Automatic Control of the Addition of Pitching Yeast

By S. Riess

ABSTRACT

This paper describes a new technique for the addition of yeast to wort. The technique is based on a recently developed in-line measurement instrument that senses yeast cell count in pinched wort. The sensor assembly is combined with automatic controls to allow continuous, accurate dosing of yeast into wort. By providing a consistent yeast cell count in the flowing stream of pitched wort, this technique allows improved control of the fermentation process.

SINTESIS

Este trabajo describe una nueva técnica para la adición de la levadura al mosto. La técnica se basa en un instrumento de medición en la línea desarrollado recientemente que percibe el conteo de células de levadura en el mosto inoculado. El dispositivo sensor está combinado con controles automáticos para permitir una dosificación continua y precisa de levadura al mosto. Esta técnica permite un mejor control del proceso de fermentación al proveer un conteo consistente de células de levadura en la corriente del mosto inoculado.

UNCERTAINTIES WITH CURRENT YEAST PITCHING METHODS

A uniform fermentation process plays an essential role in maintaining consistent beer quality. It is widely accepted that accurate repeatability of the wort pitching procedure is a major prerequisite for uniform fermentation.

Consistent wort pitching depends on four parameters. These are:

- consistent wort quality
- exact wort aeration (O_2 mg/l)
- precise pitching temperature
- accurate yeast addition (cells/ml)

This paper describes a method for improving the uniformity of yeast addition.

Present-day and traditional methods of yeast addition are all based upon adding a measured volume or weight of yeast to a known quantity of wort. These techniques are recognized as inaccurate because of varying yeast consistency and because of problems with the laboratory procedures which attempt to relate yeast sample information to the required yeast pitching strategy.

Because it is widely accepted that the accurate control of yeast cell counts in a fermenter is a desirable objective, many methods have been devised for controlling pitching quantities. Examples of these techniques are:

- measurement of centrifugal dry substances in a laboratory centrifuge and
- measurement of conductivity in a yeast suspension.

These methods can lead to more precise yeast additions but they are cumbersome, and the relationship between the measurement and the required information is indirect.

Even the measurement of yeast by means of the "Thoma-chamber" is as much as 25% inaccurate for single counts, as well as being quite time consuming. Coulter counters work more precisely but their application to the determination of yeast cell count in the brewing process has not been widely accepted.

All of these methods for the control of yeast pitching quantities have one common deficiency—the results of the laboratory procedures are not reproducible in the real process.

YEAST PITCHING BY CELL COUNT

Recently the direct measurement of yeast cell count in pitched wort has become practical. The physical principle involved is the measurement of turbidity using photodetectors which work on the absorption principle. Generically, such instruments are known as extinction turbidimeters. The operation of the specific devices used for measuring yeast cell counts in pitched wort are based upon the extinction of light in the near-infrared range.

A direct correlation has been recognized between extinction and yeast cell count. The relationship is described by the Lambert-Beer-Bouguer law. This law is as follows:

$$E = e \cdot c \cdot d$$

e = molar extinction coefficient [cm²/mole]
c = concentration [moles/cm³]
d = layer thickness [cm]

or

$$E = \log \frac{Io}{I}$$

Io = intensity of radiated light
I = intensity of transmitted light

The ratio I/Io, expressed in percentage, is called "transparency".

In brewing process applications it has been found that the linear relationship between extinction and cell count includes values between 5 million and 60 million yeast cells/ml. Pitching yeast additions to wort are generally between 15 and 25 million yeast cells/ml.

Today, pitching control systems based on this measurement principle provide the most accurate known method for yeast dosing.

Continuous pitching of yeast according to cell count from the beginning to the end of wort flow gives the brewer control of one more process parameter. This means that fast fermentation starts and exact fermentation progress can now be obtained more reliably than with weight-based or volume-based pitching.

Of course, fermentation capacity and other characteristics of a particular yeast strain continue to play their role. Also, the number of dead yeast cells and other particles that are present will influence the cell count measurement. In spite of this, the use of yeast cell count as the measured value permits more accurate pitching than other techniques. This is because particles other than live yeast cells are quite constant in most pitching yeast supplies. Thus, these particles can be taken into account and compensated for in selecting a set point for the pitching control system.

The turbidimeter used in the pitching control system provides particulate measurement across the entire cross-section of the pipe. This ensures direct measurement of the total turbidity.

