The Comparison of 2 methods to de-alcoholise beer using reverse osmosis and distillation

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Introduction

In this work both distillation and reverse osmosis technology was analysed for use in the production of low alcohol (1.2% ABV)(1) and de-alcoholised (0.5% ABV)(1) beers. The beer used in all experiments was made under the same batch and was hopped and carbonated after removal of ethanol from the beer had taken place. The processes were carried out under varying parameters, with the best solution being found to be reverse osmosis with dialysis under high pressures and low temperatures. The distillations would look at using varying temperatures and different techniques of distillation such as open distillation and use of a fractional column. The reverse osmosis experiments would vary the inlet pressure from 12-32 bar, temperature from 8°C to 33°C, membrane area from 0.36m^2 to 0.72m^2. Also changing pH was considered alongside strength of hermetic seal and run time of the experiment.

Method

- The beer was first brewed as a 4.7% ABV pale ale beer (recipe ratios: 85% Marris Otter, 10% Wheat Malt, 5% Torrified Wheat). However hops were left out and only added after removal of the alcohol, maximising the aroma profile of the de-alcoholised beer

- A plate and frame filter system was used to remove yeast from the beer before either process of de-alcoholisation. This used 6 filters at 0.8 microns and a further 14 filters at 0.3 microns.

- The reverse osmosis experiment used a strong hermetic seal to prevent oxidation of the beer, the parameters changed during the experiments were:

Table 1. experiments and parameters used for reverse osmosis

Experiment	Vol (litres)	Length of run	Number of membranes	Pressure in	Pressure out	Dialysis	Hermetic seal	Chiller
1	5	4:00	20	12	2	no	no	Small chiller – co current
2	7	4:45	20	12	2.5	De-ionised	weak	Small chiller - counter current
3	7	6:20	20	12	2	De-ionised	weak	Multi loop cooling
4	9	6:05	20	18	2	De-ionised water	weak	Multiloop and replace water
5	9	5:25	20	18	2	pH4 de-ionised water	weak	Multiloop
6	30	11:07	20	22	6	Distilled permeate	strong	Multiloop
7	30	5:34	20	28	6	Distilled permeate	strong	Multiloop
8	45	14:04	40	32	6	Distilled permeate	strong	Multiloop
9	120	14:26	40	32	6	no	strong	Multiloop

- The distillation experiments used a column still for 2 experiments, the cooling water flow rate in the column was varied for 2 experiments:
  - the 1st experiment kept the outlet temperature of the cooling water at 60°C (allowing mainly only alcohol to evaporate through the column).
  - The 2nd experiment, the outlet cooling water temperature was kept to 98°C (allowing more water to evaporate with the ethanol in a shorter time period).
  - The 3rd experiment used an open distillation with no column to allow ethanol to go to atmosphere keeping the beer temperature at 60oC.

