Winemaking process engineering: On line fermentation monitoring - sensors and equipment

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Abstract

Wine production is directly linked with the monitoring of its production by measuring certain critical fermentation parameters. The critical parameters for the monitoring of the wine production are the total sugars concentration, the ethanol concentration and the CO_2 production. The CO_2 production is linearly yeast growth associated. There are of course some other parameters which although are important to the quality of produced wine they are not measured on a daily basis. In fact a method for on line measurement of the three mentioned parameters can be helpful in many ways. It is less labour intensive as well as it helps in a more accurate and organised industrial process. The present system is using pressure transducers in combination with the CO_2 measurement on line through a mass flow meter. The measurements are taken at the same time and the data are logged in a computer programme.
The correlation of the on line measurements are compared to the manually measurements. The system has been tested for the production of ethanol and for the production of white wine.

The present work has been based on the use of an external system used for the monitoring and measurement of the density as a result of the pressure difference from the two pressure transducers. As well as the measurement of the CO_2 concentration with the use of a CO_2 mass flow meter. Both set of measurements were combined in a model developed for this process.

Keywords: online alcoholic fermentation, process engineering, sensors, pressure transmitters, mass flowmeters

Introduction

The on line measurement and monitoring of wine and alcoholic fermentations have been the subjects of various research laboratories in different countries (Boulton, 1980; Blouin, 1996; Sablayoroles *et al.,* 1987;1989; Sablayoroles & Barre 1986;1989; Bely *et al.,* 1990; Wheat, 1991; Schugerl, 2001; Aguera *et al.,* 2005a,b,c). The on-line measurements of the different parameters which otherwise performed in a manual manner on a daily basis have a drastic reduction on the production cost.

In parallel different projects have been developed to measure the extraction of colour, tannin and total phonemics during red wine fermentations and the in-line measurement of yeast cell mass for white wines.
The monitoring of the weight loss has been studied using sensors of pressure fitted inside the fermentor (El Haloui *et al.*,1988; El Haloui *et al.*,1989).
In this work the sensors have been applied in an external tube linked to the fermentor with tubing.
The process can run in different modes and the data from the CO2 mass flow meter are combined with the pressure transducers measurements using a software developed for this process.

Methods and Materials

Description of the fermentation system

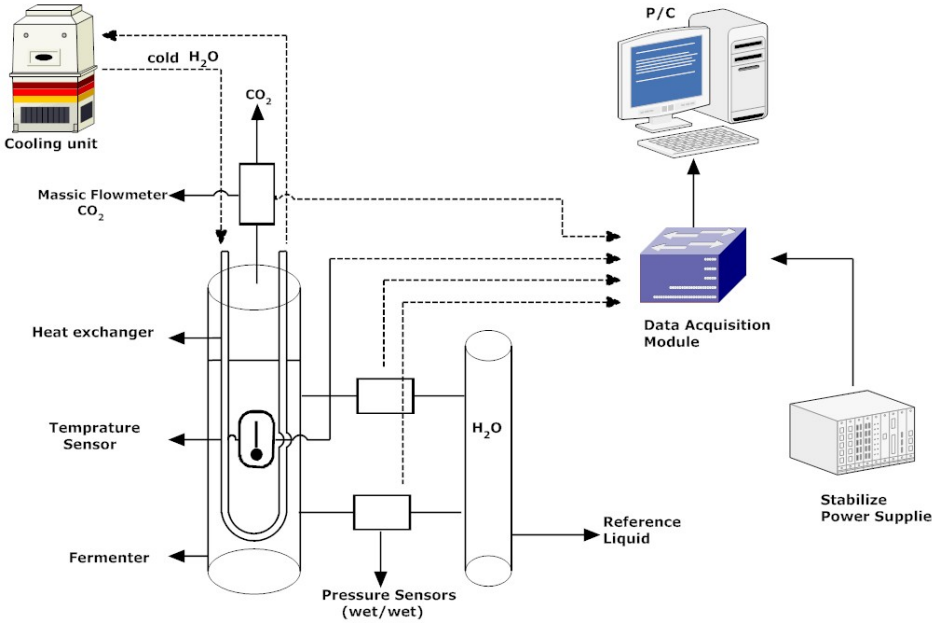

Photo 1. The fermentation system .