The fundamental measurement principle for pitching control is that the sum of the cross-sections of all particles which are carried past the sensor in the flowing wort is detected. By placing two such sensors in series so that one of them is upstream of a wort pitching point and the other is downstream of the yeast injector, a differential turbidity value can be obtained. This value has been shown to have a linear relationship

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to yeast cell count even in the presence of varying background turbidity from such sources as trub.

DESCRIPTION OF THE PITCHING CONTROL UNIT

A modular unit has been designed and built so that the principles previously described in this paper can be applied to actual brewery situations. A description of this process module follows.

The pitching control unit consists of the following devices (all identification numbers refer to the schematic drawing of the unit in Figure 1):

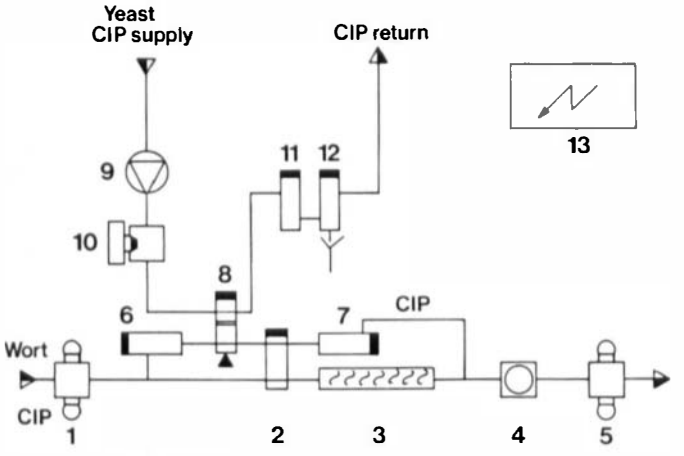

Figure 1. Flow diagram

1. upstream turbidity measuring head
2. yeast dosing valve
3. static mixer
4. illuminated sight glass
5. downstream turbidity measuring head
6. & 7. static mixer bypass valves
8. yeast/wort circuit-separating valve
9. centrifugal yeast pump
10. in-line turbidity switch
11. yeast line drain and CIP connection.

The unit is built in accordance with Matrix Piping principles. This ensures that the entire unit can be fully cleaned using automatic CIP techniques. The system can best be understood by recognizing that the yeast piping and the wort piping are totally independent circuits except at the yeast/wort circuit-separating valve (8).

The liquid flow pathways employed in the yeast pitching module are as follows:

Wort Route:

Wort enters the module via the pipeline upstream of the first turbidity sensor (1). It then flows past the yeast dosing valve (2). If yeast injection is underway, yeast enters the wort stream at this point. The wort continues via the static mixer (3), the illuminated sight glass (4) and the downstream turbidity sensor (5). Wort finally exits from the module via the outlet pipe.

Yeast Route:

During pitching operations, the yeast to be dosed is transferred from the yeast tank via the yeast pump (9). It flows past the in-line turbidity switch (10), then through the circuit-separating valve (8) and into the wort via the dosing valve (2).

Wort piping and yeast supply piping can be CIPed independently of each other. This is because a circuit separating valve (8) is provided. This valve is a double seat mixproof valve.

CIP of Wort Circuit:

The design of the wort pitching control module described in this paper anticipates that the start-up, wort recovery, and shut-down operations of the brewery's wort system will be a function of a wort line control system that resides outside the module. It is assumed that a cleaning and sterilization regimen has been provided for the wort line as part of this system. Obviously, control over these operations can also be provided from the pitching control module by assigning these functions to the controls which are present in the module.

In most cases, the user's current wort line cleaning regimen can be used with only minor modifications for cleaning the wort piping in the pitching control module. The main wort route (as described above) can be treated in the same way as any other length of pipe in the cold wort piping system.

Special comment must be made, however, concerning the static mixer bypass line. This line exists only to allow cleaning of the upper part of the yeast dosing valve during wort line CIP operations. At that time the lower part of the dosing valve housing is cleaned by direct flow through the main wort pipe while the upper housing is cleaned by the bypass flow through valves (6) and (7).

Flow occurs in the bypass line due to the pressure differential across the static mixer (3). The yeast dosing valve (2) is opened during wort line CIP so that its internal parts are fully cleaned.

CIP of Yeast Circuit:

When pitching operations are not underway, valve (8) closes and all cleaning, pushout and other yeast line operations can be conducted without reference to any operation which is underway in the wort line. CIP supply and push-out water originate from the brewery's existing facilities upstream of the yeast pump. CIP solutions are returned to the CIP system via valves (11) and (12). Water is displaced from the yeast piping via valves (11) and (12). The turbidity switch (10) detects the interface between water and yeast or between yeast and water during yeast line push-out operations.

