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Double-stage Batch Fermentation of Beer

Part Ⅱ. Trials under Plant Fermention Conditions

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二段回分式 麥酒醱酵

第Ⅱ報 工場醱酵條件下에서의 試釀

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Abstract

In order to ferment beer more effectively under conditions similar to the conventional batch fermentation, a part of the wort which had been fermenting for three days was replaced with un-pitched fresh wort and completed the rest of the fermentation in four to six days. The taste test panel accepted the beers fermented for five days after diluting with one third or one half volume of fresh wort giving fermentation efficiency gains by 22% or 28% over the regular nine-day batch fermentation respectively.

Introduction

Five elemental factors relatecd to the fermentation condition of the conventional beer, i. e., fermentation period, heterothermal condition, spontaneous agitation, stratification, and foam covering during the fermentation were examined previously and found to be responsible for the development of flavor components in the traditional beer. [1] Based on the findings the author proposed a new effective way of fermentation in which the above factors were preserved as much as possible. [2] A substantial increase in the overall fermentation efficiency has been expected by utilizing the yeast cells at their most active stage for an extented period, that is by adding certain amount of fresh wort to the fermenting body at the end of the third day of the normal fermentation followed by a completion in four to six days. The present study is to confirm the possibility in an experimental scale.

Materials and Methods

When an industrial-scale batch fermentor in a commercial brewery plant was filled with yeast-pitched wort to start the regular fermentation, a part of the wort was transferred into a small fermentor which is a sylindrical aluminum tank of 20-liter capacity. Then the small fermentor was suspended in the wort of the commercial fermentor in order to subject the content to ferment under the same temperature condition as the sur-

rounding wort. The unique pattern of wort temperature changing with the time of fermentation in the conventional batch beer fermentor was described in the previous report.[1] The amounts of the wort in the small fermentors and their fermentation schedules are as follows; a) For the single-stage batch fermentation, each of four fermentors was filled with 15 liters of wort and was subjected to ferment for six, seven, eight, and nine days respectively. b) For the double-stage batch fermentation replacing with one half volume fresh wort, the fermentation was started with three fermentors having eight liters of wort each. After three days of the first-stage fermentation, another eight liters of un-pitched fresh wort was added to each tank to make 16 liters of total content and were continued to ferment for four, five, and six more days respectively as the second-stage of the fermentation. c) For the double-stage fermentation replacing with one third volume fresh wort, the first-stage fermentation was initiated with three fermentors having ten liters of wort each. After three days. each tank received five more liters of yeast-free fresh wort to make 15 liters total and fermented for four, five, and six more days as the second-stage fermentation. During the period of fermentation the dry weight of the suspended yeast cells was deter mined at 24-hour intervals as well as recording the degree of Balling in the fermenting wort. After fermentation was completed yeast cells were removed by centrifuging. The supernatant beer was carbonated by leaving for two to three days under ten pounds of CO_2 pressure at 0°C. The carbonated green beers were served to the taste test panel of eight trained members for triangular comparison tests. The nine-day single-stage batch fermented beer was used as a control in this taste test.

Results

Suspended yeast concentation The change of the yeast population in the wort disregarding the inactive settled yeast during the period of fermentation is shown in Figure 1. The parabolic be-

