, 1811), p. 247.

⁴⁰ William Harrison, *The description of England: the classic contemporary account of Tudor life*, ed. Georges Edelen (Washington, DC, and New York, NY, 2011). From around this time, Gervase Markham's ordinary beer was weaker at around 1 bushel to 20.25 gallons. See Gervase Markham, *Countrey contentments or The English huswife* (London, 1623).

⁴¹ M. K. Dale, ed., *The household book of Dame Alice de Bryene of Acton Hall, Suffolk: September 1412 to September 1413* (Ipswich, 1984), p. 2.

⁴² Muldrew, *Food*, pp. 77–8.

⁴³ C. Klose et al., 'Brewing with 100% oat malt', *Journal of the Institute of Brewing*, 117 (2011), pp. 411–21.

⁴⁴ NRO, Fitzwilliam Manuscripts (Irish), MSS 51, 52. In the early 1590s, in the same household, a greater volume of oats than barley was used for both the strong beer and the ordinary beer. See NRO, Fitzwilliam Manuscripts (Irish), MSS 30–7.

⁴⁵ At the lord deputy's household at Kilmainham in the summer of 1562, the ratio of oat malt to beer malt by volume was 3.1:1. See The National Archives (TNA), Kew, State Papers Ireland, 63/7, fos. 76r–79r. In the twelve times the proctor of Christchurch Cathedral brewed for the stone masons in 1565, he used an average oat to barley ratio of 7.6:1. See Gillespie, ed., *Proctor's accounts*,

Their consumption, in the form of bread as well as beer, has been seen as one of the features of a characteristically Irish diet in this period.⁴⁶ Throughout the middle ages, oats were a core ingredient of ales across Europe.⁴⁷ Over the course of the sixteenth century, however, as cultivation of other cereals increased, there was a general drift away from oats towards barley-based beers.⁴⁸ English writers like Harrison and Gervase Markham proposed adding only a small quantity of oats in their recipes. Even then, caution was advised. Brewing with oats was risky if not carefully managed, the grain being prone to ‘clunter [clot] and fall into lumps...thereby becoming unprofitable’.⁴⁹ Tastes may have changed too: there were warnings that using too much oat malt could cause bitterness or ‘give the drink a smack’.⁵⁰ Irish beer, then, might be seen as a throwback to earlier tastes.

Ireland, however, was far from an outlier. There were exceptions to the shift from oats in regions like the Low Countries, where oat beers continued to be popular.⁵¹ Brewing with oats may also have remained common in Scotland and the north of England.⁵² Meanwhile, in the West Country, where oats were a prominent cereal, ale and beer were disparaged much like Irish examples. Andrew Boorde mocked Cornish ales as ‘dycke and smoky...lyke wash, as pygges had wrestled dryn’.⁵³ An English visitor to Ireland criticized ‘a kind of beer (which I durst not taste) called charter beer, mighty thick, muddy stuff’.⁵⁴ In fact, in southern England, there is also evidence of a sustained interest in oat beers. A manuscript recipe in the possession of Elizabethan courtier Sir Hugh Plat includes instructions for a beer with ‘halfe oate malte & halfe barly malte’ – the same ratio employed at Dublin Castle.⁵⁵ Even physicians recommended their application. Tobias Venner concluded that beer made of equal parts oat and barley was better than that made of barley alone, being

pp. 56, 59–60, 62, 66, 69, 77, 81, 87, 94, 104, 110. At Trinity College in 1598, the proposed ratio was 2:1. See Trinity College Dublin Archives, MUN/P/1/35.

⁴⁶ For example, see A. T. Lucas, ‘Irish food before the potato’, *Gwerin*, 3 (1960), p. 11; L. M. Cullen, *The emergence of modern Ireland, 1600–1900* (London, 1981), pp. 141–2.

⁴⁷ Unger, *Beer*, p. 157; Slavin, *Bread and ale*, pp. 161–2.

⁴⁸ Unger, *Beer*, p. 158.

⁴⁹ Harrison, *Description*, p. 137; Markham, *Countrey contentments*, pp. 227–8.

⁵⁰ John Worlidge, *Dictionarium rusticum and urbanicum* (London, 1704; 1726), cited in Sambrook, *Country house brewing*, p. 131.

⁵¹ Unger, *Beer*, p. 161.

⁵² On the cultivation of oats, see Joan Thirsk, ‘The farming regions of England’, in Joan Thirsk, ed., *The agrarian history of England and Wales, V: 1500–1640* (Cambridge, 1967), p. 19; Mark Dawson, *Plenti and grase: food and drink in a sixteenth-century household* (Totnes, 2009), p. 55; Muldrew, *Food*, p. 60. Gervase Markham noted that the making of oat malt was common in parts of England where barley was scarce. See Markham, *Countrey contentments*, p. 27.

⁵³ Andrew Boorde, *The fyrst booke of the introduction of knowledge*, ed. F. J. Furnivall (London, 1870), pp. 122–3.

⁵⁴ William Brereton, *Travels in Holland, the United Provinces, England, Scotland and Ireland, 1634–1635*, ed. Edward Hawkins (Manchester, 1844), p. 397, Corpus of Electronic Texts (CELT), <https://celt.ucc.ie/published/E630001.html> (accessed 22 Sept. 2022).

⁵⁵ Hugh Plat & TT, a manuscript acquired by the Elizabethan courtier Sir Hugh Plat, written by a hand known only as ‘TT’ and variously added to and annotated by Plat: British Library (BL), Sloane MS 2189, fo. 59.

more effective at quenching thirst and balancing the humors while also being more 'lively' in taste.⁵⁶ This means that recreating a beer made with plenty of oats is highly relevant for the swathes of Europe where the cereal remained central to brewing. For the purposes of comparison, the specific Irish recipe, selected from Dublin Castle in 1574, has a significant but not overwhelming proportion of oats. This allows us to consider the nature of oat-based beer, while ensuring the conclusions remain useful for places and periods where barley was the dominant malt.

II

While the evidence is clear about the balance of malts used in the past, sourcing appropriate grains for the purposes of reconstructing the beer is challenging. There are two main issues. First, there is uncertainty surrounding the exact cereals in use. This problem is not new. Even in 1726, Caleb Threlkeld, in his *Synopsis stirpium hibernicarum*, noted that 'botanists [were] confused about the kinds of barley' grown in Britain and Ireland.⁵⁷ Second, assuming that we could distinguish which species were used for beer-making, the characteristics of early modern cereals were different from their modern counterparts. Before advances in genetics and plant-breeding, which proliferated from the early twentieth century, most crops were kept as landraces.⁵⁸ Within species, individual crops were genetically distinct, with seed from the most successful crops selected, stored, and reproduced according to the local climate and soil and farming conditions. Few landraces survive today and, even where their seed has been preserved in gene banks, there is generally no information on provenance and only miniscule quantities are available for research. This is a problem because, where these older varieties are grown successfully, they stand out from hybridized, modern-day strains. In general, they have a greater root mass to mine deeper in less fertile soils, and they grow taller and have less standing ability than modern varieties.⁵⁹ This also has implications for their nutritional properties and taste. Studies of their use in brewing have suggested that landrace malts produce distinctive flavours, but also lower alcohol yields, mainly due to the smaller grain size and higher nitrogen levels.⁶⁰

When it came to sourcing oats for this project, neither the historical nor the archaeological evidence proved of assistance. The Irish archaeological record reveals the cultivation of *Avena sativa* or common oats and, less frequently, *Avena strigosa* or black oats. Despite extensive collation of archaeobotanical remains as part of the wider FoodCult Project, no examples of germinating oats have been found which would have suggested the species was used for

⁵⁶ Venner, *Via recta*, p. 42.

