Research article

Received: 21 July 2018 Revised: 1 November 2018 Accepted: 6 November 2018 Published online in Wiley Online Library

(wileyonlinelibrary.com) DOI 10.1002/jib.551

Draught beer hygiene: a survey of on-trade quality

James R. Mallett and David E. Quain*

The quality of draught beer in 57 on-trade licensed premises in 10 locations in the UK Midlands was assessed using a forcing test. Of 149 samples of standard lager ('SL', abv ≤ 4.2%), 44% were in the 'excellent' quality band compared with 16% of 88 samples of keg ale ('KA', abv ≤ 4.2%). Of the total of 237 samples, >90% were represented by two lager and two ale national brands. There were differences in the quality index (QI) between the brands, with lager SL3 having a QI of 84% compared with 72% for lager SL6, 71% for ale KA5 and 68% for ale KA1. The susceptibility of the four brands to spoilage was assessed using a challenge test with microorganisms taken from forced draught beer samples of the brands. Ale KA5 (challenge test QI = 87.5%) was the most resistant to spoilage followed by lager SL3 (81.3%), lager SL6 (75%) and ale KA1 (62.5%). Keg beers in accounts with a national cask beer quality accreditation had the same QI as those without accreditation. Analysis of price vs quality showed that the most expensive price band had the lowest quality. Draught beer quality declined as the number of dispense taps increased across the bar. It was also noted that dispense into branded half-pint glasses had variable take-up, with lager SL3 served in the correct branded glassware on 71% of occasions but only on 5% of occasions for lager SL6. None of the keg ales were served in correctly branded glassware. © 2018 The Institute of Brewing & Distilling

Keywords: dispense; quality; survey; spoilage

Introduction

Between 2000 and 2016, UK beer sales declined by 12.9 mhL from 56.6 to 43.7 mhL *(1)*. Over the same period, draught beer sales fell by 15.6 mhL from 35.2 to 19.6 mhL. This reflects the decline in draught beer from 62.3% of total sales in 2000 to 44.7% in 2016. In terms of the category, the UK draught market in 2016 was dominated by pasteurised keg beers, including lager (62.4%), keg ale (12.8%) and stout (6.7%). Unpasteurised cask beers account for 18.1% of the draught beer market.

There are a host of reasons for the long-term decline in beer sales in general and draught beer in particular. A PEST (political, economic, social and technological) analysis of the on-trade identified some 27 factors which – to a lesser or greater extent – are considered to have contributed to the decline *(2)*. Of these, 'quality' is a perennial issue for draught beer. Quality can be compromised by the dispense process (slow throughput, temperature, over/under carbonation), glassware (dirty, wrong glass) and hygiene (bacteria and yeast generating off-flavours, aromas and haze). Although draught beer hygiene quality varies widely, measurement ranges from indirect (data logging) *(3,4)* and subjective (clarity, aroma, appearance) *(5)* to objective (isolation and quantification of microorganisms) *(6–8)*. As these approaches have their limitations, a new approach has been reported to assess the hygiene quality of draught beer based on the microbial loading at dispense *(8)*.

The method *(8)* is based on the long established 'forcing' principle, in this case, forcing draught beer at 30°C for four days. The increase in turbidity of beer post incubation relates to the initial loading of beer spoilage microorganisms. Accordingly, beer of 'excellent' quality exhibits little or no increase in turbidity, which with increasing initial microbial loading reduces to 'acceptable' through to 'poor' or, worse still, with a major increase in turbidity, 'unacceptable'.

Here, we report the application of the forcing method to assess the quality of draught beer in the on-trade. Samples (237) of leading brand keg ales and lagers were purchased in 57 on-trade licensed premises ('accounts') in 10 locations on typically two occasions. In addition to beer quality, other metrics were recorded including quality accreditation, cost, number of taps on the bar and the use of branded glassware.

Materials and methods

Beer samples (half pint) were purchased locally from on-trade licensed premises (pubs and bars) in two cities (Derby and Nottingham), three towns (Burton-on-Trent, Loughborough and Market Harborough) and five villages (near to Derby). The combined population of these locations is about 750,000. For clarity, a city is defined as having a cathedral and/or a university, a town has a market and a village has a church.

The work reported here was over a period of nine months from May 2016 to January 2017. The focus of the survey was on two draught beer categories, 'standard' lager (SL) and keg ale (KA). Both categories have an abv of ≤4.2% *(1)* and are flash pasteurised into kegs. In all, 237 samples were purchased, comprising of 149 lagers and 88 keg ales. For both categories, two brands predominated, accounting for 96% (lager SL3 and SL6 – both 4% abv) and 93%

* Correspondence to: David Quain, International Centre for Brewing Science, School of Biosciences, University of Nottingham, Sutton Bonington Campus, Loughborough, Leicestershire, LE12 5RD, UK. E-mail: david.quain@nottingham.ac.uk

International Centre for Brewing Science, School of Biosciences, University of Nottingham, Sutton Bonington CampusLoughboroughLeicestershire LE12 5RD, UK

(ale KA1, KA5 – both 3.6% abv) of the samples. In accounts without a keg ale, a second standard lager sample (≤4.2%) was purchased.