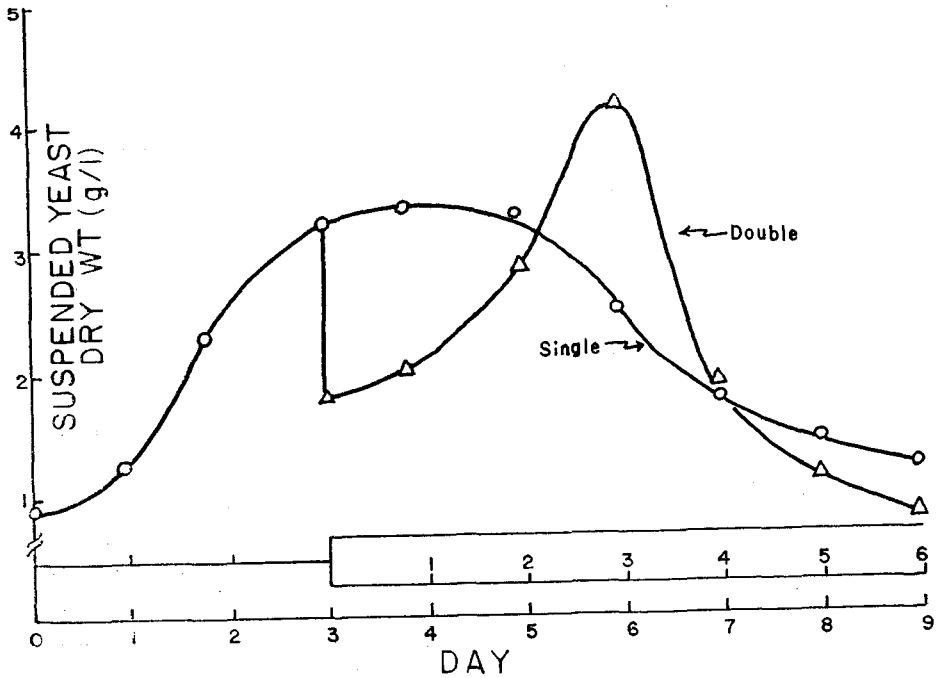

Fig. 1. The Concentration of Yeast Cells Suspended in the Wort during the Single and Double-stage Fermentations. —○—; Regular 9-day single-stage batch fermentation. —△—; Double-stage batch fermentation replaced with one half volume of yeast-free fresh wort after three days of the normal fermentation.

havior of the suspended yeast concentration during the conventional single-stage batch fermentation was already described in the previous report (1). In the case of double-stage fermentation, the reduction in the yeast concentration resulted from the dilution of the fermenting body was recovered in two days followed by a sharp increase. At its maximum the yeast concentration was higher than that in the single-stage fermentation by about 0.8 gram per liter (dry weight). The cells settled rapidly thereafter.

Subste utilization Figure 2 shows the consumption of fermentable sugars in the wort during fermentation indicated by the reduction in the degree of Balling. In the regular fermentation (single-stage) the Balling reaches the minimal revel in seven days. In the same period of time the reduction of Balling in the double-stage fermentor also completes due to a higher rate of substrate utilization after the addition of the fresh wort.

The resulting beers were evaluated by comparing organoleptically to the beer fermented for nine days without dilution (9-day single-stage batch) which is the normal way of fermentation in the brewery (Tab. 1). In the case of single-stage batch fermentation the taste panel could not detect the difference between the beers fermented for eight days and nine days suggesting a peossibility of gaining 11% in the fermentation efficiency. However, the difference was significant at 5% level when the fermentation period was further cut to seven days to gain the efficiency by 22%. The same efficiency gain of 22% was possible by applying the double-stage batch method in which one third volume of fermenting body was replaced with fresh wort after three days and followed by five days as the second stage fermentation. The possible efficiency gain was even greater when one half volume of wort was exchanged in the double-stage fermentation with the total period of eight days. The estimated gain was 28% in this case without giving any significant change in the taste.