System and Sensors

The fermentation system consists of a tower fermentor, a monitoring devise which consists of a plastic (Plexiglass) reference pressure tube and a Computer. The computer communicates with the system with an USB interface (National Instruments, USA, USB 9161 controller) which is connected to the wet/wet differential pressure transducers (Part No 68071/72, Cole Palmer, Illinois, USA) and the carbon dioxide mass flow meter (5850TR, Brooks Instrument, Hatfield, PA, USA) fitted on the top of the tower fermentor. The system is equipped with LM35 precision integrated-circuit temperature sensors (National Semiconductor, California, USA) and a temperature control system. Sensors were powered with a Marconi The software used was developed with the LabView platform (trademark of National Instruments, USA). An early prototype of the system has been presented by the authors elsewere (Tataridis & Nerantzis, 2007; Nerantzis *et al.*, 2006;2007)

Enological yeast strain *Saccharomyces serevisiae* Uvaferm 228 (Lallemand S.A., France) was used for inoculation

Chemical analyses

Total reducing sugars, ethanol and density analysis were conducted according to the standard methods of the European methods of analysis for musts and wines (EEC Regulation No. 2676/90).

Results and discussion

On line measurements

The system was tested using different initial sugar concentrations 100 and 200 g./L. Samples were taken and the density was measured both manually and on line. In the first two experiments the functionality of the two sensor systems (density and carbon dioxide) was assessed individually.

Figure 1 shows the results of the density measurements manually and on line under the temperature of 30 ^{o}C and initial sugar concentration of 100g/Lt. It shows very close proximity of the two sets of measurements. The gaps on the graph of the on line samples are due to the power cut off during the experimentation (not adequate power supply). The normalization was set to integrate the mean value of 60 measurements per hour.

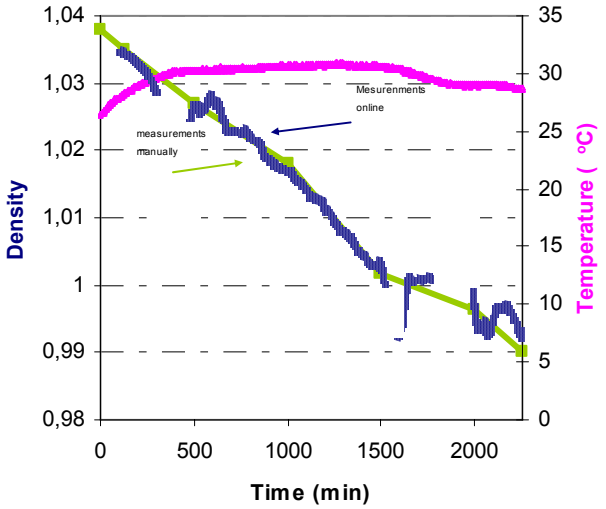

Figure 1. Measurement of the Density during the fermentation of substrate with sugar concentration 100g/L and temperature 30°C

For the testing of the carbon dioxide sensor (CO_2) fermentations were conducted with an initial sugar concentration of 100 g/L at temperatures of 22°C and 30°C, respectively, as shown in figures 2,3 and 4.