Sampling

Of the 57 accounts, 44 were visited twice, 11 were sampled more than twice and two were sampled once. Sampling was between 13.00 and 18.30 on various days of the working week (Monday to Friday) and was covert. Repeat sampling was to reduce the influence of unknown factors that impact on draught beer quality, such as line cleaning, throughput, length of time on sale, etc. Samples were decanted directly from the half pint glass into sterile Duran (250 mL) bottles. Some pick up of oxygen was inevitable but is unlikely to impact on forcing as draught keg beer has been found to contain oxygen at the point of dispense (unpublished observations). Samples were stored in a cool box with cold blocks to minimise warming during transit.

Forcing test

Draught beer quality was determined using a forcing test *(8)*. Samples were processed on the same day as sampling or, where required, the next day after overnight storage in a refrigerator. Samples (2 × 25 mL) in sterile polystyrene universal bottles were incubated at 30°C for 96 h. Quality was measured by the increase in absorbance at 660 nm. Beers were classified as excellent or band A (increase in absorbance between 0 and 0.3), acceptable/band B (>0.3–0.6), poor (C, >0.6–0.9) and unacceptable (D, >0.9).

Quality index

For groups of related samples, a 'quality index' was calculated from the sum of the individual scores for each quality band (where A = 4, B = 3, C = 2, D = 1) divided by (number of samples × 4) × 100.

$$\text{Quality index } (\%) = \frac{\Sigma \text{ quality score}}{\text{number of samples} \times 4} \times 100$$

If all samples are measured as excellent (quality band A), the quality index is 100%, whereas if all samples are in quality band B (acceptable), the index is 75%.

Challenge test

The vulnerability to spoilage of the lager and ale brands (SL3, SL6, KA1 and KA5) sampled in this work was compared in challenge tests. Draught beer samples of each brand from four different accounts were forced (as above). An aliquot of hazy beer equivalent to $A_{660} = 1$ was diluted with sterile water to a final volume of 5 mL. From this, 0.1 mL ($A_{660} = 0.02$) of brand specific spoilage microorganisms were inoculated into all four brands (25 mL, from pasteurised beer from cans or bottles) in triplicate, forced at 30°C for 96 h and the increase in A_{660} measured.

Data collection

The work reported here was observational and did not interfere in its generation *(9)*. Accordingly, sampling was random with no influence on handling or storage, staff training or hygienic status of the dispense systems.

Results and discussion

Quality of draught ale and lager – all accounts

Analysis of the quality of 237 samples of draught beer from 57 accounts (Fig. 1) showed clear differences between lager and ale. Of 149 samples of draught lager, 44.3% were in the 'excellent' quality band compared with 15.9% of the 88 ale samples. Despite this, approximately three quarters of the lager (77.9%) and the ale