⁵⁷ Caleb Threlkeld, *Synopsis stirpium hibernicarum* (Dublin, 1726), p. 102.

⁵⁸ On the creation of hybrid varieties in early twentieth-century Ireland, see Herbert Hunter, 'Irish barley growing experiments', *Journal of the Institute of Brewing*, 19 (1923), pp. 79–81.

⁵⁹ 'What are landraces?', *Living Field*, 6 Oct. 2014, www.livingfield.co.uk/corn/what-are-landraces (accessed 23 Feb. 2022).

⁶⁰ Peter Martin and John Wishart, 'Just here for the bere: distilleries and breweries help to conserve ancient Scottish barley', *Brewer & Distiller International*, 11 (2015), pp. 28–9.

malting.⁶¹ Furthermore, no gene bank holds seeds from Irish landraces of *Avena sativa*. We attempted to malt a heritage crop of Irish ‘Sonos’ oats which, while not a landrace, do share characteristics with earlier varieties, but they only germinated to 84 per cent, insufficient to make malt.⁶² Given these issues, the only practical solution was to work with modern flaked oat malt, in the knowledge that this may have had a slight impact on the beer.

Distinguishing and accessing viable barley afforded more satisfactory results. Many sources record the cultivation of several types of barley in pre-modern Ireland. Threlkeld’s *Synopsis* identified three: *Hordeum distichum* or common barley (two rows); *Hordeum polystichum vernum* or bigg (six rows); and *Hordeum polystichum hibernum* or beer barley (six rows).⁶³ An anonymous 1636 poem from Ireland notes that ‘They spar’d not to beat bear, barley and wheat.’⁶⁴ A proclamation made by the country’s lord lieutenant in Dublin in 1644, raising levies on various commodities, pointed to a similar range of cereals, with ‘rye, beare, barley, pease, beans and buckwheat’ all accruing an imposition of 18s per peck.⁶⁵ Importantly, there is evidence that of the types available, bere was a common choice for malting and brewing. In household accounts, barley malt is variously referred to as ‘beare’, ‘bere’, or ‘beyre’ malt.⁶⁶ This is further supported by descriptive sources. In 1690, an English officer observed that all Irish beer and ale, as well as some cakes, were made from bere.⁶⁷

The cereal is no longer produced commercially in Ireland, where it has been supplanted by more efficient cultivars, as it has been elsewhere. However, bere is still grown in Orkney in Scotland, where it remains one of the oldest preserved cereal landraces in Europe. For the experiment, we secured a small quantity from the Agronomy Institute at the University of the Highlands and Islands.⁶⁸ It should be noted that, though it is an ancient varietal, modern bere differs genetically from earlier counterparts and the specific nature of any landrace depends on the local conditions where it is cultivated over a long period of time. Nonetheless, this cereal represents the most viable

⁶¹ See www.foodcult.eu.

⁶² Thanks to Cara Mac Aodháin at Ireland’s Department of Agriculture, Food, and the Marine in Ireland and Dr Noam Chayut at the Germ Plasm Resource Centre at the John Innes Centre in the UK for advice on sourcing landrace oats; to Dominic Gryson at Cornstown House for supplying the project with Sonas oats; and to Robin Appel and his team at Warminster Maltings for their efforts to micro-malt the heritage oats.

⁶³ Threlkeld, *Synopsis*, p. 102.

⁶⁴ Anon., ‘Ye merry boyes all that live in Fingaule’, in Andrew Carpenter, ed., *Verse in English from Tudor and Stuart Ireland* (Cork, 2003), p. 210.

⁶⁵ *A proclamation by the lord lieutenant and counsel, for an imposition upon diverse commodities* (Dublin, 1644), p. 4.

⁶⁶ For example, NRO, Fitzwilliam Manuscripts (Irish), MSS 30, 31, 50, 51, 56; Gillespie, ed., *Proctor’s accounts*; Kent History and Library Centre, De L’Isle Manuscripts, U1475/O25/2.

⁶⁷ John Stevens, *The journal of John Stevens, containing a brief account of the war in Ireland, 1689–1691*, ed. Robert Murray (Cork, 2010), <http://publish.ucc.ie/celt/document/E680002-001> (accessed 22 Sept. 2022). Threlkeld noted the same for the eighteenth century, in *Synopsis*, pp. 101–2.

⁶⁸ Thanks to Peter Martin and John Wishart of the Agronomy Institute at the University of the Highlands and Islands for their sustained support and assistance with the project.

landrace that can be used for the recreation of early modern beer in a northern European context.

The most significant change to occur in early modern brewing was the addition of hops. While much has been written about the pace of this innovation in England and Ireland, little information exists on the nature of historical varieties.⁶⁹ Household accounts tell us volumes but never specific varieties. They do, however, indicate that hops were imported and sometimes where they came from.⁷⁰ One of the Dublin Castle accounts from 1591 described hops that were 'Flemish' in origin.⁷¹ Our search for an appropriate candidate centred on locating a surviving heritage variety with roots in Flanders. Piecing together some of the earliest descriptions, there is evidence to suggest that one of the first varieties introduced to England was the 'Flemish red bine', though it does not survive today.⁷² The most similar extant example is 'Tolhurst', brought to England in 1882. This shares traits with the old Flemish varieties and is considered by experts to be a direct descendant.⁷³ It is also no longer produced commercially and quantities sufficient for the experiment had to be harvested from the few plants preserved in the UK's National Hop Collection.⁷⁴ Collecting the amounts required took three years, the hops being dried and stored after each harvest.⁷⁵

The final ingredient sourced was yeast. Yeasts are single-cell microorganisms naturally present in a variety of environments. They have been used by humans for producing fermented foods and beverages for thousands of years. The processes of making bread and beer are quite similar because

⁶⁹ On the early importation of hops to Ireland, see Susan Flavin, *Consumption and culture in sixteenth-century Ireland* (Woodbridge, 2014), pp. 173–8. On hops more broadly, see Sambrook, *Country house brewing*, p. 133; Bennett, *Ale, beer and brewsters*, pp. 77–97; Unger, *Beer*, pp. 97–103; Joan Thirsk, *Food in early modern England: phases, fads, fashions, 1500–1760* (London, 2007), pp. 305–6.

⁷⁰ Until the late seventeenth century, imported varieties were typically described by their geographical origin (such as Alsace, Hallertau, or Bohemia) or sometimes by physical attributes, especially in relation to bine colour and maturity (such as early green or late red). Much of the information from hops derives from personal communications with Dr Peter Darby (2021).

⁷¹ NRO, Fitzwilliam Manuscripts (Irish), MS 35.

⁷² Hop experts currently believe that the Flemish red bine was the same as the never black, one of the varieties found in England by 1700 and resistant to aphids that cause leaves to go black with sooty mould. Peter Darby pers. com. For descriptions of early varieties, see E. J. Lance, *The hop farmer* (London, 1838); John Percival, 'The hop and its English varieties', *Journal of the Royal Agricultural Society of England*, 62 (1901), pp. 67–95; George Clinch, *English hops: a history of cultivation and preparation for the market from the earliest times* (London, 1919).