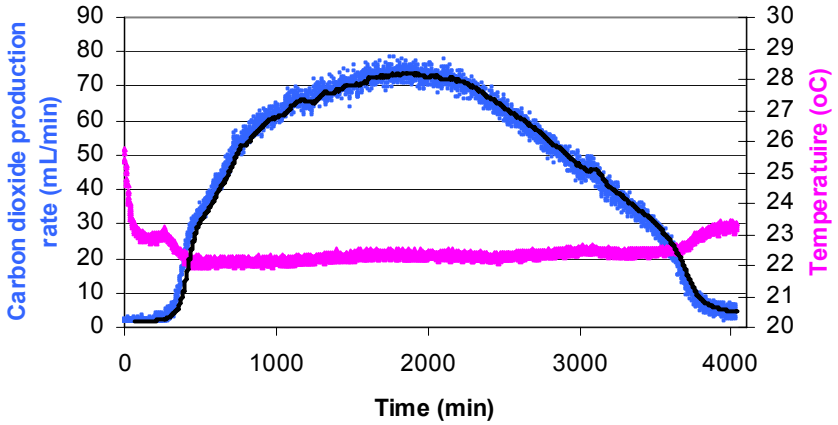

Figure 2. Measurement of the carbon dioxide during the fermentation of substrate with sugar concentration 100g/L and temperature 22°C. Black line represents the mean value of CO_2 flow per hour.

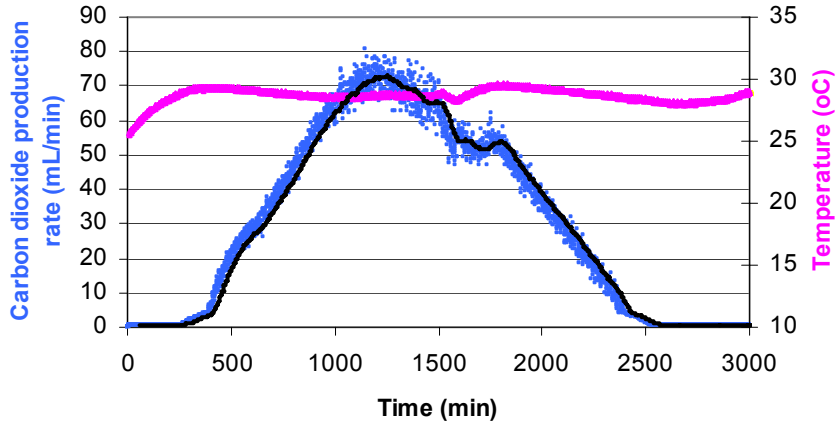

Figure 3. Measurement of the carbon dioxide during the fermentation of substrate with sugar concentration 100g/L and temperature 30°C. Black line represents the mean value of CO_2 flow per hour.

As shown in figures 2 and 3 untreated (raw) data from the CO_2 mass flow meter have low background noise. The calculation of the mean value per hour (black line) eliminates completely the background noise. The system responds rapidly to external influence. Carbon dioxide flow is sensitive to temperature change as an increase in temperature accelerates yeast growth and thus sugar fermentation, as well as forced air input as seen in figure 2 at 1650 min.

The fermentation at 22^{o}C was repeated (figure 4), in mid fermentation 2 L of medium were subtracted and replaced with 2L of fresh medium in order to test fed-batch conditions. The CO_2 emission responded rapidly and the background noise does not increase.

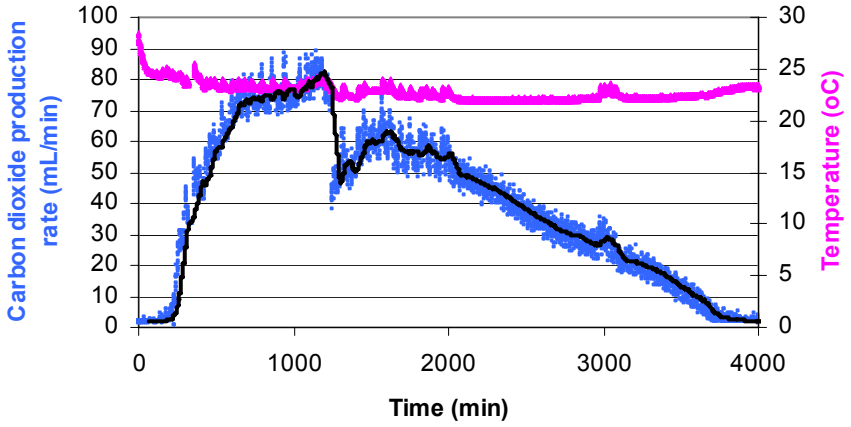

Figure 4. Measurement of the carbon dioxide during fed-batch fermentation of substrate with sugar concentration 100g/L and temperature 22°C. Black line represents the mean value of CO_2 flow per hour.

