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EXPERIENCES IN MEASURING DENSITY BY FIBER OPTIC SENSORS IN THE GRAPE JUICE FERMENTATION PROCESS

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Abstract – This work presents results in measurement density in grape juice by mean of fiber optic sensors. This measure, which provides alcohol level in the fermentation process, has several problems that are shown as a limitation of these kinds of sensors in practical applications.

Keywords: Fiber optic sensor, density measurement, wine fermentation.

1. INTRODUCTION

Alcoholic fermentation is the process to mainly transform the grape juice sugar contents to alcoholic ethyl, as well as other minor products. This process is carried out by means of micro fungus from the vineyard soil, being called yeast, which, when they are without air, convert sugar in alcohol and carbonic gas.

During that process is essential to control the density, in order to know the sugar quantity remaining in the grape juice, and the temperature, since an excessive warming level can stop the process due the yeast death. Then, the temperature must be keeping around 18 centigrade degrees.

The end of the fermentation is spontaneously achieved when the sugar contents (residual sugar) in the wine juice doesn't exceed a certain value, around 4 or 5 gr per litre. This process lasts around two weeks.

Therefore the wine fermentation is subject to many variables that need to be carefully monitored and controlled. The control of the fermentation is very important to ensure a sustained level of wine quality, as well as to detect a possible premature stoppage of the process, which may causes the lost of the total barrel contents. The final products depend in great part of the conditions of fermentation, being essential that it is completed. If the fermentation is too slow, the bacteria or leavenings can form detrimental secondary products at organoleptic and chemical level. On the other hand, if the fermentation is too fast, the temperature rises causing the loss of aromas, consequently, the final product is a wine of smaller quality [1].

During the alcoholic fermentation, the sugars of the grape (glucose and fructose) produce ethylic alcohol, carbonic anhydride and other products [2]. In 1810, Gay-Lussac obtained the total equation of the fermentation (1). The alcoholic fermentation is considered complete when the must sugars (fructose and glucose) are completely used [3], Fig. 1.

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2 \qquad (1)$$

Then, the measure of the density, as a good indicator of the sugar concentration level, is essential. Currently, the automation degree in the wine industries is poor mainly due to the commercialized sensors shortage at a low cost to facilitate its spread in the small exploitations, where, nowadays, the density measure is manually carried out. To do this, two or three times in a day, the worker has to take a juice sample in the central area of each tank.

The plastic fiber optic sensors have a wide set of advantages due to its technical characteristic [4], [5], as for example: their capability to be in contact with food products, their chemical stability, and their low cost. The utilized measuring principle is based on the lost introduced by a curved and devoid of its covering.

These losses depend on the refraction index of the medium in which the fiber is immersed and, at the same time, this index depends on the medium density. This kind of sensors has been studied by several authors [6]. In the beginning, the results of the laboratory experiments, carried out with little quantities of grape juice, allow us to think in the possibility of achieving a reliable and low cost sensor to do a continuous and automatic measure.

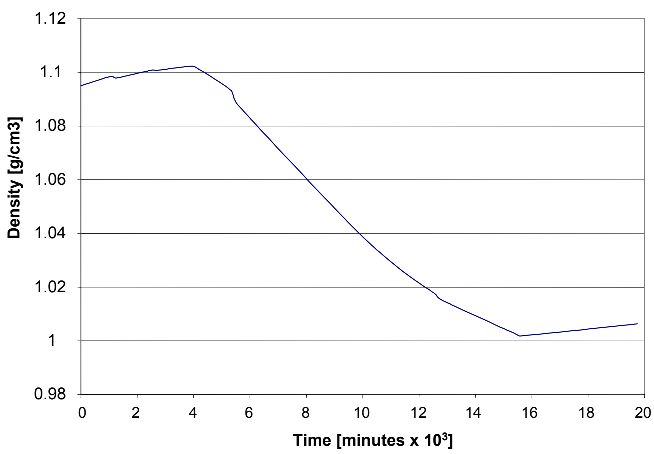

Fig. 1. Density variation trough the fermentation process.

2. DEVELOPED SENSOR

The developed sensor, which follows the scheme of Fig. 2, is based on two plastic optic fibers, one as a reference and another to do the measure (Fig. 3 and Fig. 4), which provide a differential signal. By this way, effects of deviations in the biasing point of the optical devices due, for example, to the temperature changes, are avoided. This configuration has been used in other applications as, for example, to control the battery charge with goods results [7], [8].

The measuring system, shown in Fig. 5, is completed with a data acquisition card and a PC interface (Fig. 6), which provide trends for the density and temperature, as well as, calibration process and data storage. To calibrate the sensor, due its second order response curve (parabolic), three points are needed and, therefore three different solutions, which were obtained from the Brix scale.

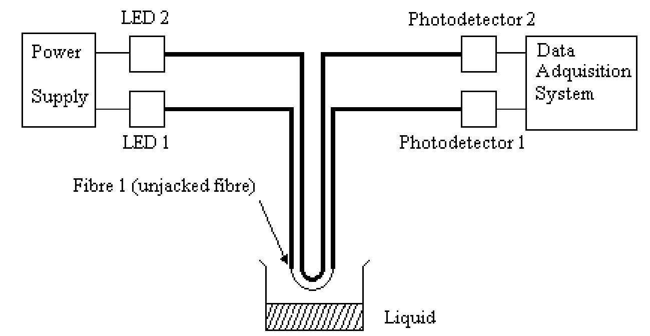

Fig. 2. Setup of the density measuring system based on two curved fiber, one with covered and another without.