⁷³ Tolhurst's distinguishing feature is its highly uncommon tolerance of the aphid pest, a trait it shares with the Flemish red bine. Genetically, Tolhurst is also distinct from other historic English varieties. See John A. Henning, Jamie Coggins, and Matthew Peterson, 'Simple SNP-based minimal marker genotyping for *Humulus lupulus* L. identification and variety validation', *BMC Research Notes*, 8 (2015), p. 524.

⁷⁴ Thanks to Dr Peter Darby and Klara Hajdu from the National Hops Collection in the UK and Dorothy Holamby from A Bushel of Hops, who work to conserve heritage varieties and generously contributed the hops to the project and offered advice on their storage and use.

⁷⁵ This process was deemed appropriate on the grounds that in the sixteenth century, hops would sometimes be at least one year old as this lessened the bitterness but retained the preservation properties.

they involve the same yeast metabolic activity: namely, the conversion of simple sugars derived from grain into alcohol and carbon dioxide. Although many yeasts are capable of alcoholic fermentation, humans have selected particular strains of the species *Saccharomyces cerevisiae* to perform our fermentations. These strains, sometimes colloquially referred to as 'baker's' or 'brewer's' yeast, evolved characteristics that make them especially suitable for baking and brewing. Examples include a superior ability to use barley-derived sugar maltose as a food source, and tolerance to ethanol.⁷⁶

Little is known about the nature and use of yeast in historical brewing. It is generally assumed that in this period it was transferred from one batch of drink to the next as barm, the froth reserved from the fermenting wort.⁷⁷ In the Irish records considered here, this was not always the case, with yeast occasionally purchased for brewers at considerable cost, suggesting some standardization of preferred strains by the late sixteenth century.⁷⁸ Ideally, this study would have used a sixteenth-century strain but this is not possible because the first pure cultures of yeast were only cultivated by Emil Christian Hansen working for Carlsberg in 1883.

The search for the most appropriate proxy was led by Professor John Morrissey, in collaboration with the UK National Collection of Yeast Cultures (NCYC). Recent research into the evolution of modern yeast strains has indicated that around the fifteenth century a lineage emerged that is a direct ancestor of all modern beer (ale) and bread strains. It can be assumed that this group was well suited to brewing and so was circulated among European brewers, rapidly becoming dominant.⁷⁹ While we do not have the ancestral strains, it is possible to use modern genome science and molecular archaeology to infer what might be the closest living yeasts to the ancestor. Among those used for fermentation, there are two large families or clades, termed 'Beer 1' and 'Beer 2'. The former contains two main groups, one associated with Belgium and Germany and the other with Britain and the USA. Some studies described a family of 'Irish/British ale yeasts'.⁸⁰ Therefore, it can be postulated that strains closest to the root of the British and Irish clade are genetically close to those used at Dublin Castle.

We consulted Jo Dicks and Carmen Nueno-Palop at the NCYC, a collection of yeasts deposited by British breweries during the twentieth century. Following analysis of their genome sequences, two strains, NCYC 84 and NCYC 1026, were

⁷⁶ Elizabeth J. Lodolo et al., 'The yeast *Saccharomyces cerevisiae* – the main character in beer brewing', *FEMS Yeast Research*, 8 (2008), pp. 1018–36; Sofia Dashko et al., 'Why, when, and how did yeast evolve alcoholic fermentation?', *FEMS Yeast Research*, 14 (2014), pp. 826–32.

⁷⁷ For example, see Harrison, *Description*, p. 137.

⁷⁸ For example, Lord Deputy Sidney's household in 1566 purchased yeast specifically for brewing. See household accounts for Ireland of Sir Henry Sidney, 1566–8: Kent History and Library Centre, De L'Isle Manuscripts, U1475/O25/1, entries for 6 and 10 Mar. 1566. A fresh batch would have been required if the yeast became contaminated or spoiled.

⁷⁹ B. Gallone et al., 'Domestication and divergence of *Saccharomyces cerevisiae* beer yeasts', *Cell*, 66 (2016), pp. 1397–410.

⁸⁰ M. Gonçalves et al., 'Distinct domestication trajectories in top-fermenting beer yeasts and wine yeasts', *Current Biology*, 26 (2016), pp. 2750–61.

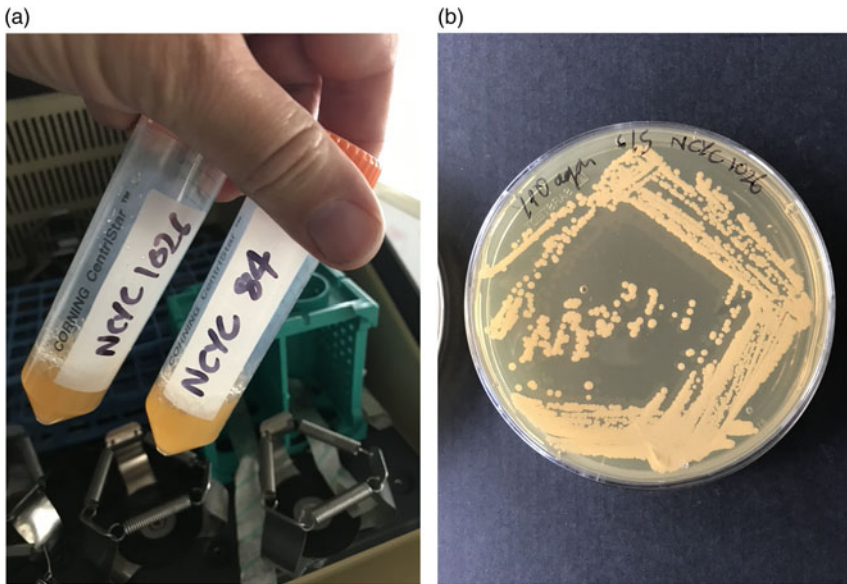


Figure 2a and b. Reconstitution of candidate yeast strains in the laboratory.

Source: Images © John Morrissey.

selected on the basis that they are genetically close to the root of the tree. These strains were recovered from cryopreserved stocks and tested to ensure that they retained brewing traits of interest. In fermentation trials, NCYC 1026, as shown in Figure 2, exhibited more robust growth on both barley wort and ethanol-enriched media, so was chosen for the experiment. It had the further advantage that it had been examined in a previous scientific comparative study.⁸¹ Sufficient NCYC 1026 was grown in bioreactors using wort as the nutrient source, concentrated to a slurry, and shipped on ice back to the UK.

Once the raw materials were selected, the next stage was making malt. Little is known about the process in sixteenth-century Ireland, but it is likely that, as in England, most grain was malted in purpose-built premises by specialist maltsters who were a feature of every market town. The methods hardly changed before the eighteenth century.⁸² Contemporary accounts describe a sequence of soaking the grain in a cistern for a few nights, draining and resting or ‘couching’ it in a heap, before spreading it on a floor to be turned regularly until it germinated. The last step was kilning, which halted the germination

⁸¹ N. Parker et al., ‘Investigating flavour characteristics of British ale yeasts: techniques, resources and opportunities for innovation’, *Yeast*, 32 (2015), pp. 281–7.