Fermentations were also conducted with both systems in simultaneous operation in order to assess their combined functionality. At 100 g/L initial sugar concentration, the density showed grater fluctuations even after the on line calculation of the mean value, and differed significantly from manual measurements (figure 5). Possible reasons for this are the sensors range and in between distance as well as a small over due to the addition of the CO_2 flow meter, resulting in an increase of hydrostatic pressure in the fermentor. Another source of possible influence is the increase in pressure in the tubes that connect the fermentor to the pressure sensor due to biomass build-up and fermentation. The gas produced in these tube exerts an additional pressure to the sensors, resulting in false measurements. The CO_2 production rate was not influenced by the simultaneous use of the pressure sensor system (figure 6). The same phenomena were observed at and 200g/L (results not shown).

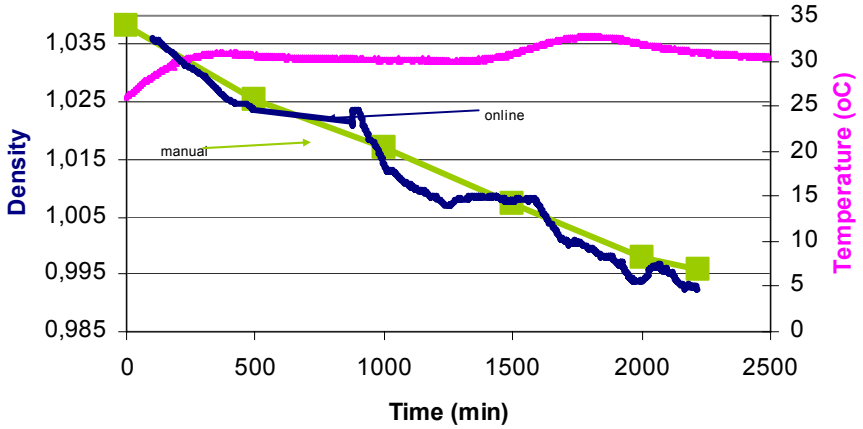

Figure 5. Measurement of the density during fed-batch fermentation of substrate with sugar concentration 100g/L and temperature 30°C, with CO_2 flow meter attached.

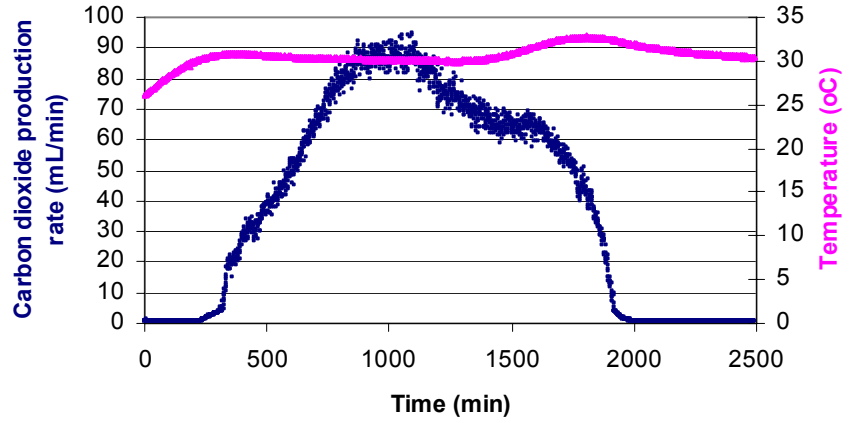

Figure 6. Measurement of the carbon dioxide production rate during fed-batch fermentation of substrate with sugar concentration 100g/L and temperature 30°C.

