Taking Advantage of Temperature Changes to Determine the Progress of a Cider Fermentation

Carlos de la Roza,[1] Adriana Laca,[1] Luis A. García,[1] and Mario Díaz[1,2]

ABSTRACT

J. Inst. Brew. 108(1):32–33, 2002

New, simpler and cheaper tools are necessary to properly control fermentation processes at the industrial level. In this paper, a simple method to calculate a major parameter, ethanol concentration, at any time in the fermentation medium by measuring only the temperature evolution, has been developed and successfully applied to industrial cider fermentation.

Key words: Cider, control, ethanol, fermentation, temperature.

INTRODUCTION

The determination of substrate and metabolite concentrations during fermentation processes is a complex task requiring expensive measuring equipment together with qualified personnel. Information of this type is gathered in many fermentation systems and used for control purposes. However, this approach is not within the economic reach of many cider factories, which are often small and family owned, and do not address large production markets. This underscores the need for more simple control tools to achieve a standard quality product.

Temperature is a parameter that exerts a great influence over apple juice fermentation. High temperatures often favour metabolic pathways that result in the production of compounds with undesired organoleptic properties. Nevertheless, some fermenters used for industrial beverage production do not use any form of temperature control. This is common not only in small-scale cider fermentations but is also a frequent occurrence in other traditional beverage fermentations. What normally does however exist is a temperature sensor, for on line monitoring, all along the fermentation process. These devices are low cost, easy to operate and readily available.

In this paper, attempts are made to relate temperature to the evolution of ethanol concentration inside the fermenter. As described earlier, for beer and cider production, ethanol evolution can also be related to the evolution of substrates and other primary and secondary metabolites[1–6], which suggests that there is the possibility of relating all of these parameters. Thus by measuring the temperature, it should be possible to predict the stage of development of the fermentation process (substrate and products) and use this information in the control of the whole system.

[1] Dept. of Chemical Engineering and Environmental Technology, University of Oviedo. C/Julián Clavería 8, 33006, Oviedo, Spain.
[2] Corresponding author. E-mail: mdf@sauron.quimica.uniovi.es

Publication no. G-2002-0319-01R

RESULTS AND DISCUSSION

A typical profile of temperature changes in cider fermentation, carried out in a 45,000 litre tank, is shown in Fig. 1. The temperature starts to increase as the primary fermentation takes place and afterwards decreases until the cellar temperature is reached. From ten days on, the cider temperature in the fermenter followed the oscillations existing in the cellar, although these oscillations were reduced due to the great volume of liquid in the fermenter.

The fermentation temperature is directly related to the energy released from the reaction of ethanol production, and therefore with the ethanol concentration in the fermentation medium.

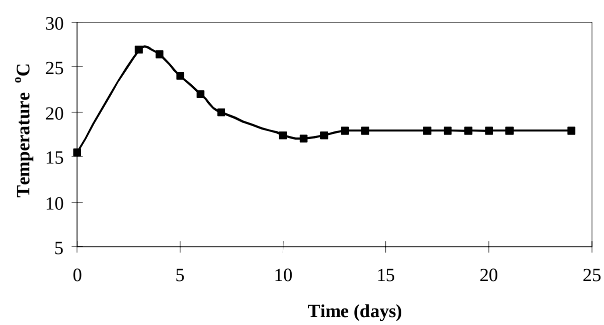

FIG. 1 Evolution of temperature during an industrial 45,000-litre cider fermentation.

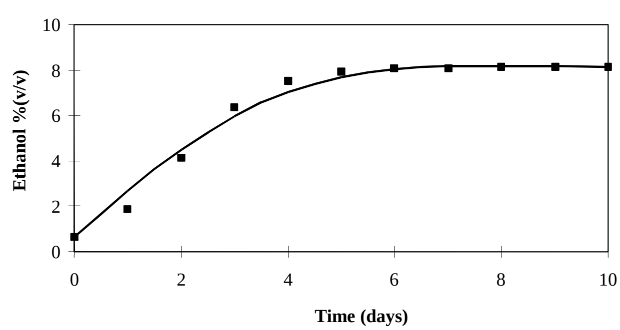

FIG. 2. Fitting of ethanol concentration on the basis of fermentation temperature: theoretical (line) and experimental (symbols) data.

