Effects of Vessel Geometry, Fermenting Volume and Yeast Repitching on Fermenting Beer

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ABSTRACT

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This paper statistically examines the effect of tank shape and size, fermenting volume and yeast pitching number on fermentation parameters routinely monitored in a series of industrial fermentations. With the fermenter tanks employed in this pilot study, little effect of tank shape existed between any of the parameters. The number of brews fermented or fermenting volume had a significant difference ($p<0.05$) on the apparent extract at 48 h, the final pH and the apparent degree of fermentation (ADF). Interestingly, the number of yeast repitchings (up to 13) did not show any effect on any of the parameters. We conclude, as have other studies, that the automatic practise of discarding the yeast crop after 10 fermentations (and the related expense of early yeast repropagation) could be questioned and is worthy of further study.

Key words: beer flavour, fermentation kinetics, tank geometry.

INTRODUCTION

It is apparent that while the industry has almost completely converted to cylindro-conical fermenters, little discussion of the tank size and shape on fermentation speed has been published. While some literature reports on the effects of serial repitching in industrial situations exist, it is not clear why many large brewers do not repitch yeast crops after 10 fermentations.

In searching the literature the first modern report of cylindro-conical fermentation vessels was made by Nathan in 1930[2]. Shardlow[5] reviewed the experience of Whitbread during the 60s and made a number of recommendations which included the following:

1. Use of a steep cone angle (90° or less preferred).
2. Use of a green beer centrifuge at the end of attemperation was unnecessary with the correct choice of yeast and led to unacceptable flavour changes.
3. Attemperation should be as rapid as possible at the end of attenuation.

Most surprisingly, it was also found that a normal top cropping (ale) yeast used in shallow rectangular open fermenters effectively acted as a bottom fermenting yeast in a cylindroconical vessel. This action was presumed to be due to the delayed yeast harvest. Using this style vessel also reduced bitterness loss (by 15%) and increased foam retention and decreased fermentation times (~62 h versus 96 h)[5]. This allowed Whitbread to reduce hopping levels accordingly.

Unterstein[7] In 1994 commented on studies at Weihenstephan and recommended that fermenters with a cone angle of 60° should have a maximum total height of 15 m with 12 m preferred. Work on yeast viability and stability within the cone by Powell et al.[3] also underscored the preference for a narrow cone angle to control cone temperature. Unterstein[7] also recommended a 1:1 relationship between diameter and (cylindrical) wall height. However, in practice tank heights of 17 and 20 m were in use prior to the 1990s[1,5].

Aside from our meager understanding of the effect of tank geometry on fermentation flavour, there are few literature reports using industrial fermentation data. In 2003, the concept of Evidence Based Practice was discussed[6] and it was noted that fermentation velocity and final apparent extract were significantly influenced by the starting temperature ($p>0.001$). However, most interestingly, reuse of the yeast crop (up to 10 pitchings) had no effect on fermentation speed ($p>0.05$). While the negative effects of serial repitchings have been reported by researchers[8] (e.g., petite generation and flocculation mutations), others have indicated little change in lager yeast serially repitched up to 135 times[4]. In this paper we provide a preliminary report on the influence of tank shape and size as well as the number of serial repitchings on the fermentation of one lager brand.

MATERIALS AND METHODS

A number of process parameters were collected using confidential but standard industry analyses for the fermentation of one lager brand with a fixed pitching rate and temperature profile in cylindrical and cylindroconical fermenters of various volumes as noted in Table I. The conical portions of fermenters 1–4, 8 and 17–21 were not equipped with cooling jackets. A total of 163 fermentations of this one lager brand had the parameters measured as shown below and the number of data-points collected is indicated in brackets.

- Yeast crop number (i.e., number of previous fermentations) (79),
- Plato value at 48 h (163),
- Final diacetyl (150),
- Final 2,3 pentanedione (140)
- Final pH (151),

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- Hours to tank drop (128),
- Final apparent extract (144)
- Apparent degree of fermentation (55)

All statistical analysis was performed with Systat (Systat Software Inc. Ver. 11.0 Chicago, IL).

The yeast was pitched with the first brew and each brew was oxygenated. The fermenter was only considered started (i.e., time = 0 h) once the fermenter was full. Filling of each brew took approximately 2 h. Yeast was removed to yeast brinks taking care to remove trub and stored at ~5°C until repitching. No stratification of the fermentation was evident in any of the fermenters used.

With the available data it was possible to examine the effects of fermenter tank shape, fermenting volume and yeast crop number. Figure 1 shows the tank dimensions of the fermenters monitored in this work. A three-way ANOVA between tank shape, fermenting volume and yeast crop number indicated no significant difference ($p>0.05$) existed between tank shape for any of the parameters listed above. A similar student's t-test between cone and flat bottom tanks of fermenting volume ~840 hL, also indicated that the tank geometry did not have a significant effect ($p>0.05$) on any of the parameters measured.

An ANOVA of the measured parameters with the fermenting volume as the main effect and yeast crop number as a covariate was then undertaken to examine the influence of fermenting volume on these fermentations. Table I shows the results of this ANOVA. Table II presents the Bonnferoni analysis indicating which of the fermenting volume means were significantly different from one another.

Table I. An ANOVA of the effect of fermenting volume and yeast crop number on fermentation parameters.