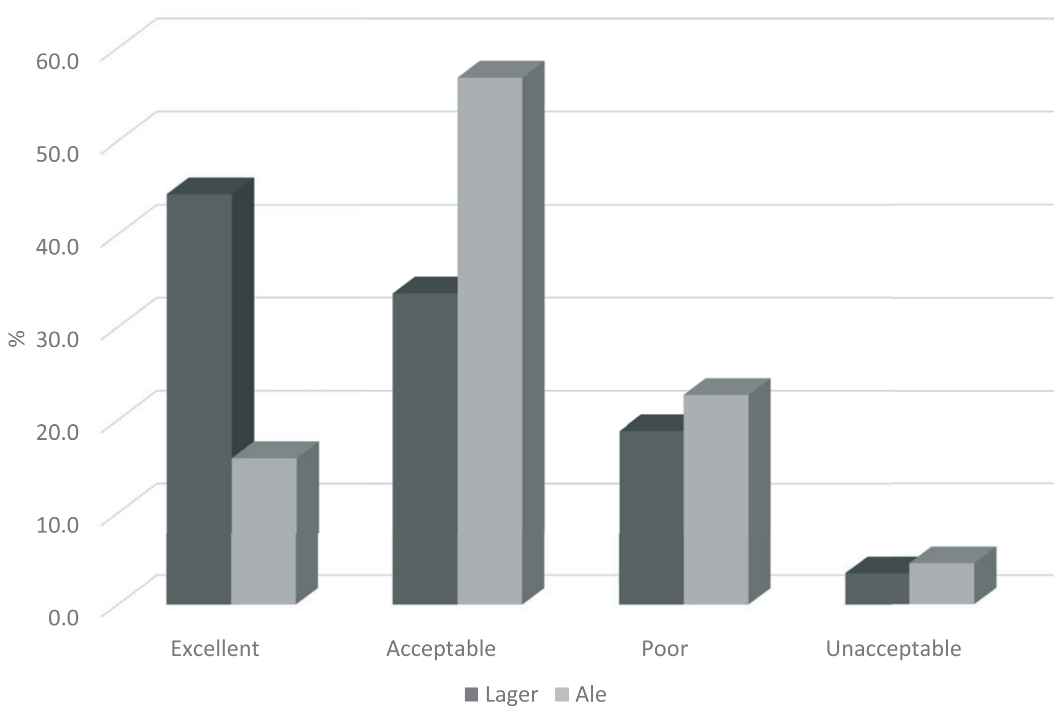

Figure 1. The quality of draught lager and ale in the on-trade.

samples (72.7%) were either 'excellent' or 'acceptable'. Overall the quality index of the lager samples was 79.7% compared with 71% for the ale samples.

Quality of draught ale and lager – common accounts

In 42 on-trade licensed premises, both standard lager and keg ale were sampled. The quality of 90 lager samples was compared with that of 87 keg ale samples. Overall, the draught lager samples had a quality index of 80% compared with 71.3% for draught ale. In terms of the 'excellent' quality band there was a marked difference with 39 (42.4%) samples of lager rated as excellent compared with 12 (13.3%) of the ale samples.

Student's *t*-test (two-tailed) confirmed that there was a significant difference between the two data sets, with a *p*-value of 0.002 showing that lager was of significantly better quality than keg ale in these accounts.

Quality of two draught lager brands (abv 4%)

Of the 149 samples of draught standard lager, 142 were from two of the leading UK on-trade brands, SL3 and SL6. Analysis (Table 1) using the forcing test showed lager SL3 (109 samples) to be of better quality with 52.3% 'excellent' (A band) compared with 23.5% of lager SL6 (33 samples). At the other end of the quality spectrum, none of the SL3 lager samples were 'unacceptable' (D band) compared with 5.9% of SL6 samples. Overall these differences are reflected by a quality index of 84% for lager SL3 compared with 72% for lager SL6.

High street or main shopping street accounts with 20 and often more taps are able to offer the same brands across the bar alongside similar competing brands. To minimise the account-to account 'noise' in comparing lagers SL3 and SL6, 18 samples of each brand were obtained from 12 accounts. Two-way ANOVA, with account as the random factor and brand as the fixed factor, showed the brands to be statistically significantly different ($p < 0.0001$).

Quality of two draught ale brands (abv 3.6%)

Keg ale is in long-term decline, accounting for 9.8% (mixed gas of carbon dioxide and nitrogen) and 2.9% (CO_2) of draught beer sales in the UK in 2016 *(1)*. However, the keg ale category is still offered in many accounts, although usually just the one brand. Two of the leading UK on-trade (mixed gas) ale brands – KA1 and KA5 – were sampled and analysed (82 samples) using the forcing test (Table 1). As might be anticipated from the results for the ale category (above), the predominant quality band for both brands was 'acceptable' with 58.7% (KA1) and 42.1% (KA5). However, 27% (KA1) and 36.8% (KA5) of the samples are in the 'poor' (band C) category. This was reflected by the quality index of ca. 70% for both brands (Table 1).

Quality in accounts

The quality index for the beers sampled in the 57 accounts varied widely (Fig. 2). The average number of samples from an account was 4.2 ranging from two to a maximum of eight. The quality index for broadly half of the accounts was in the acceptable to excellent bands (75–100%). Conversely 50% were dispensing beer in the poor category (50–74%).

Spoilage

Generically, beer is inhospitable to microorganisms, with numerous compositional hurdles including low pH, ethanol, colour, hop bitter acids, reduced nutrients (e.g. free amino nitrogen), low oxygen, low temperature, undissociated sulphur dioxide *(10,11)* and phenolic compounds *(12)*.

Accordingly, for spoilage, there is selective pressure for environmental organisms that can survive and, critically, grow in draught beer. These include bacteria (*Lactobacillus*, *Pediococcus*, *Acetobacter*) and yeasts (*Saccharomyces*, *Brettanomyces*, *Pichia* and *Candida*) *(7)*. Spoilage of draught beer is ill-defined and reflects the mix of contaminating microorganisms. Outcomes of spoilage include acidification, super attenuation, sourness, haze and a blend of aromas (and flavours) from esters, higher alcohols, phenols, organic acids, diacetyl, short chain fatty acids and sulphur compounds *(7)*.