Making an energy balance, the next equation is obtained:

$$mC_p \frac{dT}{dt} = \frac{m}{\rho} \sum \Delta H_i \frac{dC_i}{dt} - UA(T - T_A)$$

where m: cider mass; Cp: heat capacity; T: cider temperature; T_A: cellar temperature; ρ: cider density; ΔH_i: chemical reaction's enthalpy; C_i: product concentration; U: heat transmission global coefficient; A: fermenter surface; t: fermentation time.

When alcoholic or primary fermentation is taking place, the next assumptions are made:

(i) a homogeneous temperature is considered at any point of the fermenter

(ii) the main transformation occurring is ethanol production from sugars and all energy produced by chemical reactions comes from these transformations.

When applying these assumptions, taking increments, and expressing the ethanol concentration as an explicit function of the temperature, the next expression is obtained:

$$\Delta C_e = a(T_i - T_{i-1}) + b(T_i - T_A)\Delta t$$

where: $a = \frac{\rho C_p}{\Delta H_e}$, and $b = \frac{\rho UA}{m \Delta H_e}$, parameters that can be considered constants for the same fermenter and original apple juices of similar characteristics.

When this model is compared with the experimental data from the industrial fermentation shown in Fig. 1, the parameters obtained are: a = 4.39 10^{-2} mol litre^{-1} ºC^{-1}; b = 1.19 10^{-3} mol litre^{-1} ºC^{-1} h^{-1}. Taking these values into account the next values for heat capacity and heat transmission global coefficient are obtained: Cp = 1.22 cal g^{-1} ºC^{-1}; U = 20 kcal m^{-2} ºC^{-1} h^{-1}. These values are in keeping with the type of the systems used and therefore all assumptions previously made appear to be correct. Moreover, and what is more important, a good fit of data was obtained, as can be observed in Fig. 2. This indicates the utility of the method in evaluating the evolution of ethanol production and other important parameters that can induce actuations in the process.

Since a and b fitting parameters remain constant for a determined fermentation, and a defined tank geometry, and provided that the characteristics of the original apple must are kept constant, the method presented here appears to be simple, cheap and quick and allows the calculation at any time of the ethanol concentration in the fermentation medium, by only measuring the temperature evolution. Since it was possible to relate the ethanol concentration to the concentration of other metabolites (fusel alcohols, esters, organic acids, etc.), then with the method presented here, the concentration of all compounds in the fermentation medium can be predicted.

Finally, it is possible to suggest that this method for controlling the fermentation process through the use of one major parameter, temperature, appears suitable for use in industrial plants producing other fermentation products including wine, beer, cider, etc.

REFERENCES

1. García, A.I., García, L.A. and Díaz, M., Prediction of ester production in industrial beer fermentation. *Enzyme Microb. Technol.*, 1994, **16**, 66-71.
2. García, A.I., García, L.A. and Díaz, M., Fusel alcohol production in beer fermentation processes. *Process Biochem.*, 1994, **29**, 303-309.
3. García, A.I., García, L.A. and Díaz, M., Modelling of diacetyl evolution during beer fermentation. *J. Inst. Brew.*, 1994, **100**, 179-183.
4. Herrero, M., de la Roza, C., García, L.A. and Díaz, M., Simultaneous and sequential fermentations with yeast and lactic acid bacteria in apple juice. *J. Ind. Microbiol. Biotechnol.*, 1999, **22**, 48-51.
5. Herrero, M., Cuesta, I., García, L.A. and Díaz, M. Changes in organic acids during malolactic fermentation at different temperatures in yeast-fermented apple juice. *J. Inst. Brew.*, 1999, **105 (3)**, 191-195.
6. Herrero, M., García, L.A. and Díaz, M. Organic acids in cider with simultaneous inoculation of yeast and malolactic bacteria: Effect of fermentation temperature. *J. Inst. Brew.*, 1999, **105 (4)**, 229-232.

(Manuscript accepted for publication October 2001)