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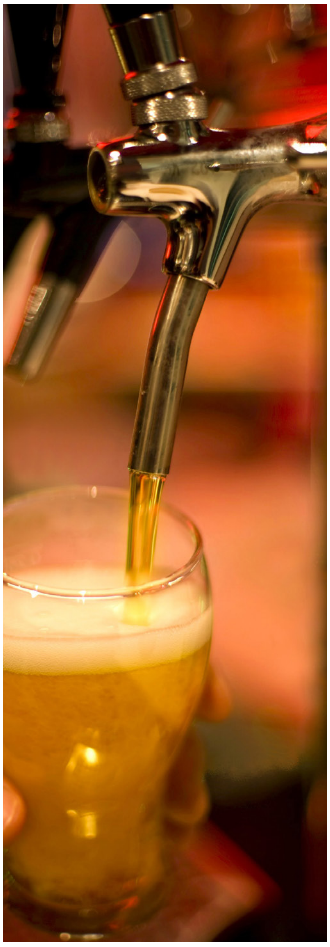
Instrument Assessment Report

Campden BRI
food and drink innovation

Brewfitt Ltd - CoolTube

Assessment of energy and beverage savings with a novel cooling system for dispensed product



Executive summary

Brewfitt's FOD (future of dispense) draught dispense system consisting of a hydrocarbon cooler and CoolTube units (compact under-bar coolers for product cooling without remote cooler coils) was compared, in terms of energy efficiency and carbon emissions, to a traditional system consisting of a standard remote cooler and long 8m cooling coils, POD and Flash coolers. Three different dispense situations were simulated: no dispense, a low demand scenario with 20 pints drawn per tap per hour and a high demand situation with 60 pints dispensed per tap per hour.

The FOD system was found to have a ~40% energy efficiency advantage compared to the traditional dispense system for the high demand scenario and a ~15% advantage for the low demand test. The carbon emissions were reduced by up to 22% depending on the dispense situation. Additionally, due to the small volume of product contained within the CoolTube unit, less beverage losses occur each time dispense lines are purged for cleaning. In turn this results in a reduction in carbon emissions from production of less wasted beer.

Background

Brewfitt have developed a novel type of remote cooler (hydro carbon cooler) and a new under-bar heat exchanger (CoolTube) using a promising innovative technology. The combination of remote cooler and under-bar heat exchanger is called 'Future of Dispense' (FOD). CoolTube has a very significantly reduced size and weight compared to a standard under-bar cooler allowing for space savings. Beverages can be dispensed at a range of temperatures (sub-zero to ambient) by adjusting the coolant flow rate. The use of the FOD system should lead to substantial energy savings. Also, the loss of beverage during line cleaning would be reduced due to the elimination of cooling coils. Brewfitt have approached Campden BRI to confirm energy savings.

Scope of Work

The project evaluated the performance of the FOD in terms of energy savings compared to the common pub dispense system.

Experimental

To establish whether the new FOD cooling system is more energy efficient than the traditional dispense system, 5 kegged products (2 lager beers, 1 stout, 1 ale and 1 cider) were dispensed through the two systems.

A) Standard dispense set-up

The kegs were attemperated for 72hrs and held at cellar temperature (12°C). The beverages were passed through a remote cooler (water ice bank) with standard coils being used for the lagers and stout and long 8m-coils being employed for the ale and cider. The drinks then passed through a 25m python with 19mm lagging and containing recirculation lines for cooling water. Approximately 2 metres of the python was in the cellar with the remainder being at room temperature. The lager lines were connected to standard pod under-bar coolers and the stout line to a standard flash cooler. The remote cooler and the flash cooler were fitted with energy monitors.

B) FOD dispense set-up

The kegs were attemperated for 72hrs and held at cellar temperature (12°C). The beverages were passed through 25m lines within a python with 19mm lagging. Approximately 2 metres of the python was in the cellar with the remainder being at room temperature. All 5 dispense lines were connected to 5 separate CoolTube units positioned under the bar and then routed to the taps. The hydro carbon cooler was positioned in the cellar with the coolant being circulated to the 5 CoolTube devices via recirculation lines in the python. The coolant flow through the units was set to aim for the required beverage dispense temperature. The remote cooler was fitted with an energy monitor.