Most studies of beer spoilage have focussed on hop-resistant *Lactobacillus* and *Pediococcus*. This reflects the report that these genera account for 60–90% of microbiological spoilage events in Germany between 1980 and 2002 *(13)* and 2010–2013 *(14)*. Despite the generic hurdles, the growth of hop-resistant lactic acid bacteria (notably *L. brevis*) is supported by maltose, maltotriose and maltotetraose *(14)* together with organic acids including citrate, pyruvate, malate and succinate *(11,14,15)*. Further, Rainbow *(16)* noted that beer spoilage lactobacilli need 'exogenous supplies of most α-amino acids, several growth factors of the vitamin B complex and one or more purine and pyrimidine bases'.

For draught beer, the concentration of spoilage organisms in the dispense system is managed by the application of hygienic practices. Key to this is effective and regular line cleaning *(7)*, which removes biofilm from surfaces (lines, connectors, FOB detectors). The frequency of line cleaning is often compromised such that one in three pints is reported to be dispensed through an unclean beer line *(3,4)*. This inevitably damages beer quality and increases wastage. Further, managing the entry of yeast and bacteria at

Table 1. Quality of draught beer

Quality band	Lager SL3			Lager SL6			Ale KA1			Ale KA5		
	No.	%	QI (%)	No.	%	QI (%)	No.	%	QI (%)	No.	%	QI (%)
A	57	52.3	84.0	8	23.5	72.0	6	9.5	68.3	4	21.1	71.1
B	34	31.2		15	44.1		37	58.7		8	42.1	
C	18	16.5		8	23.5		17	27		7	36.8	
D	0	0		2	5.9		3	4.8		0	0	
Total	109			33			63			19		

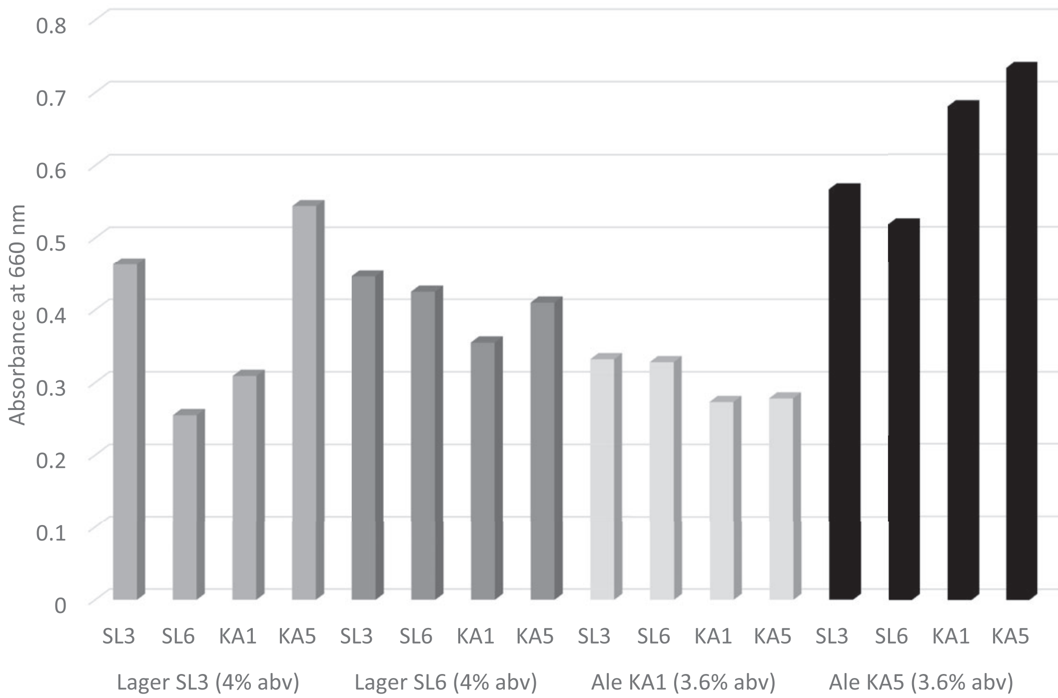

Figure 2. The susceptibility to spoilage of lager and ale brands.

the 'ends' of the dispense system is recommended by sanitising the keg coupler/spear and tap/nozzle *(7,8,17)*, but take-up by the on-trade is, at best, poor. Product throughput also contributes to quality and ideally a keg should be consumed within a week, which was only achieved in 39% of all keg taps in the UK, as reported in the 2017 Beer Quality Report *(4)*. In practice, time on sale varies widely within and between accounts, reflecting brand popularity, container size, trading hours, footfall and consumer demographics. Of course, commercially, the bottom line is the need to empty the container irrespective of how long it is on sale.