⁸² Amber Patrick, *Strategy for the historic industrial environment, report no. 1: maltings in England* (Swindon, 2004), pp. 4–5. Sambrook disagrees, arguing that much malting was domestic. See Sambrook, *Country house brewing*, p. 128. The first evidence of malthouses in Ireland comes from the mid-seventeenth century, in ‘The index of proprietors in 1641’, in Robert Simmington, ed., *The civil survey of Waterford* (Dublin, 1942). Thanks to Dr Clodagh Tait for this reference.

and dried the malt.⁸³ Although building an early modern malthouse would be a worthwhile venture, it was outside the scope of this experiment. The bere was shipped to Warminster Maltings in Wiltshire, the oldest operational malthouse in the UK and one of a few establishments still using traditional floor-malting methods. Warminster's set up compares well with what is known about excavated Irish malthouses. They were also arranged along an in-line model, with a steeping trough adjacent to a clay-tiled germination floor, with a kiln nearby.⁸⁴

The malt was ground using a hand-operated quern, as shown in Figure 3.⁸⁵ For the volumes required, working by hand allowed greater control and the ability to tweak the process as needed.⁸⁶ Large institutional brewhouses, like the one at Dublin Castle, probably relied on a local water mill.⁸⁷ For smaller institutions, however, hand-querning was common. An inventory dated to 1590 for a castle in Co. Kerry listed a pair of querns to grind malt, along with miscellaneous brewing equipment.⁸⁸ They were common in England too: William Harrison's wife ground her malt on a quern-stone at home, to avoid paying a toll to the miller.⁸⁹

III

While written evidence for the components of beer is abundant, descriptions of the equipment and techniques early brewers used are vague and thin on the ground. Wills and inventories record brewing kit, but without further details.⁹⁰ Examples of this equipment rarely survive, and there is no pictorial evidence

⁸³ Watkins, *Complete English brewer*, pp. 13–17; Markham, *Country contentments*, pp. 210–14; Harrison, *Description*, pp. 135–6. See also Sambrook, *Country house brewing*, p. 128.

⁸⁴ James Littleton, 'Castlequarter, Clohamon, Co. Wexford' (unpublished report), <https://excavations.ie/report/2011/Wexford/0022892/> (accessed 22 Sept. 2022).

⁸⁵ Numerous querns were trialled, including a rotary quern, the type archaeologists would expect to have been used in a sixteenth-century Irish context, certainly for producing bread flour. Interestingly, this produced too fine a grist and instead an earlier 'pudding stone' design was found to be most suitable. This may indicate that querns used for the purposes of malting and grinding bread flour were distinctive in this period.

⁸⁶ A coarser grind is needed for brewing than for making bread but descriptions of the consistency of the actual grist used in brewing do not exist, or at least are very vague. For example, see Harrison, *Description*, p. 136. From Robin Appel at Warminster Maltings, we learned that the standard milling process today produces approximately 20 per cent husk, 70 per cent grist, and 10 per cent flour. This is what we aimed for, based on visual inspection.

⁸⁷ For example, fifteen men were hired in 1566 to carry malt to a mill; see Kent History and Library Centre, De L'Isle Manuscripts, U1475/O25/1, entries for 3 Dec. 1566.

⁸⁸ K. O'Shea, 'A Castleisland inventory, 1590', *Journal of the Kerry Archaeological and Historical Society* (1982), p. 43.

⁸⁹ Harrison, *Description*, p. 137.

⁹⁰ See, for example, the wills of Richard Mathew (1582), William Skiddie (1578), Nicholas Faggan (1578), and Edmond FitzNicholls (1580), who bequeathed brewing pans and aqua vitae pots, in Cork City and County Archives, Caulfield will transcripts, U226, pp. 8, 14, 37, 22, 32. An inventory of the duke and duchess of Ormond's goods, at Clonmel, in 1675 records that the brewhouse had a 'furnaise' or furnace, in Jane Fenlon, ed., *Goods and chattels* (Kilkenny, 2003), p. 85. There were brewing pans, various vessels, a wort strainer, and brewing kettle, in the account book of the bishop of Down and Connor's steward, at PRONI, D2056/1.



Figure 3. Quern stone with bere malt.

Source: Image © Susan Flavin.

for Ireland. The visual sources that exist from elsewhere in Europe, such as [Figure 4](#), are formulaic, typically showing an idealized image of a man or woman stirring a pot. Despite these limitations, it seems that most of the paraphernalia used in sixteenth-century brewing was relatively simple and standard.⁹¹ It comprised a boiling vessel or copper to heat water; a ‘mash vat’ or tub in which water was added to ground malt; stirring implements or a brewing oar for mixing; an ‘underbuck’ or tub for collecting the wort drained from the mash vat; ladles to move wort from the underbuck back to the copper for re-boiling with hops; a cooler or tub for allowing the wort’s temperature to drop; and a cask in which the wort was fermented. Exactly this list of equipment was itemized in a set of inventories of Henry VIII’s brew-houses at Portsmouth in 1525/6.⁹² Over time, this arrangement was scaled up, the gap widening between large commercial or military production and the kitchen-based brewing of small homes, but in essence brewing technology and techniques remained broadly consistent between the middle ages and the end of the seventeenth century.⁹³ The Dublin Castle brewhouse, pumping out around 10 hogsheads of 54 gallons each week, was at the larger end of the spectrum.

The only exception to this standardization appears in the method and use of the mash vat. Before the late seventeenth century, brewers did

⁹¹ Sambrook, *Country house brewing*, pp. 22–71.

⁹² Inventories of the king’s brewhouses at Portsmouth, 1525/6: TNA, SP 1/33, fos. 108r–111v.

⁹³ On changes due to the shift from ale to beer production, see Bennett, *Ale, beer and brewers*, pp. 86–9; on continuities in technology, see Sambrook, *Country house brewing*, p. 22.



Figure 4. A sixteenth-century brewhouse.

Source: Jost Amman, 'Der Bierbreuwer', 1568: Wellcome Library, 34958i.

'top-mashing', pouring malt into the vessel from above. After the allotted time, the wort was run off through a drain in the centre of the tun and the grains were left behind. To facilitate this process, various sieving systems were employed. Although no set of brewing instructions describes the sixteenth-century mash vat, we know that three methods of sieving were used in Europe: the 'long tap' (also called a tapstaff or mash staff), 'huckmuck', and tube tap. The decision on which adopt was based on early brewing

histories, along with artefacts and manuscript sources. The firmest evidence was in favour of the tube tap. With this method, the tub has a hole towards the bottom of one of the staves. A tube and tap are fitted into this hole. Withdrawing the tap allows wort to flow from the tub. Affixed internally to the back of the tube is a 'wilch', a woven wicker filter. According to a work on traditional Norwegian brewing, this system was the most common in southern England.⁹⁴ Aside from general mentions of wort sieves, few sources point to which system was used in Irish brewing.⁹⁵ But imports from the 1560s of large quantities of 'taps and cannells', in tandem with rising inward shipments of hops, implies the use of similar technology.⁹⁶ Models for a tube tap and wilch are scarce. However, there are published images of historic brewing equipment, and surviving examples at the Museum of English Rural Life and the Museum of East Anglian Life.⁹⁷ These provided exemplars for replication, as depicted in Figure 5.

The reproduction of the brewhouse took three years and drew on the expertise of craftspeople from across Europe, including coppersmiths, historical woodworkers, a cooper, and a wicker-weaver, all commissioned by the project's lead brewer.⁹⁸ The brewhouse was assembled at the Weald and Downland Living Museum, which hosted the project in the pre-existing Tudor kitchen, as shown in Figures 6 and 7.⁹⁹ This site offered the most authentic environment available, as well as access to a range of technological expertise. It was also chosen because of its water quality. For comparison, water was tested from a surviving portion of the medieval watercourse on the River Dodder in Dublin.¹⁰⁰ This showed hardness in the 200–300 milligram range, not far off the levels at the museum. Once the on-site water was filtered to remove modern additives, the pH and hardness were almost identical to the Dublin samples.