Dispensing of product

Three different dispensing situations were simulated:

1. No dispense situation

The remote coolers were run for several days to reach a steady state. Energy consumption was then measured over 24 hours while no product was dispensed. This represents the energy used to cover the equipment cooling losses.

2. Low demand situation

Pints were drawn every 3 minutes over 1 hour from each of the 5 taps; a total of 20 pints were dispensed per tap, making 100 pints overall.

3. High demand situation

Pints were drawn every minute over 1 hour from each of the 5 taps; a total of 60 pints were dispensed per tap, making 300 pints overall.

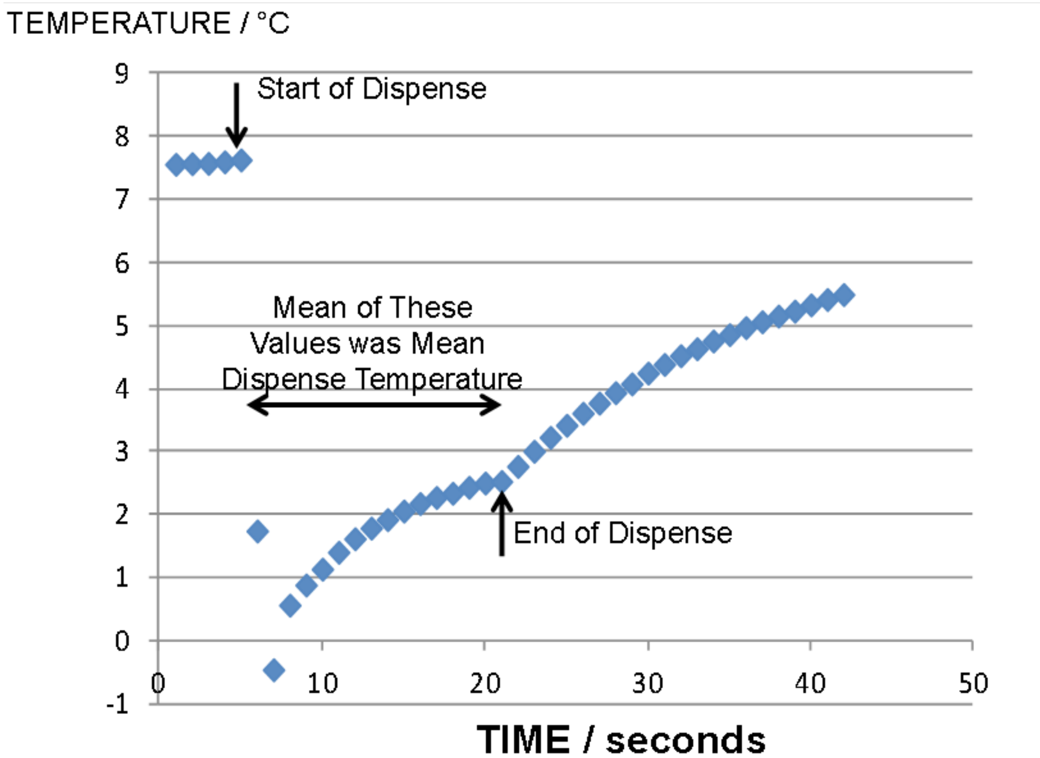
Measurements

1. Energy consumption was monitored for all three dispensing situations. For the 'no dispense' situation the energy was measured over 24 hours. For the low and high demand situations the energy consumed over the hour of dispense was determined, as well as over the 2 hours following the 1hr dispense.
2. The cellar temperature was measured to establish product temperature in keg.
3. The temperature of dispensed product as it exited the taps was measured every second by thermocouples fitted inside the taps and logged using a data logger.
4. The volume of liquid in the 8m coils, the pod cooler + standard coil, the Flash cooler + standard coil and the CoolTube were determined.