In this work, using the forcing test, there were differences in draught beer quality/spoilage between brands and categories (ale and lager; Table 1, Figure 1). Whilst, this may reflect 'account' factors (above), beer composition could also contribute as, in challenge tests, beers have been reported to vary in susceptibility to microbial spoilage *(10–12,18)*. Accordingly, the spoilage of the major brands in this work was compared by inoculating (spoiled forced) samples of draught beer into the parent brand and the other three brands with microorganisms from SL3 into SL3, SL6, KA1 and KA5, SL6 into SL6, SL3, KA1, KA5 and so on.

Using this standardised challenge test, the 'spoilability' of the four brands could be compared. Figure 3 shows that the four brands respond differently to draught beer spoilage organisms. Calculation of the quality index of the individual lager brands suggests that SL3 (81.3%) was slightly less susceptible to spoilage than SL6 (75%). However, keg ale KA5 (87.5%) was markedly more robust to spoilage than KA1 (62.5%). Comparison of the quality index of samples in trade (Table 1) with the quality index from challenge testing (above) shows, with the exception of KA5, a similar outcome with lagers SL3 (84 v 81.3%) and SL6 (72 v 75%) and keg ales KA5 (71.1 v 87.5%) and KA1 (68.3 v 62.5%). For ale KA5, the quality index for the trade samples was derived from a comparatively small number of samples compared with the other brands.

Accreditation and quality

Assessment of draught beer quality in the UK on-trade has mostly focused on cask beer and – with the exception of temperature – is qualitative. Cask Marque *(5)*, a non-profit making organisation, was established in 1998 with the laudable aim to 'address the void in beer quality'. Its assessors visit subscribing outlets at least twice a year. Visits are unannounced and involve a yes/no measurement of temperature and clarity and a sip test to assess the flavour and aroma of cask beers.

For the work reported here, it was noted whether the on-trade accounts were Cask Marque accredited. Of the 57 accounts sampled, 29 were Cask Marque accredited and 28 were not. Analysis of beer quality (Table 2) showed no difference in individual quality bands or overall beer quality in accounts with Cask Marque (QI = 76.8%) and those without (QI = 76.1%). As the focus of Cask Marque is on cask beer it is perhaps not surprising that keg beer quality was – in this study – indistinguishable from the quality of keg beer in accounts which are not accredited. However, a 'halo effect' might be anticipated where the 'quality message' underpinning the dispense of cask beer contributes to the assurance of keg beer quality.

Price vs quality

The linkage between price and quality has long been part of the marketing mix. McConnell *(19)* labelled the same commercial bottled beer at three different price points: high, medium and low. Using a cohort of 'sixty beer drinkers', they demonstrated that the higher-priced brand was perceived to be of higher quality than the medium-priced brand. Building on this, Jacoby *et al.* *(20)* confirmed the linkage between price and perceived quality when it was the only signal available to consumers. However, branding had a greater impact on the perception of quality particularly 'for brands with strong positive images'. Reassuringly though,