CONSTRUCTION FEATURES

Figure 2 is a photograph of the unit described in the foregoing text.

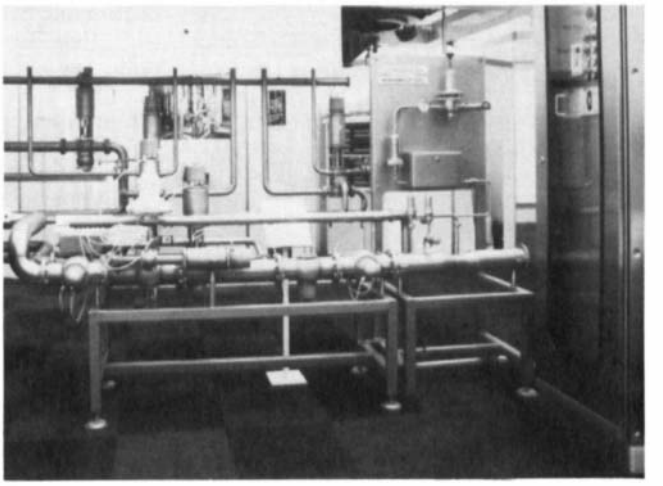

Figure 2. Photograph of yeast dosing installation.

The unit shown in the photo is designed for installation in a horizontal wort line. Obviously, modules can be designed with other flow orientations as required.

The entire unit, including the support frame, is made of stainless steel. Piping connections are made with flanges. The unit can also be built with any common piping connections at the interface between the pitching control module and the rest of the brewery.

In standard systems, the control cabinet (also made of stainless steel) is mounted on the same frame as the process equip-

ment. This cabinet can also be located remote from the pitching control module as shown on the photo. The only restriction is that the length of the cables between the turbidity measuring heads and the control cabinet cannot exceed 100 meters.

CONTROLS

Inside the control cabinet (13) are the control units for the two turbidity sensors plus the electrical connections for the in-line turbidity switch and the sight glass lamp. This panel also contains the solenoid valves and the control air supply for the pneumatic valves on the module. In addition, the panel shown in the photo contains a contactor for the yeast pump.

Additional devices are mounted on the face of the control panel. These items include a programmable process controller with membrane keyboard and digital display. This unit modulates yeast flow through the yeast dosing valve in response to turbidity signals.

The face of the control cabinet also provides an operating panel which contains push buttons, indicating lamps and switches as follows:

a — dosing "start" (for manual operation)
b — wort on
c — yeast on
d — CIP on
e — lack of yeast
f — wort turbidity alarm
g — yeast dosing alarm
h — error
i — yeast dosing pump
j — manual operation of all valves
k — manual/auto key switch
l — yeast circuit CIP
m — wort circuit CIP

FUNCTIONAL DESCRIPTION

The upstream measuring head (1) measures the basic turbidity of the wort currently being processed. The downstream measuring head (5) measures the total turbidity value of the wort plus the dosed yeast cells. A programmable process controller determines the turbidity contribution of the dosed yeast cells by subtracting the upstream turbidity value from the downstream turbidity value.

The calculated yeast turbidity value is scaled in millions of yeast cells/ml and displayed on the controller. This value is compared with the yeast set-point. The controller adjusts yeast flow by modulating the yeast control valve to eliminate differences between the set point and the current yeast turbidity value.

Prior to the start of pitching, yeast from the yeast tank is automatically sent to the yeast dosing valve (2). Water in the yeast pipe is displaced to the drain via valves (11) and (12). The in-line turbidity switch (10) recognizes the change in turbidity when the interface between yeast and water arrives. After a short time delay the push-out valve (12) closes. At this time, the yeast is ready for injection.

In many European breweries, yeast is stored in pressurized yeast vessels. If this pressure is high enough, pitching yeast can be delivered directly. Otherwise a yeast dosing pump (9) is used. In any case, yeast must be delivered in adequate quantity and under sufficient pressure to the yeast dosing valve (2) via the circuit separation valve (8). Enough yeast is dosed into the wort pipe to meet the controller set point.

The yeast is thoroughly mixed with the wort in the static mixer (3). The illuminated sight glass (4) is provided for visual inspection of the mixed product. The downstream measuring head (5) furnishes exact results because the yeast is distributed uniformly over the entire pipe cross section. Aeration of the pitched yeast should take place downstream of the unit, since gas bubbles interfere with the turbidity measurement technique that has been described.