After replacement of the connection tubes between sensors and fermentor, with large that included valves for biomass extraction, the experiment were repeated (figure 7 and 8). The periodic cleaning of the tubes (biomass removal) resulted in improvement for the density calculation. Background signal noise was significantly lower and correlation with manual density measurements was significantly improved (figure 7). The results are in accordance with those from other authors (Aguera *et al.*, 2005).

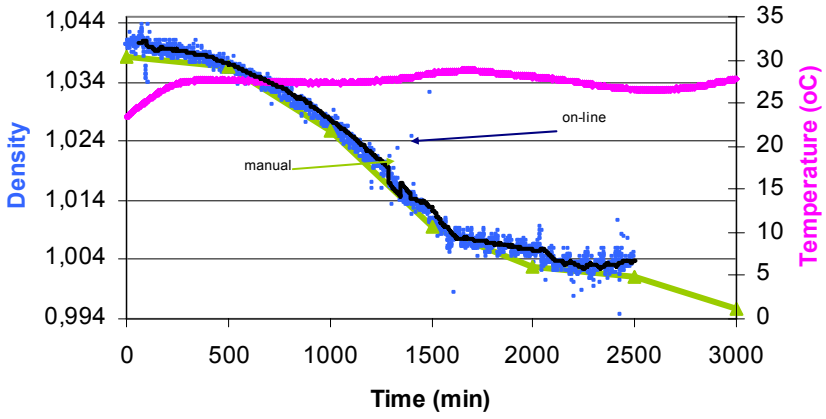

Figure 6. Measurement of the density during fed-batch fermentation of substrate with sugar concentration 100g/L and temperature 30°C, with CO_2 flow meter attached, after system improvement.

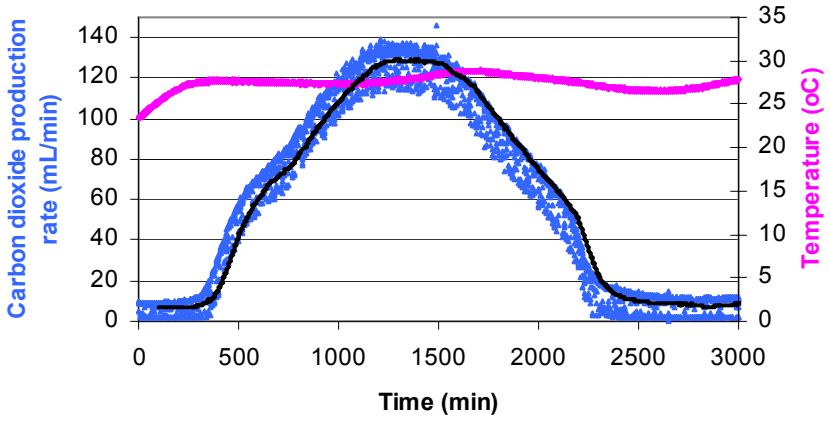

Figure 6. Measurement of the carbon dioxide production rate during fed-batch fermentation of substrate with sugar concentration 100g/L and temperature 30°C, after system improvement.

Conclusions

On-line wine fermentation monitoring permits the real time calculation of the density and of the CO_2 release rate of fermentation. The obtained data can be used to predict fermentation duration and stuck or sluggish fermentations, as well as timely addition of nutrients improving fermentation efficiency. In the present study a new system was used successfully for the on-line measurement in real time of fermentation kinetics. The system included 2 pressure sensors for the calculation of fermentation density and a CO_2 mass flow meter for the measurement of the carbon dioxide production rate. Experimental results show that an accurate measurement is possible and that the obtained data could be used for the prediction of fermentation kinetics.

Acknowledgments
The authors would like to thank Mr. D. Skoutelas and Mr. Ath. Georgilas, students of the Dept. of Enology & Beverages Technology (TEI of Athens Greece) for their participation in the project. The Project is co-funded by the European Social Fund and National Resources - (EPEAEK II) ARXIMHDHS.