⁹⁴ Odd Nordland, *Brewing and beer traditions in Norway* (Oslo, 1969), p. 71.

⁹⁵ PRONI, D2056/1.

⁹⁶ For example, see Bristol port books, 1575–6: TNA, E 190/1129/12, fos. 6v, 7r, 19r–19v. Cannells were apparently pipes for cast, as defined in 'cannel, n. 2', OED Online, www.oed.com (accessed 23 Sept. 2022).

⁹⁷ Basketwork strainer, Museum of English Rural Life, Reading, 51/854. Published images can be found in George Ewart Evans, *Ask the fellows who cut the hay* (London, 1956), fig. 12; *Country Life*, 4 Mar. 1949, fig. 4. The wicker was also modelled on finds on the *Mary Rose*, such as Wicker Flask: *Mary Rose*, Portsmouth, 81A3288.

⁹⁸ The copper was produced by Iberian Coppers LDA, Portugal, www.copper-alembic.com/en/ (accessed 23 Sept. 2022). Historical woodworker Robert Hoare made the tube taps; Adrian Warrell the paddles and the ironwork stand for the copper; cooper Les Skinner the barrels and mash vat; and wicker-weaver Linda Mills the wilch. The craftspeople were directed by Marc Meltonville, historical brewer and food historian.

⁹⁹ Our thanks to Simon Wardell and Lucy Hockley at the Weald and Downland Museum.

¹⁰⁰ This is still accessible at a weir in Dodder Valley Park. Our thanks to Professor Howard Clarke for his advice on the city's watercourse. For a basic account and map, see H. Clarke et al., *Dublinia: the story of medieval Dublin* (Dublin, 2002), pp. 96–7; H. B. Clarke, *Dublin. Part I, to 1610*, Irish Historic Towns Atlas 11 (Dublin, 2003), p. 8, fig. 6.



Figure 5. Replica tube tap with wilch made by historic wicker-worker, Linda Mills.
Source: Image © Susan Flavin.

IV

Brewing was carried out over a two-week period in September 2021. The recipe selected was from Dublin Castle in May 1574, when in one seven-day span, the brewer produced 11.75 hogsheads (635 gallons), from 47 bushels of malt, comprising 23.5 of bere and 23.5 of oats, with the addition of 20.5 lb of hops. These details were not quite enough. The buttery accounts do not state how much water was added to reach the final volume of beer, even though this entirely determines the strength of beer and therefore is essential for recreating the same type of drink (a point that historians rarely acknowledge). This is part of the craft knowledge of the brewer and is arguably unknowable. Every brew-house and each brew were unique. Evaporation from boiling would have depended on local conditions such as the building's air flow, and the dimensions of kettles and tubs. Yet the brewing instructions of Hugh Plat and Edward Whitaker give an indication.¹⁰¹ Allowing for the liquid lost in mashing and boiling, both noted that achieving 3 gallons of beer required starting with 5 gallons of water. Through the experiment, we found that these figures were accurate, with some flexing for each brew. With a sense of how concentrated the wort should be, the original Dublin Castle recipe was scaled down to match our equipment, which could produce up to 36 gallons a day, as shown in Table 1.

In the months before the experiment proper, two practice runs were carried out with modern grains to test the kit and develop the project team's brewing

¹⁰¹ Edward Whitaker, *Directions for brewing malt liquors* (London, 1700), p. 8; BL, Sloane MS 2189, fo. 60.



Figure 6. Detail of the mash vat at the assembled brewhouse.

Source: Image © Susan Flavin.

Table 1. Dublin Castle ordinary beer recipe, week ending 15 May 1574

| To produce c. 27 gallons of beer* | |
|-----------------------------------|---------------|
| Barley malt | 1 bushel |
| Oat malt | 1 bushel |
| Hops | 12 ounces |
| Water | c. 36 gallons |

*Scaled down from the weekly production of 635 gallons.



Figure 7. The assembled brewhouse at the Weald and Downland Living Museum.

Source: Image © Susan Flavin.

proficiency. In September, the aim was to repeat the Dublin Castle recipe three times and carry out two further runs, one using modern grains and yeast, and a further using two bushels of bere, producing the same volume of beer but omitting the oats. This was to assess the technical and nutritional significance of the oats and to produce a beer closer to some contemporary English versions. In practice, we had to brew the Irish beer a fourth time, as one of the efforts produced a ‘stuck mash’, when the oats turned to porridge in the tun.

Before each brew, the malt was measured using a replica Winchester bushel, shown in Figure 8. This simple process had interesting results. A bushel of ground malted barley weighed on average 33.7 lb (15.31 kg) and a bushel of flaked oat malt 41 lb (18.63 kg). In the past, the weight of the volume measure would have varied somewhat depending on the crop, levels of moisture, and the method of malting. But the figure for the barley was considerably less than the 42 lb per bushel applied by historians quantifying the calories available in beer, emphasizing the benefit of integrating practical methods.¹⁰²

Our brewing protocol followed numerous contemporary printed and manuscript guides.¹⁰³ According to a principle adhered to throughout, data was

¹⁰² The 42 lb figure is based on early twentieth-century estimations. For example, Muldrew, *Food*, p. 74; Campbell, *The book of beer*, pp. 62–3; Sambrook, *Country house brewing*, p. 130.

¹⁰³ The key brewing directions derive from Holger Funk, ‘A little known, mid-16th century description of the production of English ale by John Caius’, *Brewery History*, 165 (2016), pp. 19–



Figure 8. Striking a bushel.

Source: Image ©Susan Flavin.

collected using modern scientific equipment, but this was never allowed to guide the process. On each brewing day, the fire was lit under the copper boiler filled with water. The water was brought to a boil then allowed to cool in the copper ‘till the steam is near spent, and you can see your face in it’.¹⁰⁴ When checked with a thermometer, the water was ready at 60–70 °C.¹⁰⁵ After this, the liquor was ladled into the mash vat and the combined bushels of bere and oats were added, a paddle being used to stir and break up any lumps. At this stage, around 25 gallons of water were added to the tun. After an hour, a ladleful of wort was tapped off from the bottom and poured back over the grains. After a further thirty minutes, the wort was drained. Following early modern advice,

29; Harrison, *Description*; Hugh Plat, *The jewel house of art and nature* (London, 1594); Hugh Plat, *Delights for ladies* (London, 1602); BL, Sloane MS 2189; Markham, *Country contentments*; Tryon, *New art*; Holme, *Academy of armory*; Whitaker, *Directions for brewing malt liquors*; William Ellis, *The London and country brewer* (London, 1734); Watkins, *Complete English brewer*; ‘Mrs Beales method of brewing’: private collection of Malcolm Thick; Anon., ‘To make Tamworth ale’: private collection of Malcolm Thick. Our thanks to Malcolm Thick for his advice, and for making his collection available to the project. For an analysis of Plat’s annotations in the British Library manuscript to 1790, see Malcolm Thick, *Sir Hugh Plat: the search for useful knowledge in early modern London* (London, 2010). Our thanks to Robert Hoare for providing transcripts of unpublished sources.

¹⁰⁴ For example, Ellis, *London and country brewer*, p. 27.

¹⁰⁵ On speculations around the significance of temperature to ale quality, see Slavin, *Bread and ale*, p. 162.