Calculations

1. Energy

The beer cooling effect was determined as the difference between the cellar temperature of 12.0°C and the mean value of the product temperature as it left the dispense tap. The latter value was measured as the mean value recorded by the thermocouple in the nozzle over the dispense time for each pint. This method of measurement prevented variables such as ambient temperature and glass temperature from affecting the results. Measurement of mean temperature of dispense was performed as shown in the example below:



The cooling energy per pint dispensed may be calculated as:

$$Q = m \times Cp \times (12.0 - Tm)$$

Q = cooling energy (J)
m = mass of product (taken as 1.007 kg/litre x 0.568 litres)
Tm = mean dispense temperature as calculated above (°C).

Thus, the total cooling energy was the total of all the cooling energy values for all pints over the hour. It was necessary to calculate values of Q for every dispensed pint because in most cases the dispense temperatures varied over the 1-hour dispense.

A bespoke "Coefficient of Performance" (COP) was calculated that was defined as the ratio of the cooling effect on dispensed product (determined by calculation of Q from temperature of dispensed product, see calculation above) to the electrical energy input to the refrigeration process (see blow). Thus the higher the COP the more efficient the cooling effect.

There was a need to take into account two complicating factors to calculate the COP as a function of actual cooling effect on the dispensed beer:

- Cooling losses from the equipment. This was determined from the twenty-four hour 'no dispense' energy monitor; losses per hour were calculated.
- The cooling systems take some time to return to their "stand by" state after dispense operation for one hour. So, by monitoring its energy consumption for two hours following the dispense period this energy requirement could be taken into account.

The electrical energy product cooling input was therefore calculated as:

Cooling energy (energy consumption during 1 hr dispense)
\+ Energy to 'recover' system (energy consumption during 2hrs following dispense)
\- Equipment cooling losses (3 hrs of 'no dispense' energy consumption)

2. Carbon

The differences in carbon emissions between the 2 dispense systems, as a result of differences in energy efficiency and in beer losses upon line cleaning, were determined.

Carbon emissions are expressed in CO_2 equivalents and were calculated based on the total electricity use by both system set ups measured over 24 hours of no dispense, as well as the low and high demand dispense scenarios. For the low and high demand situations electricity use during the 2 hour recovery time following the 1hr dispense was included but the slight differences in product temperature at dispense were neglected. CO_2e emissions include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions calculated based on the grid rolling average electricity factor for the UK published by DEFRA[1].

The volumes of liquid held in the CoolTube and the 8m remote cooler coil were measured. The difference in beer losses during a line clean were converted into equivalent differences in carbon emissions from the beer production process. The carbon emissions of beer production were calculated based on the Life Cycle Analysis (LCA) study of draught beer by Nørrebro Bryghus[2] which estimated that their Global Ale has a carbon footprint of 82.373 kg CO_2 per hl of draught beer.

[1]DEFRA 2012 greenhouse gas conversion factors for company reporting, http://www.defra.gov.uk/publications/2012/05/30/pb13773-2012-ghg-conversion/
[2]Novozymes, Comparative Life Cycle Assessment of Malt-based beer and 100% barley beer, 2009; http://www.novozymes.com/en/sustainability/best-sustainable-practices/how-to-use-lca/published-LCA-studies/Documents/BarleyBeer.pdf
and Nørrebro Bryghus (2009); http://noerrebrobryghus.dk/uploads/media/CO2Regnskab_01.pdf

Results

Table 1 below shows the measured electrical energy consumption for the various test situations.

	Energy consumption (kWh)			
		Traditional system		
	FOD	Flash cooler	Remote cooler	Total
No dispense; 24hr monitor	9.21	1.61	8.71	10.32
Low demand (20 pints/hour)				
1hr monitor (during dispense)	0.61	0.10	0.66	0.76
2hr monitor (post dispense)	1.25	0.13	1.19	1.32
High demand (60 pints/hour)				
1hr monitor (during dispense)	0.63	0.15	0.70	0.85
2hr monitor (post dispense)	1.28	0.17	1.42	1.59

Table 1 Energy consumption measured for the different dispense set-ups and different dispense situations

As can be seen in the 'no dispense' situation the 24hr energy consumption of the FOD cooler is lower than for the traditional remote cooler + flash cooler. It has to be born in mind that the FOD coolant is held at sub-zero temperature rather than at 0°C in the traditional ice-bank cooler. This would mean that cooling losses would be higher due to larger temperature gradient with room temperature. Thus, this hydrocarbon cooler appears to work very efficiently.