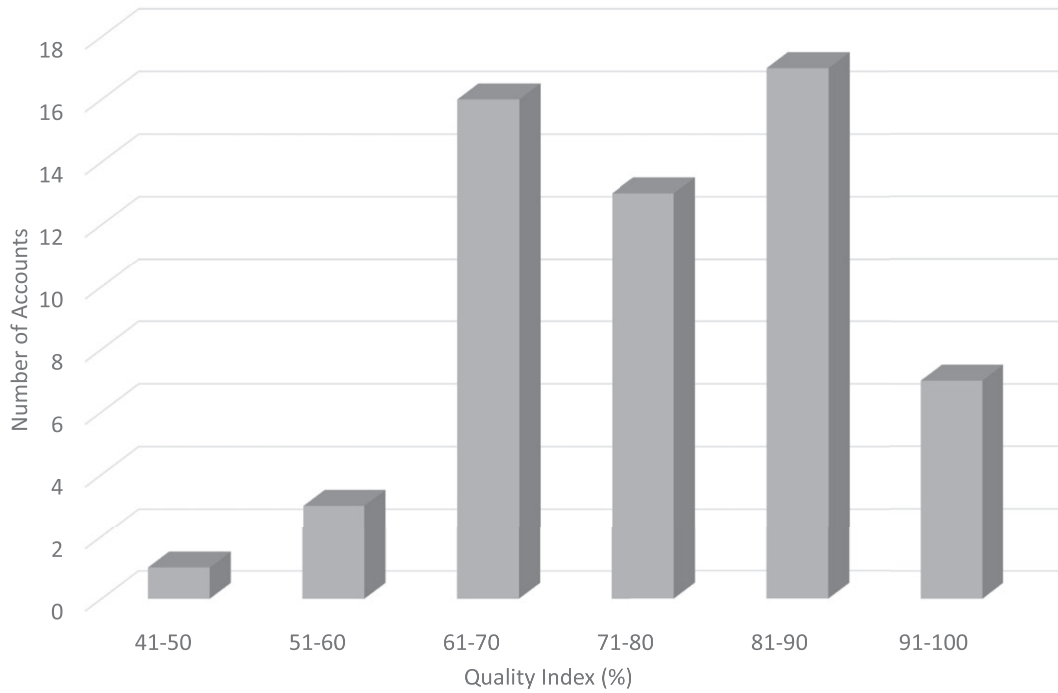

Figure 3. Quality index of on-trade accounts.

Table 2. Quality of draught beer from accounts with and without quality accreditation

Accreditation	No. of accounts	No. of samples	Quality band (%)				Quality index (%)
			A	B	C	D	
Cask Marque	29	126	34.1	42.9	19.0	4.0	76.8
None	28	111	33.3	41.4	21.6	3.6	76.1

consumers were able to discriminate quality differences in the beers using 'only taste and aroma cues'.

The quality of the individual beers against the combined price of the samples from each on-trade account is reported in Table 3. The beers that were sampled were predominantly national brands and, in the case of the lagers, supported by TV advertising. As the work reported here was covert, only the combined price of the two lager and ale samples was captured. In 2016, the average price in the UK for a pint of draught lager was £3.38 and for ale it was £2.99 *(1)*. This is equivalent to an average combined price of £3.19 which appropriately is in the most popular band (£3.01–3.50), accounting for 39% of the samples. Indeed, this price band had the best quality index of the four price bands, being marginally better than the two cheaper bands. However, the most expensive price band (£3.31–4.00) had a notably lower quality index.

Table 3. Price of draught beer vs quality

Price band (£)	Number of samples	Quality band (%)				Quality index (%)
		A	B	C	D	
2.01–2.50	54	35.2	42.6	18.5	3.7	77.3
2.51–3.00	63	30.2	50.8	15.9	3.2	77.0
3.01–3.50	92	38.0	41.3	17.4	3.3	78.5
3.51–4.00	28	25.0	25.0	42.9	7.1	67.0

Number of taps and location

In the UK, the number of dispense taps on the bar varies greatly. In this work, the accounts were defined by the number of taps from ≤10 to 11–20 and ≥21. Table 4 shows the distribution of the 57 accounts by village, town and city and number of taps. However, the draught beer quality index declined as the number of taps increased from ≤10 (88%) to 11–20 (76.7%) and ≥21 (75.9%). This decline in quality may reflect usage as it is likely that, as the number of taps increase, some – typically away at either end of the bar – are only used during heavy trading sessions from Thursday to Sunday. Indeed, it has been reported that 16–20% of keg beer taps deliver fewer than 20 pints per week *(4)*. Such 'overfonting' will result in the quality of beer in underused taps being compromised. However, the number of taps per account increased with the size of the community (Table 5) such that half of the accounts sampled in towns and cities had >21 taps compared with none of the village accounts. Price though was broadly comparable in the towns and cities but was higher in village accounts, possibly reflecting the reduced competition in these locations.

Glassware

Glassware has become an important part of the draught beer 'offer' in the UK. Although the unbranded 'conical' and 'nonic' glasses are commonplace, for some accounts single (or multibrand)

Table 4. Number of draught beer taps vs quality

Taps	Location	No of accounts	Samples	Price (£)	Quality band				Quality index (%)
					A	B	C	D	
≤10	Village	3	8	3.45	2	6	1	0	88.0
	Town	3	8	3.00	5	2	1	0	
	City	2	9	3.09	1	4	3	0	
11–20	Village	9	34	3.20	13	10	9	2	76.7
	Town	4	16	3.04	6	7	3	0	
	City	11	55	3.31	18	26	8	3	
≥21	Village	0	—	—	—	—	—	—	75.9
	Town	8	30	2.64	13	13	4	0	
	City	17	77	2.75	22	32	19	4	

Table 5. Account location vs price of draught beer

	No. of taps	No. of accounts	%	£
Village	≤10	12	25	3.25 ± 0.09
	11–20		75	
	≥21			
Town	≤10	15	20	2.82 ± 0.19
	11–20		26.7	
	≥21		53.3	
City	≤10	30	6.6	2.99 ± 0.27
	11–20		36.7	
	≥21		56.7	

glassware increasingly predominate. Branded glasses can be of different shapes *(21)* as this can contribute to the sensory experience *(22)*. Other marketing tools may include the thickness of the glass and tactile design when the glass is held *(23)*. Functionally, laser etched 'nucleation sites' on the base of (typically) lager glassware promote bubble release to replenish the foam. In practice, these interventions can be compromised by dirty glassware – estimated at one in five glasses *(3)* – or dispense into the wrong branded glass.