Figure 9. Wort running through the wilch and tube tap into the ladle.

Source: Image © Susan Flavin.

the speed was kept slow, the flow regulated so it was running ‘as small as a straw’ (Figure 9).¹⁰⁶ This avoided spillages and disruption of the settled grain bed inside the mash vat. Along with the wilch on the end of the tap, the grain bed filtered the wort which, except in one case, worked efficiently and ran clear.

After draining, this first wash returned about 19–20 gallons of wort. This was stored in the buck. As we were making an entire ordinary beer, we added another 10–15 gallons of hot water to the mash vat (the exact amount depended on how much wort was initially produced, as we were aiming to achieve 25–8 gallons at the end). Once again, the mash was left for an hour

¹⁰⁶ Ellis, *London and country brewer*, p. 27.

and a half, with a gallon of tapped-off wort poured over thirty minutes before the time was up.

After the allotted wait, the second wash was drained and poured into the copper, along with the wort from the first wash waiting in the buck. The combined wort was brought to the boil. At that point, 12 oz of dried hops were added, and the liquid was left to boil for a further ninety minutes. Finally, the wort was ladled into buckets and transferred to a covered barrel and left to cool overnight. The following morning, the starter culture of yeast was fed with a small measure of wort. Once the barrel's temperature had dropped to room temperature, described as 'blood warm' in contemporary instructions, the yeast was pitched.¹⁰⁷ The preparation was poured into the barrel and stirred vigorously, providing the yeast with plenty of oxygen.

Fermentation took place in upright casks with the heads removed, which were lidded but not sealed. The yeast began working quickly. Daily visual checks were carried out for the end of fermentation, looking for signs like a reduction in bubbling and a flat surface to the beer. It continued for five to seven days, at which point the yeast sank to the bottom. As one manuscript source put it, the beer could be tunned once the 'barme on ye head...doth descend'.¹⁰⁸ The finished drink was then decanted into casks for storage.

Throughout the process, a complex sampling regime was followed.¹⁰⁹ For the present study, samples were collected when the wort was boiled with hops before the addition of yeast; after fermentation was complete; and after three weeks of storage, when the beer had cleared and was considered ripe for drinking. This timing was influenced by a seventeenth-century indenture from Trinity College Dublin, which indicates that contemporary beers should be at least three weeks old before consumption.¹¹⁰

V

The experiment produced five batches of beer. The results considered here relate to the three completed Dublin Castle beers which, owing to repetition, supplied the most meaningful data. These batches had a slightly bitter taste, with a gentle flavour from the hops. They had a light honey colour and

¹⁰⁷ The most common instruction is to add yeast when the wort is 'blood warm' or at the temperature of 'new milk'. See, for example, Wellcome Library, MS 7721, p. 30; Wellcome Library, MS 7892a, p. 53; Sir Kenelme Digbie, *The closet opened* (London, 1669), p. 83; Whitaker, *Directions for brewing malt liquors*, p. 16. This is taken to mean room temperature.

¹⁰⁸ PRONI, D2056/1.

¹⁰⁹ Samples at different time stages of the fermentation were collected for the microbiology laboratory at University College Cork, to analyse the specific yeast strain. Samples of malt, water, wort, and finished beer at different points were also taken for another project based at Durham University, examining changes in oxygen isotopes throughout the process to improve understanding of human mobility and migration. Examination of carbon, nitrogen, and strontium isotopes will inform the study of diet.

¹¹⁰ Trinity College Dublin Archives, MUN/P/1/35. Beer may have been consumed after a longer storage period, from one to six months, depending on strength. See Venner, *Via recta*, p. 40.

were hazy, probably due to the oats.¹¹¹ The samples were sent to the International Centre for Brewing Science at the University of Nottingham for examination. The analysis used various modern methods to quantify the alcohol and carbohydrates, and thus infer the total calorie content.¹¹²

Initially, the specific gravity (SG) of the wort was characterized, a measure that broadly describes the degree of fermentability based on available sugars for fermentation. Another way this can be described is by Degrees Plato, defined as a measure of the amount of extracted soluble material (predominantly fermentable sugars) as a percentage of total wort mass.¹¹³ Furthermore, the total nitrogen content of each batch of wort was calculated, as yeast requires both sugar and protein for successful propagation and fermentation. Despite following the same procedure for sample preparation, there was some variation in the quantity of extract in each batch of wort (Table 2). Likewise, there were significant differences in the SG of the three brews.

On measuring the alcohol content of the fresh beer, batch 1 recorded a much lower value than batches 2 and 3 (Table 3). These two batches provided alcohol by volume (ABV) values quite close to a typical modern English cask ale. Furthermore, their fermentation performance, as described by the apparent degrees of fermentation (ADF), behaved in a manner not dissimilar to modern ale fermentations.

To further understand the difference in SG and ABV, the specific sugars in each batch of wort were quantified (Table 4). Wort from batch 1 had a reduced concentration of both maltose and maltotriose, the main sugars fermented into alcohol by yeast and products of the enzymatic hydrolysis of solubilized starch during mashing. The enzymes are sensitive to temperature, so it is plausible that the temperature of wort production for batch 1 was greater than the optimum range for starch hydrolysis (63–73 °C), resulting in less fermentable sugar that could produce alcohol. The variation in values could also be attributed to fluctuations in the volume of water used. Batch 1 produced 28 gallons of wort from 39 gallons of water, while batches 2 and 3 both returned 26 gallons from 35 and 36 gallons of water respectively. More or less liquid was soaked up in the mash vat due to the fineness of the ground malt and the temperature of the water.

After the maturation period, all three batches showed an increase in ABV with a corresponding fall in SG (Table 5). This is to be expected, as the residual suspended yeast particles present in the beer were still alive and able to continue fermenting any residual sugars.

Nutritional analysis was restricted to the three-week old samples, deemed to be fit for consumption. The total calorie content was determined by quantifying the components that impart energy upon digestion: carbohydrates

¹¹¹ The beer produced from only bere barley had a clearer appearance, but this recipe was just produced once.

¹¹² 'Food energy - methods of analysis and conversion factors: report of a technical workshop', *FAO Food and Nutrition Paper*, 77 (Rome, 2002), <https://www.fao.org/3/y5022e/y5022e00.htm> (accessed 5 Oct. 2022).

¹¹³ G. Spedding, 'Alcohol and its measurement', in Charles Bamforth, ed., *Brewing materials and processes* (London, 2016), pp. 123–49.

Table 2. The specific gravity (as both SG and Degrees Plato), density values, and total nitrogen content of the wort samples prepared in this study using the Dublin Castle recipe

| Wort sample | Specific gravity (SG) | Degrees Plato (°P) | Density g cm-3 | Total nitrogen mg/L |
|-------------------------|-----------------------|--------------------|----------------|---------------------|
| Dublin Castle – batch 1 | 1.0420 | 10.48 | 1.04044 | 685.8 |
| Dublin Castle – batch 2 | 1.0475 | 11.79 | 1.04562 | 797.2 |
| Dublin Castle – batch 3 | 1.0447 | 11.12 | 1.04287 | 841.0 |

(starches, sugars, and dietary fibres), protein, and alcohol. Table 6 summarizes how much of these components each batch of the beer contained, as well as the total calorie content determined using the Atwater system (per litre and per UK pint or 568 mL).¹¹⁴ For comparison, we also performed the same analysis on a lager beer now consumed worldwide.