The differences in energy consumption are also apparent for the 2 dispense scenarios with the high demand situation showing the larger difference in energy performance.

However, to take into account disparities in the dispense temperatures between the 2 set-ups, the energy to cool the drinks was calculated from the temperature measured at dispense (Q values) and compared to the electrical energy input taking into account cooling energy losses in the 2 systems. Table 2 shows the calculated values.

The FOD system was about 15% more energy efficient than the traditional system during the 3 hour period analysed for the low demand dispense scenario and 40% more energy efficient for the high demand situation. It may be that a longer energy monitoring following dispense would have given slightly different results if the systems had taken longer to recover their 'steady state'. This would particularly be true for the high demand situation for which more energy was used and a longer recovery period would be expected (re-forming of icebank). Nevertheless, these values give a good indication of the FOD's better performance.

		Beer cooling energy input calculated from dispense temperature (Q) (kWh)	Beer cooling electrical energy input allowing for cooling losses (kWh)	COP, Coefficient of performance	Energy advantage of using FOD (%)
Low demand (20 pints/hour)	FOD	0.62	0.72	0.86	15
	Traditional system	0.59	0.79	0.75	
High demand (60 pints/hour)	FOD	1.60	0.77	2.08	39
	Traditional system	1.72	1.15	1.5	

Table 2 Calculated beer cooling energy, electrical energy consumed for beer cooling and comparison of energy efficiencies of both dispense systems.

The product temperatures achieved in the FOD dispense were comparable to those using the traditional system. The CoolTube units resulted in a slightly cooler lager than was achieved with the under-bar pod coolers (maximum of 0.8°C difference). Performance of CoolTube and Flash cooler were equal for the 'low demand' situation but the temperature of the extra cold stout was slightly higher (by 1.3°C; beer at 2.6°C) in the FOD than the flash cooler system for the 'high demand' scenario. In the traditional system the keg ale and cider were cooled through 8m remote cooler coils. The FOD system for these two products achieved beverage temperatures only marginal higher than the traditional system (maximum of 0.7°C difference). All temperatures of dispensed products for the individual scenarios are shown in Appendix 1.

Table 3 shows the energy consumption and the equivalent CO_2 emissions for the FOD and the traditional system in all 3 scenarios (no dispense, low and high demand).

	Energy use (kWh)		CO_2e emissions (kg)		
	FOD	Traditional	FOD	Traditional	% difference
No dispense; 24hr monitor	9.21	10.32	4.79	5.37	11
Low demand (20 pints/hour)	1.86	2.08	0.97	1.08	10
High demand (60 pints/hour)	1.91	2.44	0.99	1.27	22

Table 3 Energy consumption and corresponding CO_2e emissions of both dispense systems for the three dispense situations

The FOD system showed a carbon saving of 11% during the 24 hour 'no dispense' period, 10% carbon saving during the low demand dispense scenario and a significant 22% saving during the high demand dispense scenario.