Although not impacting on beer quality, the glassware that samples were dispensed into was recorded. It is apparent that the uptake and usage of branded glassware varies widely between independent, small and large pub groups. Although a small sample size, there were clear differences between the availability of branded half pint glassware for standard lagers and keg ales. Lager SL3 was served in the correct branded glassware on 71.4% of occasions whereas the frequency was only 5% for lager SL6. Indeed, lager SL6 was served in SL3 glassware in 20% of the accounts where the brand was sampled.

None of the keg ales was served in correctly branded glassware; indeed 13% of samples were served in the wrong branded glass with the majority (87%) in unbranded glasses. The lack of (half pint) glassware is not unexpected as the focus is on branded pint glasses, but also may reflect the declining market share of the keg ale category.

Insights – relevance and considerations

This survey of draught beer suggests that quality varies widely from excellent through to unacceptable and that the quality of keg lager is superior to that of keg ale. It is suggested that there is nothing unusual about dispense practices, configuration or complexity in the Midlands and that these results are relevant to draught beer quality in England, Scotland and Wales. In Northern Ireland, however, cellar temperatures are typically colder than 12°C and accordingly draught beer quality may well be better.

Numerous factors will have contributed either positively or negatively to sample quality. Samples from recently cleaned lines, in accounts with good hygiene practices and turnover would be expected to be of better quality than samples from accounts with infrequent line cleaning, a lack of hygienic practices and slow turnover. Accordingly, to mitigate for an 'off day' the majority of accounts were sampled at least twice.

In the work reported here, sampling was during the day between Monday and Friday, with throughputs likely to be lower than in the evening or on weekends. However, the beers (SL3, SL6, KA1 and KA5) that accounted for the majority of samples (>90%) are all national brands and would be anticipated to have a satisfactory turnover throughout the day. In turn, this was supported by the accounts being centrally located with good passing footfall.

Conclusions

Draught beer quality is an important factor for consumers, particularly as the price differential of the brand increases between the on- and off-trade. Measurement of quality post dispense, using a validated forcing test *(8)*, confirms the widely held view that draught beer quality is variable. This survey of 57 accounts in the UK Midlands is suggested to be relevant to similar dispense configurations in the UK and elsewhere.

The quality of draught standard lager (abv ≤4.2%) ex-trade was found to be superior to that of keg ale (abv ≤4.2%). This is likely to reflect a number of factors including rate of sale and dispense temperature. Overlaid on this, susceptibility to spoilage is influenced by beer composition.

The on-trade account is the major variable that determines good, indifferent or poor beer quality. Implementation of hygienic practices together with well-trained bar staff contribute to the delivery of excellent quality draught beer. Conversely, poor practice and untrained staff will result in compromised beer quality. It is noteworthy that draught beer quality was found to be inversely related to the number of taps on the bar and that the highest price point was associated with the poorest quality. Further, accreditation of an account to an industry quality scheme for cask beer had no impact on the quality of keg beer.

This work has shown that draught beer quality at the point of dispense is highly variable. Of 237 samples, 34.8% of samples were 'excellent', 42.2% 'acceptable' but 20.3% were 'poor' and 2.7% were 'unacceptable'. As keg beer ex-brewery and pre-dispense should be of 'excellent' quality, it can be argued that 65% of the keg beers sampled in this work had suffered some microbiological damage as a consequence of dispense. This is disappointing and hopefully will trigger wider studies into draught beer quality. A longer-term aim of this work is that brand owners, retailers and other stakeholders will 'own' the improvement, communication and assurance of draught beer quality.

Future reports will address the impact of hygienic best practice on draught beer quality, the importance of throughput, beer composition and variability of spoilage, and the impact of brands and accounts on product microflora.

Acknowledgements

We are grateful to the Worshipful Company of Brewers through the Brewers' Research and Education Fund together with Custom Laboratory Products Ltd for funding this research and supporting JRM. We also thank Eoin Moynihan, Laura Dulat and Hugo Alviso for help with sampling the on-trade accounts and Stephanie Brindley for proof reading the manuscript. DEQ thanks his labradoodle Molly (April 2009 - February 2018) for long daily walks and the time to reflect on projects like this.