Bibliography

Aguera E., Picou C., Perez M., Sablayrolles J.M. (2005a). Vinification à l'échelle pilote (100 l). I. Exemple de la halle pour fermentations différées de l'INRA Pech Rouge. Wine Internet Technical Journal (www.vinidea.net)

Aguera E., Sablayrolles J.M. (2005b). Vinification à l'échelle pilote (100 l). II. Caractérisation - intérêt. Wine Internet Technical Journal (www.vinidea.net)

Aguera E., Sablayrolles J.M. (2005c). Vinification à l'échelle pilote (100 l). III. Controlled Fermentation. Wine Internet Technical Journal (www.vinidea.net)

Bely, M., Sablayrolles, J. M., and Barre, P. (1990). Description of alcoholic fermentation kinetics: its variability and significance. Am. J. Enol. Vit., 41, 319-324

Blouin, J. (1986). L'automatisme en vinification: realites d'aujourd'hui et perspectives de demain. Ind. Agri. Alim., 12, 1243-1246

Boulton, R. B., V. L. Singleton, L. F. Bisson and R. E. Kunkee. (1996). Principles and Practices of Winemaking, Kluwer, New York.

EEC Regulation No. 2676/90, Official Journal No 3, *L 272*.10.90, 35-49

EL Haloui N.D., Picque, G. Gorrieu. (1988). Alcoholic fermentation in winemaking : On-line measurements of density and carbon dioxide evolution, J. Food Engineering, 8, 17-30

El Haloui, N.D., G. Gorrieu, Y. Cleran, A. Cheruy. (1989). Method for On-Line Prediction of Kinetics of Alcoholic Fermentation in Wine Making. J. Ferm. Bioeng. 68, 2, 131-135

Nerantzis E.T., P. Tataridis, S. Hatzandroulis, D. Goustouridis, P. Dimitrakis, I. Sianoudis, V. Betzios. (2006). A New Tool for On line Monitoring of Alcoholic Fermentation. International Congress on Bioprocesses in Food Industries. 18 - 21 June 2006, Patras, Greece, pp.193-194

Nerantzis E.T., P. Tataridis, S. Hatzandroulis, D. Goustouridis, P. Dimitrakis, I. Sianoudis, K. Moutsopoulos. (2007). On line Monitoring of Wine Fermentation. European BioPerspectives 30 May - 1 June 2007. Cologne, Germany. pp. 44

Sablayrolles, JM., C. Dubois, C. Manginot, JL Roustan & P. Barre. (1989).Effectiveness of Combined Ammoniacal Nitrogen and Oxygen Additions for Completion of Sluggish and Stuck Wine Fermentations. J. Ferm. Bioeng. 82, 4, 377-381

Sablayrolles, J. M., Barre, P. and Grenier, P. (1987). Design of a laboratory automatic system for studying alcoholic fermentations in anisothermal enological conditions. Biotechnol. Tech., 1, 181-184

Sablayrolles, J. M. and Barre, P. (1986). Evaluation des besoins en oxygene de fermentations alcooliques en conditions œnologiques simulees. Sci. Aliments, 6, 373-383

Sablayrolles, J.M. and Barre, P. (1989). Pilotage automatique de la temp6rature de fermentation en conditions oenologiques. Sci. Des Alim. 9, 239-251

Schugerl, K. (2001). Progress in monitoring, modeling and control of bioprocesses during the last 20 years. Journal of Biotechnology. 85, 149–173,

Tataridis P. and E. Nerantzis. (2007). Ethanol Production via Solid State Fermentation of Grape Pomace: Combined Effect of Fermentation Parameters on Ethanol Yield. In: A. Bertrand. Les Eaux De Vie Traditionnelles d' Origine Viticole. 2007. Ed. Lavoisier. Paris ISBN 978-2-7430-1040-9, pp. 195-200

Wheat K. (1991). An Automated Fermentation Monitoring System. Dept. of Enology & Viticulture, University of California Davis.