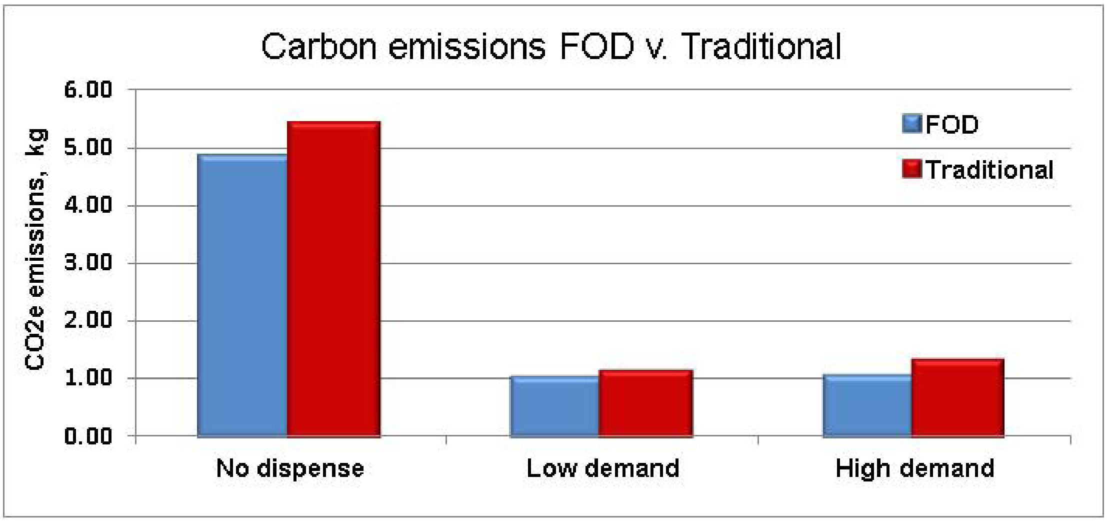


Figure 1 CO_2e emissions for FOD and traditional dispense systems and the 3 different dispense scenarios (24hr no dispense, low demand: 20 pints in 1hr + 2hrs recovery, high demand: 60 pints in 1hr + 2hrs recovery)

The volumes of liquid held in a CoolTube unit and a 8m remote cooler coil are shown in Table 4 together with the equivalent beer carbon emissions. These results are also depicted in Figure 2.

	Volume of liquid (ml)	Equivalent beer carbon emissions (kg CO_2)	Difference beer carbon emissions (kg CO_2)
Cool Tube	35	0.029	
8m coil	310	0.255	0.226
Pod cooler + std coil	327	0.269	0.240
Flash cooler + std coil	380	0.313	0.284

Table 4 Volume of liquid in CoolTube, 8m cooling coil, pod cooler + standard coil, Flash cooler + standard coil and the equivalent carbon emissions when relating to beer

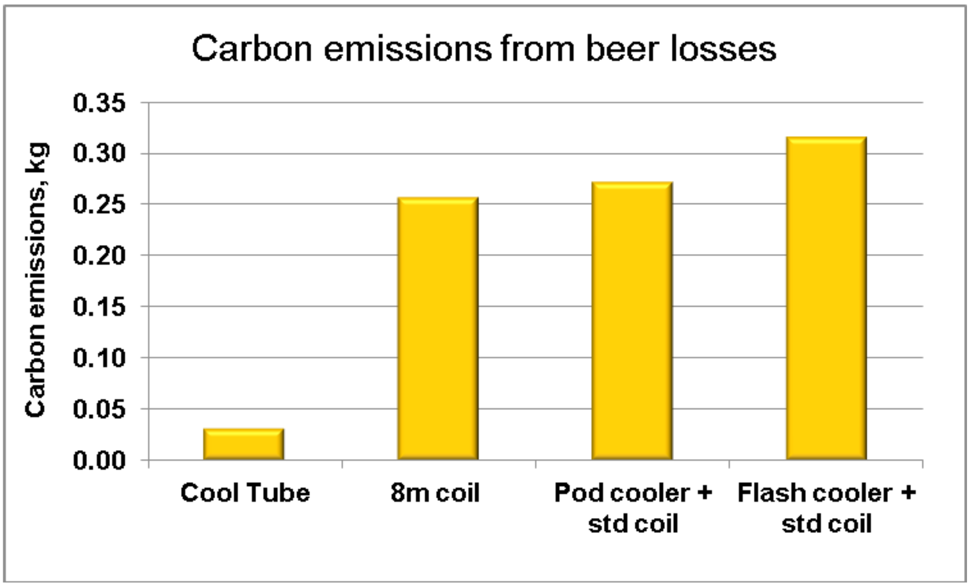


Figure 2 Difference in carbon emissions between beer held in CoolTube, 8m cooling coil, pod cooler + standard cooling coil or Flash cooler + standard cooling coil

If a CoolTube unit is used instead of an 8m remote cooling coil in a dispense system 275 ml less beer is in the system. During line cleaning, due to reduced beer losses, this would result in a reduction in CO_2 emissions of 226 grams based on the beer life cycle carbon emissions which include CO_2 emissions from raw materials, packaging, transportation and the brewing process.