When wort flow starts, the upstream turbidity sensor (1) identifies the change from water to wort. Yeast dosing starts after a time delay. Later, when the wort run ends and push-out takes place, the upstream turbidity sensor detects the change from wort to water and yeast dosing is discontinued. All parameters involved in these actions are adjustable at the controller.

Other limit values at the controller detect the following operational conditions:

— excessive turbidity in the wort
— lack of yeast in the wort
— yeast overdosing

In general, these limits are reached only in the case of a process malfunction.

OPERATING EXPERIENCE IN A BREWERY

Since the beginning of this year a yeast pitching control module similar to the one described in this paper has been working in a brewery in Hamburg, West Germany. It is applied in a wort line which serves cylindro-conical fermenters. The normal wort flow rate for this line is 350 hl/h. Yeast is dosed continuously from the beginning to the end of each brew, with a set concentration of 20 to 25 million cells/ml. The same unit is also used to dose krausening yeast into fermented beer at 30 million cells/ml. During the time it has been operating, the yeast pitching control module has been supplied with both homogenized and non-homogenized yeast.

Figure 3 shows that the pitching control module operates faultlessly in spite of varying yeast consistencies. However, as expected, the pitching control is more consistent with homogenized yeast than with yeast of varying consistency.

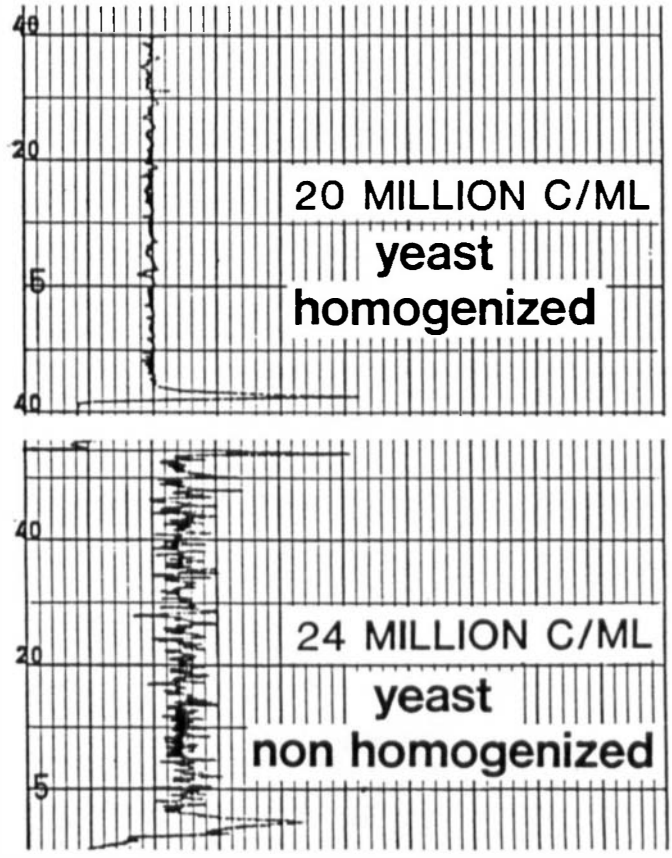

Figure 3. Actual yeast dosing recordings.

Counts performed with a "Thomachamber" have shown that the actual number of cells counted corresponds nearly

exactly to the module's preset cell count. The accuracy is always better than ±5%. Under good conditions, using homogenized yeast, the accuracy reaches even ±1%.

Through the use of the previously described pitching control module, the primary fermentations of the plant have become more uniform. This has allowed pitching temperatures to be lowered. Because of this cooler fermentation process the beer's diacetyl content has diminished.

The module has also improved the krausening operation. Control of this secondary fermentation has improved to the extent that the range of actual extracts in the finished beer only varies by 0.8%. Accurate control of yeast additions to the fermented beer for secondary fermentation has also reduced the volume of sediment in the storage tanks by 15%.

There has also been a reduction in the yeasty taste characteristic which was formerly present in the beer.

ADVANTAGES OF CONTROLLING WORT PITCHING BY CELL COUNT

A yeast pitching control module like the one described in this paper can be applied as an independent, modular component for handling yeast injection in any new or existing brewery. The modular pitching system can be controlled either from an integral automation system (as previously described) or from a central process control system.

We expect that the pitching control module will allow some interesting new yeast pitching strategies to be implemented. This is because of two facts:

- Pitching yeast no longer needs to be homogenized
- Any reasonable pitching yeast concentration can be accommodated. Practical values for yeast to be dosed cover at least the range from .5 to 3 billion cells/ml.