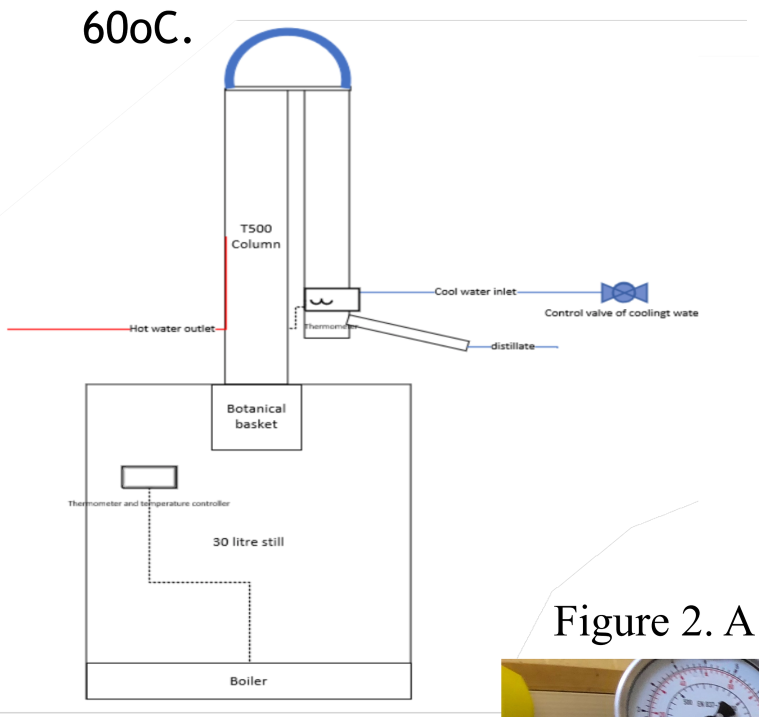

Figure 1. A diagram of the still with T500 fractional column

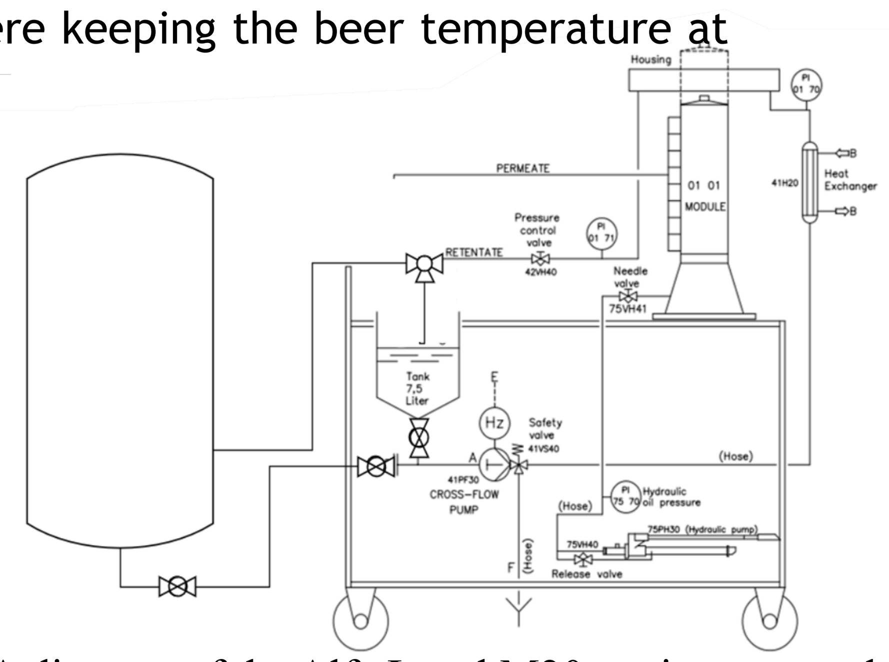

Figure 2. A diagram of the Alfa Laval M20 equipment used

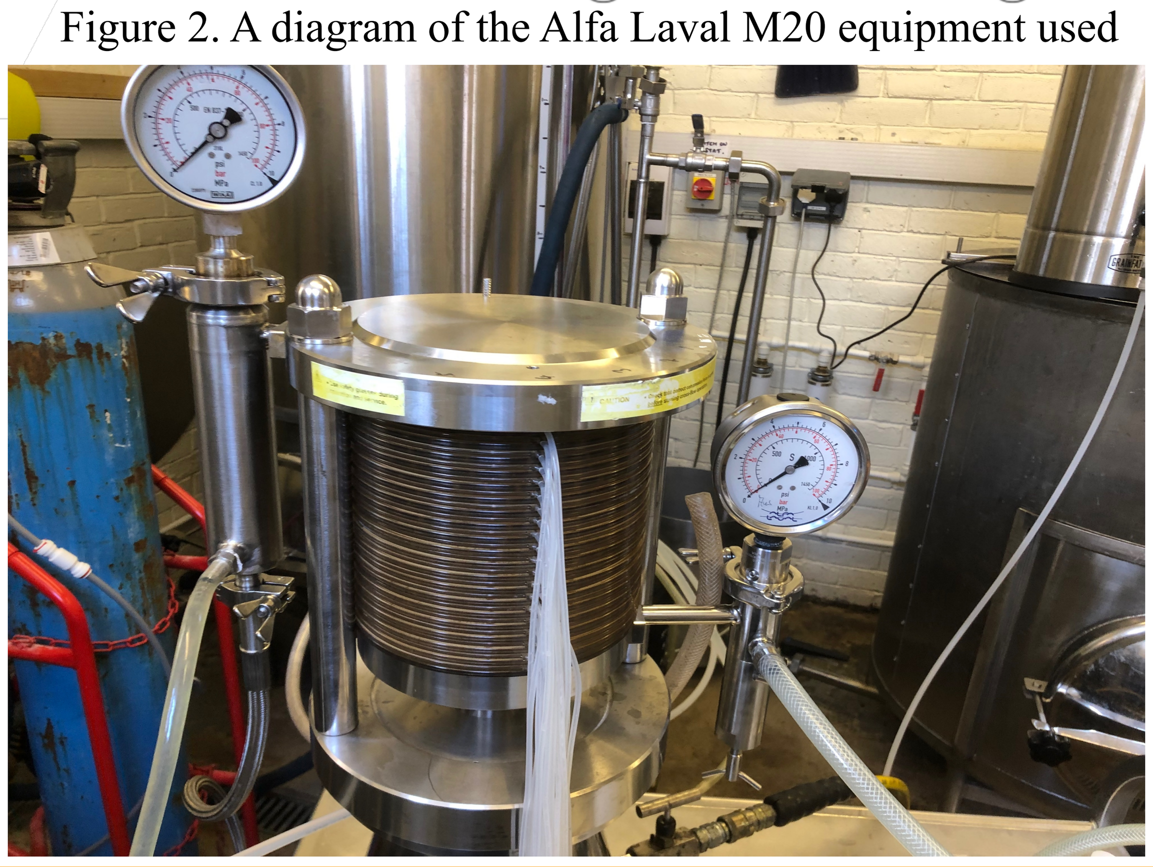