References

1. British Beer and Pub Association (2017) in *Statistical Handbook*, (Oakley, P. Ed.), Brewing Publications, London.
2. Quain, D. (2007) Draught beer quality – challenges and opportunities, *Proc. Eur. Brew. Conv. Congr. Venice*, Fachverlag Hans Carl, Nürnberg, pp. 791–801.
3. Beer Quality Report 2016. http://cask-marque.co.uk/beer-drinkers/beer-quality-report-2016 (last accessed 7 July 2018).
4. Beer Quality Report 2017. http://vianetplc.com/beer-quality-report-2017/ (last accessed 7 July 2018).
5. Cask Marque via. http://cask-marque.co.uk/ (last accessed 7 July 2018).
6. Storgårds, E. (1996) Microbiological quality of draught beer – is there a reason for concern? *Eur. Brew. Con. Monograph XXV*, Fachverlag Hans Carl, Nürnberg, pp. 92–103.
7. Quain, D. E. (2015) Assuring the microbiological quality of draught beer, in *Brewing Microbiology – Managing Microbes, Ensuring Quality and Valorising Waste*, (Hill, A. Ed.), pp. 333–352, Woodhead, Cambridge.
8. Mallett, J. R., Stuart, M. S., and Quain, D. E. (2018) Draught beer hygiene: a forcing test to assess quality, *J. Inst. Brew*. *124*, 31–37. https://doi.org/10.1002/jib.470.
9. Ott, L., and Longnecker, M. (2010) *An Introduction to Statistical Methods and Data Analysis*, 6th ed., Brooks/Cole, Pacific Grove, CA.
10. Fernandez, J. L., and Simpson, W. J. (1995) Measurement and prediction of the susceptibility of lager to spoilage by lactic acid bacteria, *J. Appl. Bacteriol*. *78*, 419–425. https://doi.org/10.1111/j.1365-2672.1995.tb03428.x.
11. Geissler, A. J., Behr, J., von Kamp, K., and Vogel, R. F. (2016) Metabolic strategies of beer spoilage lactic acid bacteria in beer, *Int. J. Food Microbiol. 216*, 60–68. https://doi.org/10.1016/j.ijfoodmicro.2015.08.016.
12. Hammond, J., Brennan, M., and Price, A. (1999) The control of microbial spoilage of beer, *J. Inst. Brew. 105*, 113–120. https://doi.org/10.1002/j.2050-0416.1999.tb00014.x.
13. Suzuki, K. (2011) Microbiological instability of beer caused by spoilage bacteria, *J. Inst. Brew. 117*, 131–155. https://doi.org/10.1002/j.2050-0416.2011.tb00454.x.
14. Suzuki, K. (2015) Gram-positive spoilage bacteria in brewing, in *Brewing Microbiology – Managing Microbes, Ensuring Quality and Valorising Waste*, (Hill, A. Ed.), pp. 141–173, Woodhead Publishing, Cambridge.
15. Suzuki, K., Iijima, K., Ozaki, K., and Yamashita, H. (2005) Study on ATP production of lactic acid bacteria in beer and development of a rapid pre-screening method for beer-spoilage bacteria, *J. Inst. Brew. 111*, 328–335. https://doi.org/10.1002/j.2050-0416.2005.tb00691.x.
16. Rainbow, C. (1977) The Horace Brown Memorial Lecture. A century of brewing microbiology, *J. Inst*. *Brew*. *83*, 9–14. https://doi.org/10.1002/j.2050-0416.1975.tb03782.x.
17. Quain, D. E. (2016) Draught beer hygiene: cleaning of dispense tap nozzles, *J. Inst. Brew. 122*, 388–396. https://doi.org/10.1002/jib.335.
18. Dolezil, L., and Kirsop, B. H. (1980) Variations amongst beers and lactic acid bacteria to beer spoilage, *J. Inst. Brew. 86*, 122–124. https://doi.org/10.1002/j.2050-0416.1980.tb03969.x.
19. McConnell, J. T. (1968) An experimental examination of the price–quality relationship, *J. Bus. 4*, 439–444.
20. Jacoby, J., Olson, J. C., and Haddock, R. A. (1971) Price, brand name, and product composition characteristics as determinants of perceived quality, *J. Appl. Psychol. 55*, 570–579. https://doi.org/10.1037/h0032045.
21. Evans, D. E., and Bamforth, C. W. (2009) Beer foam: Achieving a suitable head, in *Beer: A Quality Perspective*, (Bamforth, C. W. Ed.), pp. 255–277, Elsevier, London.
22. Mirabitoa, A., Oliphanta, M., Van Doorna, G., Watson, S., and Spence, C. (2017) Glass shape influences the flavour of beer, *Food Qual. Pref. 62*, 257–261. https://doi.org/10.1016/j.foodqual.2017.05.009.
23. Stead, M., Angus, K., Macdonald, L., and Bauld, L. (2014) Looking into the glass: Glassware as an alcohol marketing tool, and the implications for policy, *Alcohol Alcohol. 49*, 317–320. https://doi.org/10.1093/alcalc/agt178.