The total calorie content of batches 2 and 3 was almost equivalent to the modern lager. Meanwhile, batch 1 recorded a much lower figure. This can largely be attributed to the reduced level of alcohol, which has the greatest contribution to calorie content of the measured nutrients. This batch's higher content of starches derived from the incomplete starch hydrolysis during wort production.

In summary, the beer from batch 1 was an outlier with a lower alcohol and calorific content than the other two. Its differences were explained by the reduced level of fermentable sugars, perhaps due to a higher water temperature or the variable amount of water added. Despite the variability inherent to early modern brewing, batches 2 and 3 showed remarkably similar results. The Dublin Castle beer, after three weeks of maturation, had an ABV of 5–5.3 per cent and an energy content of 260–72 kCal per pint. These characteristics made it highly comparable to modern beverages.

VI

These results shed some light on the practice of early modern brewing as well as the dietary importance of beer. From a purely theoretical perspective, we might have assumed that crude equipment, top-mashing, and basic filtration limited the extraction of sugar from the malt and turned out an inconsistent product. We might also have expected that the pre-modern grains restricted the potency of the end-product, and that old yeast strains struggled to ferment either fast enough or fully. These reasonable assumptions feature in much of the historiography around beer.¹¹⁵ This is why the careful reconstruction of each stage of sixteenth-century brewing was vital. Brewed following

¹¹⁴ 'Food energy'.

¹¹⁵ For examples of such comments, see James Sumner, 'Small beer to you, perhaps', *A Blind Thermometer*, 22 Aug. 2011, www.jbsumner.com/blog/2011/08/small-beer-to-you-perhaps

Table 3. Alcohol content by volume (ABV), specific gravity (SG), Degrees Plato (°P), density and apparent degrees of fermentation (ADF) of the three batches of ‘fresh’ Dublin Castle beer

| Fresh beer sample | Alcohol content by volume (ABV, %) | Specific gravity (SG) | Degrees Plato (°P) | Density (g cm ⁻³) | Apparent degrees of fermentation (ADF, %) |
|-------------------------|------------------------------------|-----------------------|--------------------|-------------------------------|---|
| Dublin Castle – batch 1 | 1.99 | 1.0266 | 6.72 | 1.02473 | 35.87 |
| Dublin Castle – batch 2 | 4.94 | 1.0099 | 2.54 | 1.00811 | 78.46 |
| Dublin Castle – batch 3 | 4.50 | 1.0104 | 2.66 | 1.00858 | 76.08 |

Table 4. Concentration of glucose, maltose, and maltotriose in each batch of the Dublin Castle recipe beers

| Wort sample | (Glucose) (g/L) | (Maltose) (g/L) | (Maltotriose) (g/L) |
|-------------------------|--------------------|--------------------|------------------------|
| Dublin Castle – batch 1 | 3.80 | 20.91 | 14.23 |
| Dublin Castle – batch 2 | 4.51 | 43.59 | 22.52 |
| Dublin Castle – batch 3 | 4.11 | 42.17 | 20.75 |

contemporary formulas and using grains that compared to pre-industrial cereals, traditional processing techniques, and early modern technology, the Dublin Castle beer had much in common with those consumed for leisure today. By this point in the past, the experiment suggests, the key features of modern brewing were in place. This chimes with what we know about the precocious development of the trade by the sixteenth and seventeenth centuries, with large-scale, commercialized businesses servicing a mass demand already achieving efficiencies in the use of raw ingredients, fuel, and human resources.¹¹⁶ Not only did these brewers anticipate the even greater upscaling of the industrial era, but their equipment and processes were able to produce a beer with which modern drinkers would be familiar.

However, there is one major difference with the industrialized beer-making that has characterized recent history: standardization. Modern brewers have far more control of every stage in the process. Today's varieties of cereal and strains of yeast have been bred to behave in a consistent manner and produce the same end-result. Measuring temperature using a digital thermometer, rather than the brewer's eye or a dipped finger, is also necessarily more precise. Nowadays, the aim is to make the same beer each time. Despite following the same recipe and processes, the Dublin Castle brews all varied to differing extents. In the final analysis, the second two batches were much closer in composition. This was probably a question of control, particularly if a difference in water temperature lay behind the variable extraction of sugars. It also reflects the benefits of practice. The outlying batch 1 was the first of the three brews carried out. As the team gained proficiency, we quickly learned to adjust to any problems. One misstep in the experiment exemplifies this. On one aborted brewing day, the mash became 'stuck' in the tun and would not filter.¹¹⁷ After discussion and returning to contemporary instructions, we reasoned

(accessed 10 Sept. 2022); Hayes, 'European naval diets', p. 206; Sambrook, *Country house brewing*, p. 52; Muldrew, *Food*, pp. 80–1.

¹¹⁶ Peter Mathias, *The brewing industry in England, 1700–1830* (Cambridge, 1959), pp. xxiii–xiv. On development by the seventeenth century, see John R. Krenzke, 'Change is brewing: the industrialization of the London beer-brewing trade, 1400–1750' (Ph.D. thesis, Loyola University Chicago, 2014), p. vi.

¹¹⁷ This was a common problem in early modern brewing. See Sambrook, *Country house brewing*, p. 93. It is likely due to the high content of non-starch polysaccharides in oat malt creating a gel-like network in the mash. See Joshua E. S. J. Reid, Gleb E. Yakubov, and Stephen J. Lawrence,

Table 5. Alcohol content by volume (ABV), specific gravity (SG), Degrees Plato ($^{\circ}$ P), density, and apparent degrees of fermentation (ADF) of the three batches of beer prepared to the Dublin Castle recipe after conditioning

| Conditioned beer sample (3 weeks) | Alcohol content by volume (ABV, %) | Specific gravity (SG) | Degrees Plato ($^{\circ}$ P) | Density (g cm^{-3}) | Apparent degrees of fermentation (ADF, %) |
|-----------------------------------|------------------------------------|-----------------------|-------------------------------|--------------------------------|---|
| Dublin Castle – batch 1 | 2.05 | 1.0256 | 6.47 | 1.02377 | 38.26 |
| Dublin Castle – batch 2 | 5.31 | 1.0075 | 1.92 | 1.00574 | 83.72 |
| Dublin Castle – batch 3 | 5.04 | 1.0088 | 2.26 | 1.00703 | 79.68 |

Table 6. Macronutrient content and inferred total calorie content per unit volume for the three batches of matured Dublin Castle beer, as well as a modern lager beer for comparison

| Conditioned beer sample | Total starches (g/L) | Total sugars (g/L) | Total fibres (g/L) | Total alcohol (g/L) | Total protein (g/L) | Energy value (kCal / L) | Energy value (kCal / pint) |
|-------------------------|-------------------------|-----------------------|-----------------------|------------------------|------------------------|----------------------------|-------------------------------|
| Dublin Castle – batch 1 | 56.9 | 0.84 | 1.14 | 15.94 | 2.9 | 348.4 | 197.9 |
| Dublin Castle – batch 2 | 43.7 | 1.09 | 1.09 | 41.90 | 3.4 | 479.5 | 272.3 |
| Dublin Castle – batch 3 | 41.9 | 2.02 | 1.01 | 39.77 | 3.6 | 458.3 | 260.3 |
| Modern lager | 44.7 | 2.00 | 0.62 | 39.45 | 3.9 | 469.7 | 266.8 |

that the water might not have cooled sufficiently before adding the malt. By tweaking our approach and allowing the temperature to drop a while longer, this mistake was avoided in subsequent brews. This experience mirrored that of brewers in the past, who noted that when working with oat malt, 'cold' water should be added.¹¹⁸ Early beer-makers likely built up a bank of experience, developing solutions to possible problems related to the ingredients, equipment, and environment with which they worked, mitigating undesirable variations in quality and reducing the number of wasteful failures. Stripped back as their processes seem, we should not underestimate the skill and knowledge of early modern brewers.