Figure 3. A picture of the stack of membranes used in the reverse osmosis experiments

Results

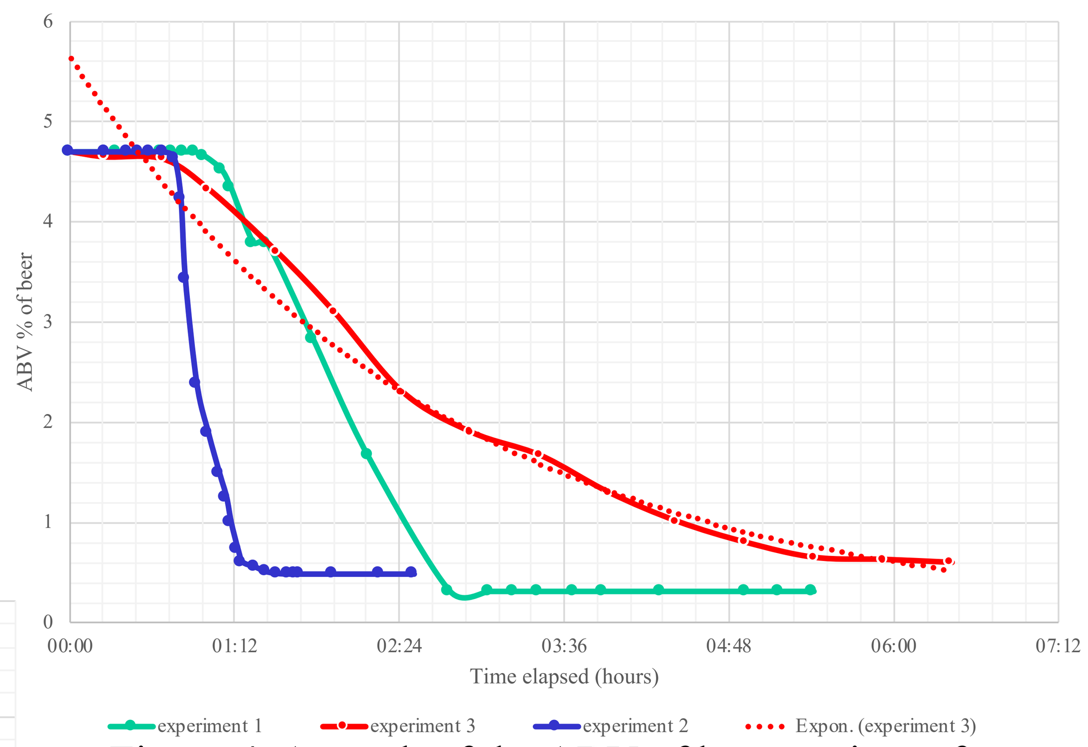

Figure 4. A graph of the ABV of beer vs time of experiment for the 3 distillation experiments.