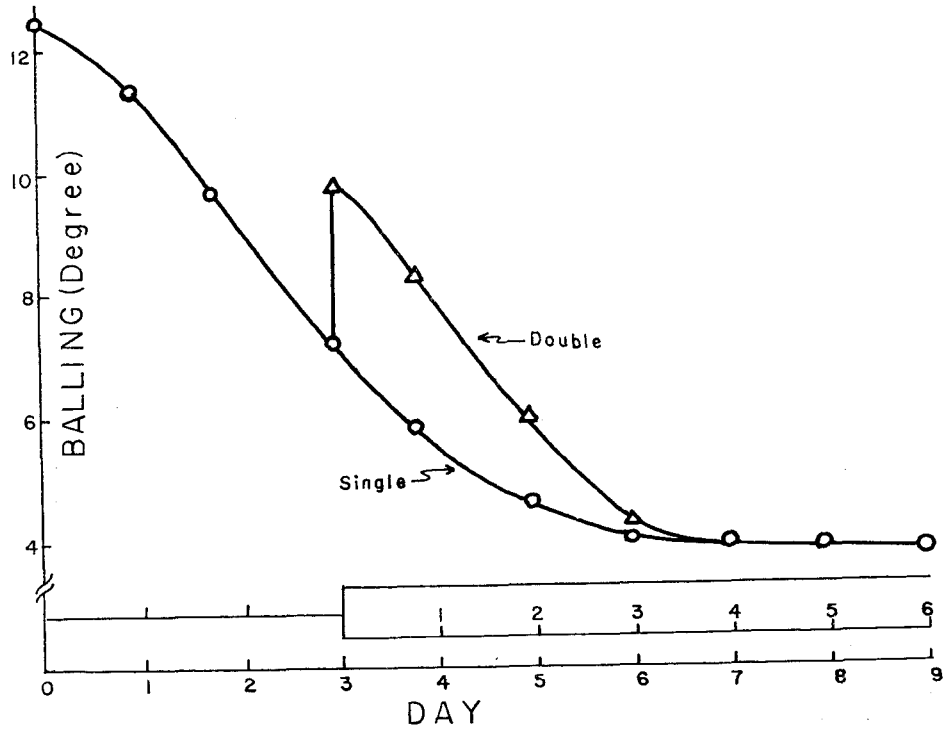

Fig. 2. The Degree of Balling in the Wort Changing with the Time of Fermentati on. —○—; Regular 9-day single-stage batch fermentation. —△—; double-stage batch fermentation replaced with one half volume of yeast-free fresh wort after three days of the normal fermentation.

Table 1. Effect of Fermentation Methodson Beer Taste. *Three samples as a set made of two different* beers including the 9-day single-stage beer as a standard were served to each of the eight members of the taste panel for comparison.

Fermentation methods	Efficiency gained(2)	Triangular comparison of beer tastes		
		Out of 8 participants		Differenceagaist
		Qualified	Disqualified	q-day single stage batch
Single stage batch				
8 days	11%	5	3	Not significant
7 days	22%	6	2	Significant (p=0.05)
6 days	33%	7	1	Significant (p=0.01)
Double stage batch with 1/2 volume fresh wort				
1st stage+2nd stage				
3 days+6 days	17%	4	4	Not significant
〃 +5 days	28%	5	3	Not significant
〃 +4 days	39%	7	1	Significant(p=0.01)
Double stage batch with 1/3 volume fresh wort				
1st stage+2nd stage				
3 days+6 days	11%	2	6	Not significant
〃 +5 days	22%	3	5	Not significant
〃 +4 days	33%	6	2	Significant(p=0.05)

Discussion

In the beer fermentation where bottom yeast is employed the fermentation speed is mainly governed by the amount of yeast cells suspended in the wort disregadirng the inactive cells settled in the bottom layer. For a larger yield of beer in a fixed fermentation period, such as in the case of the double-stage fermentation, the fermenting wort should have more cells than the normal fermentation. This was confirmed in the Figure 1. The higher yeast concentration may be attributable to a simple reactivation of the settled yeast cells car ried over from the first stage rather than to an extra growth of the yeast which may alter flavor quality of the beer. Rainbow[3] reported that fermentable sugars, especially maltose, protect the yeast cells against flocculation. An extension of the carbon dioxide libration period caused by the addition of the fresh wort may also help the dispersion of yeast cells. The assumption is further supported by the rapid settling of suspended cells after the peak (double-stage), whereas they settle more slowly in the normal single-stage fermentation (Fig. 1).

The 28% increase in the fermentation efficiency which can be achieved through the double-stage fermentation replacing with one half volume of fresh wort seems not to be as significant as other types of fermentation methods such as agitated [4~8] or tower type[9~10] fermenttations. How ever, in view of the reporduction of the traditional beer flavor, the present proposal having fermentation conditions almost identical to the conventional ones has a greater advantage. The use of existing fermentors and other fermentation facilities installed in the conventional beer plant without significant modifications is another advantage for this proposal.

要　約

在來式 醱酵法에 협사한 條件下에서 麥酒를 더욱 効率的으로 生產하기 위하여 醱酵開始 3日후에 一定量의 새로운 麥汁을 添加시키고 남어지 醱酵를 4日내지 6日사이에 完成시켜 보았다. 그 結果 $\frac{1}{3}$ 容量과 $\frac{1}{2}$ 容量의 새로운 麥汁을 添加하고 5日동안 더 醱酵한 麥酒가 味覺檢査에 合格되므로써 從來의 9日간 醱酵에 비하여 각각 22% 내지 28%의 効率增加가 可能하게 되었다.

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