Novel pitching techniques will evolve because yeast to be pitched can originate from settled fermenter yeast, from centrifuged yeast or from a pure culture propagation batch. Reliable pitching can be obtained even though the following parameters change—no matter whether the variations occur slowly over a long period of time or frequently within a single brew:

- changes in trub concentration
- variations in wort flow rates
- variations in the pressure of wort or yeast
- changes in yeast consistency
- changes in pitching temperatures

Operating experience with this module has shown that it is a significant new tool for use by the brewer in obtaining a constant and exact fermentation process. Along with the obvious advantages this holds for product consistency, it also allows a more uniform fermentation time. Thus, fermenting vessel occupation times are more predictable and fermenting cellar output can be increased. Taste tests of beer produced by this method have confirmed that it is more consistent than control samples produced with batch pitching strategies.

Compared with the usual batch method of adding yeast to fermenters, constant dosing of yeast from the beginning to the end of wort flow eliminates many problems. Included among these are:

- yeast stratification
- slow fermentation starts
- uncontrolled yeast growth

The dynamics of yeast propagation in the fermenter are more closely controlled with continuous yeast dosing techniques. Thus, the amount of waste yeast and the beer losses associated with waste yeast are reduced. This leads to reduced production costs.

OTHER APPLICATIONS

Many other brewery applications have been proposed for the general technique described in this paper. Some of these applications rely on the fact that the linear relationship between turbidity and cell count extends up to 60 million cells/ml. This permits direct measurement of other yeast cell counts using a turbidity detector.

With minor modifications, the pitching control method that has been described can provide improved ways of handling many miscellaneous brewery operations such as:

- krausening
- other yeast additions for secondary fermentations in the cellars
- yeast additions for specialty products such as weissbier and cask-conditioned ales
- addition of processing aids such as filteraids, silica gel and PVPP

Other brewery applications will result from the control of yeast cell counts in process lines in connection with separators, filters and decanters.

The basic control scheme described in this paper uses an analog blending technique for the actual addition of yeast to flowing wort. The unit is capable of being adapted for digital blending techniques where required. Adaptation to digital blending technique should permit the module to perform at ±1% accuracy for all process conditions—even with non-homogenized yeast.

Obviously, there are many non-brewery applications for units based on the technique which has been developed for yeast pitching control. These applications include all operations where organisms must be precisely dosed according to cell count in biological processes.

Also, the general idea of differential turbidity control permits measurement and control of any dosing operation which adds preset quantities of solid particles into liquids with or without background turbidity.

QUESTIONS AND ANSWERS

Q. Do you think that yeast injection by cell count offers the possibility of completely eliminating the yeast room operation?

A. No, not really. Stored yeast may be dosed directly from a cylindroconical fermenter through the yeast pitching control module. However, in my experience it is not recommended to use the same pitching yeast several times. From time to time, yeast must be degassed and aerated for reactivation and to maintain its fermentive power. Provided that yeast is pitched only twice before new yeast is added, then I think that yeast tanks may be omitted.

Q. How much practical experience have you had using the method you described?

A. We have used this system for approximately 9 months in a German brewery.

Q. Will you please explain what you mean by homogenized yeast and how you get it?

A. Homogenized yeast is obtained by stirring yeast in a yeast tank while aerating it by means of a ring aerator. Alternately, it can be done by circulating or pumping the yeast from tank to tank to make a uniform suspension.

Q. What is the name of the turbidity meter used? Has it been used for filtration control?

A. It is called the Tuchenhagen Turbidity Meter. Turbidity Meters can be used for general filtration control, before and after filtration. The smallest measuring range is 0–2 EBC units.

Q. How does your system compensate for differences in dead cell count, trub and different degrees of budding in the pitching yeast?

A. For a given brewery the average amount of dead cells, trub and other factors in the yeast usually has been established over a period of time. This figure can be added to the set point in the controller. For example, if it is known that the average amount of dead matter in the pitching yeast is 5%, then 5% can be added to the set point to compensate.

Q. How does wort aeration affect the extinction sensor? Where do you recommend that wort aeration take place?

A. Since air bubbles cause false values, aeration should be done after the turbidity meter. We therefore offer a combination of pitching control and wort aerator, with the aerator mounted downstream of the pitching unit.

COMMENT: The reference method of EBC Analytica Microbiologica is the gravimetric membrane method which gives you the dry weight of the yeast. All other methods should be correlated to this method.