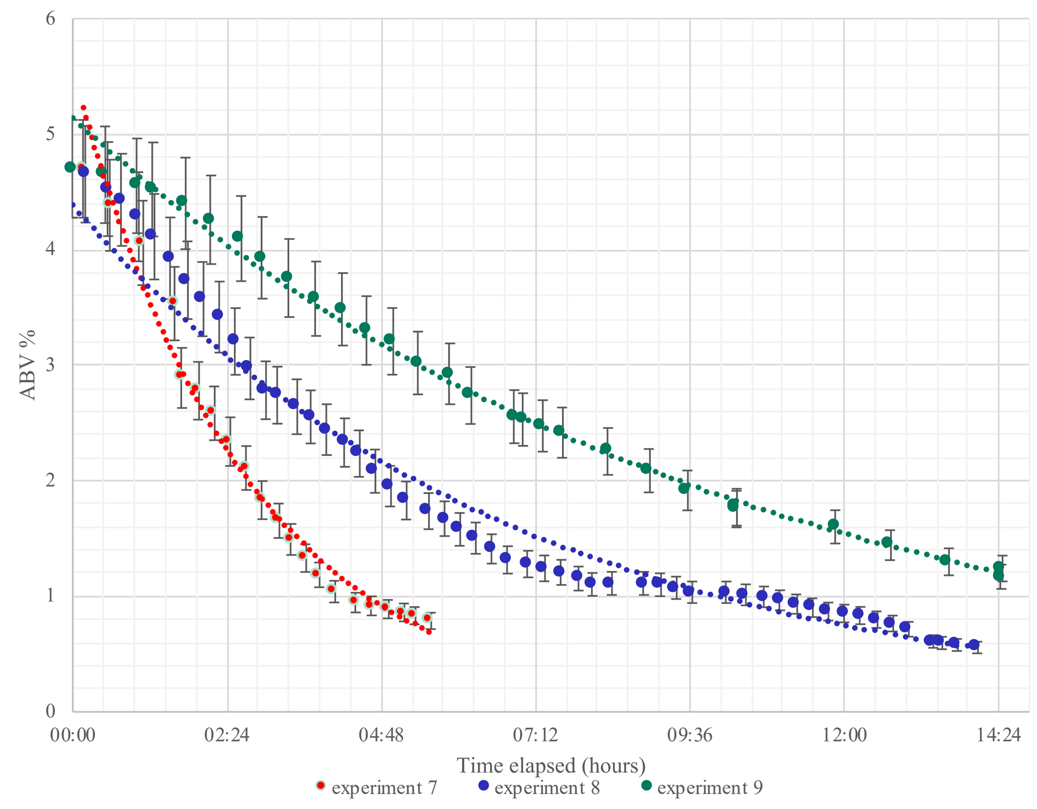

Figure 5. A graph showing the ABV% of the beer vs time elapsed.