Assuming a pub operates 10 beer lines and performs the recommended weekly line cleaning, the reduction in beer losses would accumulate to 143,000 ml a year which is equivalent to a carbon saving of 117.8 kg CO_2 per year based on the methodology used for this report.

Similarly, the use of CoolTube instead of under-bar pod or flash coolers in addition to standard remote cooler coils results in the reduction of beer losses during line cleaning. A 10-line pub with weekly cleaned lines would save 151,840 ml and 179,400 ml beer a year for lines fitted with pod and flash coolers + standard coils respectively. This would result in carbon savings of 125.1 and 147.8 kg CO_2 per year respectively.

Summary and conclusions

In this project Brewfitt's FOD (future of dispense) system consisting of a hydrocarbon cooler and CoolTube units, compact under-bar cooling devices, was evaluated in terms of energy efficiency and carbon footprinting compared to a traditional draught dispense system. The traditional set-up included a remote cooler with either an 8m coil, a Pod + standard coil or a Flash cooler + standard coil. Five products - lager, ale, stout and cider – were dispensed simultaneously simulating either a low demand situation (20 pints/hr) or a high demand situation (60 pints/hr) during which the energy consumption was monitored as well as during the 2 hours following dispense. Additionally, energy usage with no product dispense was measured. To be able to calculate the actual beer cooling energy input, the temperature of the dispensed products was continuously logged over the 1 hr dispense period. The temperatures of the drinks dispensed through the FOD system were within the expected range for keg lager, extra cold stout, keg ale and cider.

Taking into account cooling losses in the system, the FOD system was found to be about 40% more energy efficient than the traditional system for the high demand dispense scenario (300 pints/hour) and 15% more efficient for the low demand test (100 pints/hour). The calculation was based on the 3 hours for which energy was monitored. It may well be that 2 hours following the dispense the coolers had not fully recovered to their 'steady state' so that not all electrical energy used for cooling of the beverages had been accounted for.

In terms of carbon emissions the FOD system performed better than the traditional system for all dispense scenarios with carbon emissions being reduced up to 22%. Additionally, carbon savings are achieved due to the low volume of product in the CoolTube unit. Compared to an 8m remote cooler coil 275ml less drink is lost every time the line needs to be flushed for line cleaning if a CoolTube device is used instead. 292ml and 345ml product are saved if a CoolTube is installed instead of a pod or a flash cooler plus standard remote cooling coils. Assuming a pub has 10 product lines and these are cleaned on a weekly basis beer savings of 143 l, 152 l and 179 l would result corresponding to a reduction by 117.8, 125.1 and 147.8 kg CO_2 emissions for replacement of an 8m coil, standard coil + pod cooler and standard coil + flash cooler respectively.

Appendix 1

	Low demand (20 pints/hour)		High demand (60 pints/hour)	
	Traditional	FOD	Traditional	FOD
Lager 1	2.5°C (pod cooler)	1.7°C	3.3°C (pod cooler)	2.8°C
Lager 2	2.5°C (pod cooler)	2.1°C	3.0°C (pod cooler)	2.8°C
Stout	1.5°C (flash cooler)	1.5°C	1.3°C (flash cooler)	2.6°C
Ale	3.5°C (8m coil)	3.6°C	3.5°C (8m coil)	3.7°C
Cider	3.0°C (8m coil)	3.4°C	3.3°C (8m coil)	4.0°C

Temperatures of drinks dispensed through different set-ups and using low/high demand scenarios.