When considering beer's dietary importance, we should note that calculating the nutritional value of an alcoholic drink is problematic. Alcohol is an energy-dense substance, but is less easily converted by the body than carbohydrates, and the metabolic significance of this is a long-standing question among scientists. Exactly how the body uses energy from alcohol is more complex than can be explained by a simple conversion to calories.¹¹⁹ Further projects in this vein could collaborate with nutritionists to consider the different forms of available energy within historical beer. While providing a breakdown of the macronutrients, which could be powerful data underpinning future research, this experiment has employed basic energy estimates to enable comparison with previous studies.

Our results confirm that beer was a fundamental source of energy in early modern diets. Assuming that the Dublin Castle drinkers had between 5 and 10 pints a day, beer provided each member of household staff with as many as 2,700 kCal. That is still very high, but it is notable that the most energy-rich beer from the experiment (batch 2) contained 32.5 per cent fewer calories, pint for pint, than the 400 kCal estimate for ordinary table beer Craig Muldrew used in his study of pre-industrial food and energy.¹²⁰ The recipe the experiment replicated used an amount of malt that sits within the standard range of values for beer of this strength. In reality, beers would have varied significantly, even within a category, but these new results suggest the need for a downward revision in some estimates of the calories provided from drink.¹²¹ Because of the experiment's limitations, it is not the authors' intention to claim that the Dublin Castle beer should be a universal stand-in for

'Non-starch polysaccharides in beer and brewing: a review of their occurrence and significance', *Critical Reviews in Food Science and Nutrition* (2022), DOI: 10.1080/10408398.2022.2109585.

¹¹⁸ Watkins, *Complete English brewer*, p. 119.

¹¹⁹ L. A. Smolin and M. B. Grozvenor, *Nutrition: science and applications* (Hoboken, NJ, 2019), pp. 188–94; National Institute on Alcohol Abuse and Alcoholism, *Alcohol Alert*, 22 (1993), <https://pubs.niaaa.nih.gov/publications/aa22.htm> (accessed 7 Oct. 2022); Lihong Jiang et al., 'Increased brain uptake and oxidation of acetate in heavy drinkers', *Journal of Clinical Investigation*, 123 (2013), pp. 1605–14; M. J. World et al., 'Alcohol and body weight', *Alcohol and Alcoholism*, 19 (1984), pp. 1–6; Paolo M. Suter and Angelo Tremblay, 'Is alcohol consumption a risk factor for weight gain and obesity?', *Critical Reviews in Clinical Laboratory Sciences*, 42 (2005), pp. 197–227.

¹²⁰ Muldrew, *Food*, p. 80.

¹²¹ Conversely, this suggests that there is no reason to assume that ordinary beer was extremely low in calories either, as suggested in Hayes et al., 'European naval diets', p. 207.

what most people drank in this period, when calculating how successfully communities were fed and watered. While quantitative analysis always requires using generalized averages, it is important to take greater account of the conditions and processes involved in producing food in the past.

The results also make plain that ordinary beer in the early modern period could be as potent as its present-day counterpart. The two Dublin Castle batches that showed complete starch hydrolysis and good fermentation responses yielded figures of over 5 per cent.¹²² Given this finding, historians should be wary of assuming that people drank so much in the past because the beer was weaker. When converted to a measure used to track and regulate alcohol consumption today, each pint of Dublin Castle beer contained just over 3 units of alcohol.¹²³ The current UK recommendation is for both males and females to not exceed 14 units per week to avoid health risks. Even if the residents of the Irish lord deputy's household consumed just 5 pints a day, they may have hit 15 units every 24 hours. In other words, what is now considered a safe weekly limit was exceeded on most days of the week. Thus, the quantities of alcohol that staff and family members at institutions like Dublin Castle were encouraged to drink on a daily basis, as part of their regular diet, had the potential to cause significant inebriation. Once again, the authors are hesitant to over-generalize, given the preliminary nature of the experiment, but this may have implications for our understanding of the early modern concept of intoxication. If the beer that people were supposed to drink as a nutritious foodstuff was already getting them drunk, then it is little wonder that imbibing to excess in other social venues was often cast as dangerous and unruly.

These are baseline findings. As such, they raise questions beyond the scope of the initial project. Subsequent studies might consider the strength of other beers in this and earlier periods. They might look at the effect of using the same recipes at a greater or smaller scale, to mimic the circumstances of a proto-industrial, commercial brewhouse or a family making drink for themselves. They might also isolate specific variables, for example reproducing barley- or oat-only recipes or using the same ingredients with modern equipment. Developing collaborations with nutritionists might also advance our understanding of how beer was metabolized in the past, an avenue with direct relevance for scientists studying over-consumption in the present. Furthermore, what we have learned about the alcoholic strength of beer may be connected to the cultural and social contexts of drinking. Micro-studies might look at when and how people drank these great quantities and their level of inebriation. Was beer only consumed with solid food or drunk during work as hydration? Was it slugged down in great gulps or sipped throughout the day? How much extra beer was drunk for leisure, on top of workmen's allowances, and was this beer even stronger?

¹²² ABV is a measure of the amount of pure alcohol as a percentage of the total volume of liquid in a drink.

¹²³ One unit is equal to 8 g of alcohol.

VII

This experiment set out to estimate the nutritional content and alcoholic strength of early modern beer, by means of a thorough reconstruction of the equipment, ingredients, and processes employed in the past. Analysis of three batches of a drink comparable to the ordinary beer brewed at Dublin Castle in 1574 suggested that, in calorific terms, the sixteenth-century beverage was strikingly similar to a modern lager. While this may mean historians need to reduce their benchmarks for the number of calories beer provided, it was still a significant source of energy, especially given the very high levels of consumption noted in this and other studies. The analysis also indicated that this beer could ferment very well and result in an ABV on a par with present-day cask ales. Contrary to long-held assumptions, there is no reason why historical beer was necessarily weaker, though more work is needed to explore the contemporary experience of a specific drink's potency. Beyond the core research questions, the experiment offered insight into the practices of brewing at this point in European history. By the sixteenth century, beer-making techniques and technology were not essentially different from later industrial methods, which mostly made advances in scale, precision, and repeatability. Brewers like those working at Dublin Castle possessed a profound knowledge of their craft and made careful judgements based on sensory observation to produce a good quality, consistent product. Such implicit knowledge was not necessarily written down, highlighting the value in looking beyond recipes and towards experimental archaeology. Cumulatively, this project has demonstrated the benefits of radical interdisciplinarity. By engaging with colleagues in a multitude of fields, from microbiology to brewing science to craft-based historical interpretation, at an early stage in planning and throughout the analysis, more challenging questions can be posed, and more complex answers put forward. The study of food and drink lends itself to such approaches, because it can be examined from a range of perspectives, from the social and cultural to the biological and physiological. Experimentation of this kind throws up difficulties and expends plenty of resources but has the potential to paint a more holistic picture of the foundations of early modern life and help us understand issues in the present as well as the past.

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