Dependent variable	Source of variation	Probability
°Plato at 48 h	Fermenting Volume	<0.001
°Plato at 48 h	Crop Number	0.535
Hours to Drop	Fermenting Volume	0.803
Hours to Drop	Crop Number	0.063
pH	Fermenting Volume	<0.001
pH	Crop Number	0.146
Diacetyl	Fermenting Volume	0.767
Diacetyl	Crop Number	0.527
2,3 Pentanedione	Fermenting Volume	0.113
2,3 Pentanedione	Crop Number	0.294
Apparent Extract	Fermenting Volume	0.200
Apparent Extract	Crop Number	0.225
ADF[a]	Fermenting Volume	0.030
ADF	Crop Number	0.986

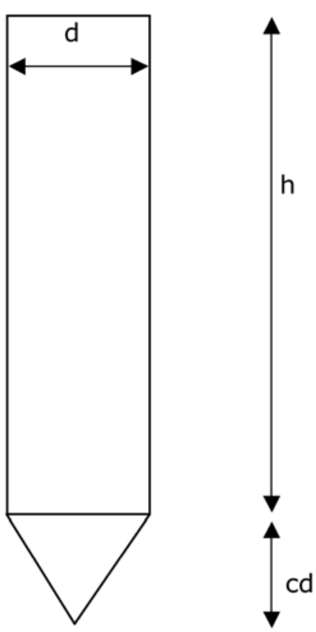
[a] Apparent degree of fermentation.

RESULTS AND DISCUSSION

Statistical examination of the parameters indicated little effect of tank shape between any of the parameters. This was perhaps surprising given that tank shapes are known to affect fermenting wort circulation patterns. The shallow cones in the 840 hL tanks may explain the lack of significance ($p>0.05$) in the t-test results (for tank numbers 1–4 and 8 vs. 5–7).

In any case, the number of brews fermented had a significant difference ($p<0.05$) on the apparent extract at 48 h, the final pH and the apparent degree of fermentation (ADF) as noted in Table I. Interestingly, the number of yeast repitchings (up to 13) did not show any effect on any of the parameters.

As noted, the number of brews pitched influenced the 'start' of the fermentation as yeast was pitched with the first brew, while the fermenter was only considered started once the fermenter was full (i.e., 2 h × the number of brews per fermenter). Thus, the apparent extract at 48 h could be expected to differ simply by the confounding effect of the staggered fermenter fill. However, since pH and ADF values were measured at the end of the fermen-



Tank #	h (M)	cd* (M)	r (M)	Volume (# brews)	Total (hL)
1-4,8	7.893	0.305	1.829	3	840
5-7	7.995	-	1.829	3	840
9-16	5.330	-	1.829	2	560
17-21	10.154	2.899	2.002	5	1,400

N.B. cd*=cone depth

Fig. 1. Tank dimensions and brew volumes used in this study.

Table II. Bonferroni analysis of fermentation parameters by fermenting volume.

Parameter	Probability	Bonferroni analysis: number of brews/fermenter (fermenting volume)	Least squared means (2 / 3 / 5)	n (2 / 3 / 5)
°Plato at 48 h	<0.001	2^1 vs. 3^1 vs. 5^2	11.1/11.0/9.60	22/36/21
pH	<0.001	2^1 vs. 3^1 vs. 5^2	3.94/3.94/4.02	22/36/20
ADF[a]	0.030	2^1 vs. $5^{1,2}$ vs. 3^2	84.6/85.2/85.1	17/20/17

Common superscripted numbers indicate means that do not differ significantly from one another via Bonferroni analysis.
[a] Apparent degree of fermentation.

tations and since there was no significant effect of fermenting volume on fermentation time (time to fermenter drop), one would not expect the staggered fill to affect final pH and ADF values.

The reasons for the significant differences in both pH and ADF levels, which both increase slightly with fermenting volume, are not clear. It may be that in this instance that the larger fermenting volumes and thus taller fermenters encouraged more vigorous fermentations enhancing yeast-to-wort contact without subjecting the yeast to excessively high hydrostatic pressures. While the increase in ADF is minor, it is significant and deserves further study.

With respect to serial yeast repitching, it was evident that reuse of the crop up to 13 times did not affect the fermentation as evidenced by the parameters measured. Although routine sensory analysis was not designed to detect an effect of yeast repitching, no effect of repitching was noted on the flavour of the brand. One could conclude, as have past studies[4,6], that serial repitching does not *inevitably* lead to reduced strain performance. Powell and Diacetis[4], when discussing the successful repitching of a lager yeast crop 135 times, concluded that "…the effects of genetic variation were diminutive and not of significance to the production of beer". Their conclusion supports our findings. Large brewers may find it worthwhile to re-examine the current practise (perhaps dogma?) of discarding their yeast after 10 fermentations. If no microbiological contamination is evident and in-house statistics indicate that their yeast strain is stable (with regard to flavour and yeast behaviour), then the expense of early yeast repropagation could be questioned.

When undertaking an industrial study of this kind, one is limited by the existing industrial practises and the data available. It would be useful to expand this study to consider a wider range of vessels, yeast strains and other sources of variability such as yeast storage and treatment, oxygenation and pitching count, to name a few. The lead author would welcome the opportunity to expand this study with additional brewing statistics.

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