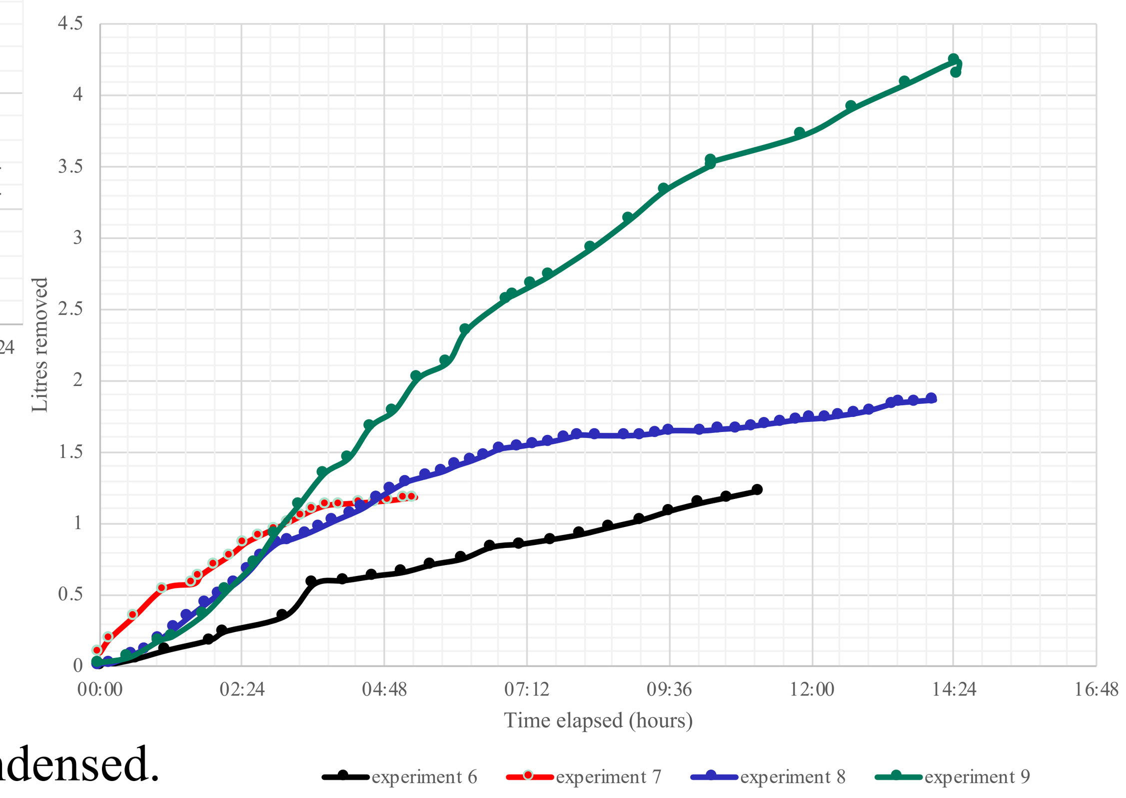

Figure 6. The cumulative alcohol removed vs time elapsed.

Table 2. The taste test results condensed.

Beer sample & ABV	A 0.5%	B 0.5% (from 0.75%)	C 1.2%	D 4.3%
Experiment	8	7	9	Original beer
Favourite (people/ percentage)	2/7.4%	9/33.3%	0/0%	16/59.3%
Correct ABV	19/70.4%	15/55.6%	7/25.9%	20/74.1%
comments	Fizzy, light, weak flavour, watery, small amount of citrus flavour, yeasty flavour, nice colour	Fruity, citrus aroma, fizzy, smooth, missing body, sweet, light, hoppy, nice colour	Watery, flat, citrus aroma, slight apple taste, bitter, bland, hoppy, nice colour	Strong flavour, bitter, full body, strong aroma, yogurt taste, slightly fruity, hoppy, nice colour, banana, sweet

Discussion

Figure 4 shows the distillation results. From these it can be seen that the quickest removal of alcohol occurred in experiment 2 using a slow cooling water flow rate. It can also be seen that the open distillation led to an exponential decrease in beer over time as would be expected(2). However heating of the beer led to caramelisation of sugars and burning of remaining yeast. This made the beers palate undesirable, due to the nature of the distillations the beer was also oxidised and would not last over time.

Figure 5 shows the decrease in beer ABV% over time, it can be seen that experiment 7s parameters decreased the alcohol level the quickest, however, this was also the smallest batch used. Figure 6 shows the total amount of alcohol removed over time for each experiment. The gradient of the line shows the rate of removal, and as can be seen experiment 9 had the quickest rate followed by experiment 7. It was also found that pH did not affect ethanol permeation rate

Table 2 shows the result from the taste test, this shows that although the favourite beer from 27 people was the original 4.3% "Lab session" beer that experiment 7 produced a beer that was likable with a strong aroma pallet and that people would buy and drink.

Conclusion

- Due to caramelisation of sugars and oxidation of the beer the distillation method was deemed unfeasable

- The best parameters for producing low alcohol beer through reverse osmosis were: low temperature, high pressure, low surface area (produces higher permeate flux) As shown from experiment 7. however this takes a long time to remove the ethanol from the beer. This leads to higher financial costs for production of the de-alcoholised beer.

- The alcohol removed from the beer could then be used to make several other products such as spirits for the drink industry or ethanol to be used in the fuel industry. The use of this by product could result in larger turnover and allow for the reverse osmosis method to be seen as a viable method financially.

- the only waste by-product was water.

References

1. "Difference between alcoholic and non alcoholic beers," Drink Aware, [Online]. Available: https://www.drinkaware.co.uk/alcohol-facts/alcoholic-drinks-units/alcoholic-and-non-alcoholic-beers/. [Accessed 21 05 2019].
2. P. S. J. G. K.D. O'Hare', " Evaporation of the Ethanol and Water Components Comprising a Binary Liquid Mixture," *Asia-Pacific journal of Chemical Engineering,* vol. 1, no. 2-3, pp. 118-128, 1993.