In order to compare the results and to have a good reliability, two systems were prepared, as it is shown in Fig. 5, which shows the system test done in the laboratory. After being calibrated, the sensors were immersed in two grape juice tanks with a capacity of 200 l (Fig. 7). The measures were carried out in real conditions in a wine research center located in the "Riasbaixas" area with a wine variety named "Albariño" (white wine).

At the beginning of the fermentation process (the first three days) the performance was good but, when the potassium and tartaric acid concentrations increased, they crystallized as potassium bitartrate. After that, the crystals and began to precipitate the fiber surface as it is shown in Fig. 8 and Fig. 9. This fact caused the lost in the effective surface of the sensor and, consequently, a lost in the sensor response. This effect is shown in Fig. 10, which compare the measures of the developed system with the measures carried out with the well known reference instrument, from Anton Paar maker.

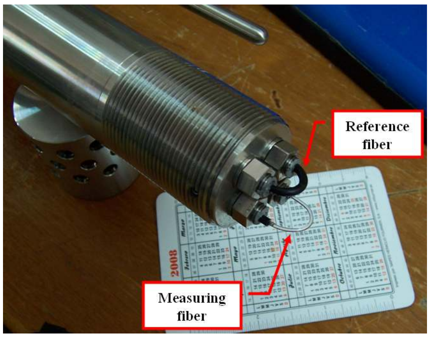

Fig. 3. Photograph that shows the fibers arrangement.

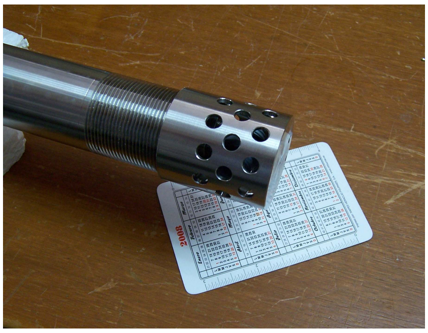

Fig. 4. Photograph showing the support of the fibers with the protection.

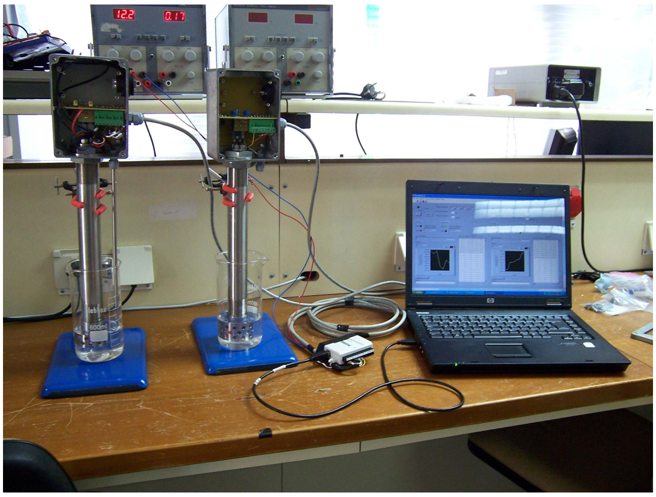

Fig. 5. Photograph showing two measuring systems in the laboratory in order to be calibrated using a sugar reference dissolution.

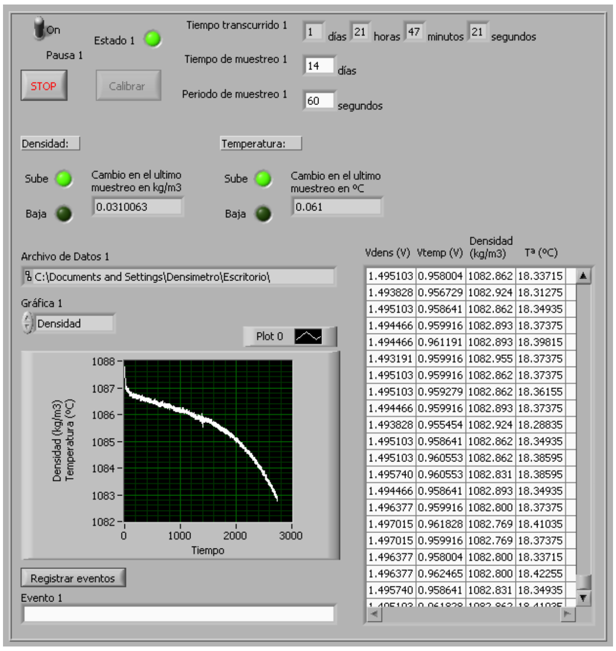

Fig. 6. User interface to control the plant process.

Fig. 7. Photograph of the sensores in the barrels.

Fig. 8. Photograph of the dusty sensores, contaminated with the deposited crystals of potassium bitartrate.

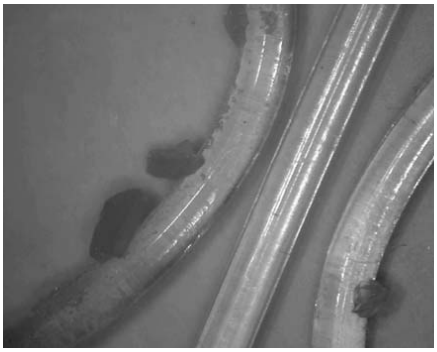

Fig. 9. Photograph with a zoom of the utilized fibers compared with a new one in the center (the width of the fiber is 1 mm). The biggest crystals are about a half mm, but micrometric crystals were also observed by the microscope.

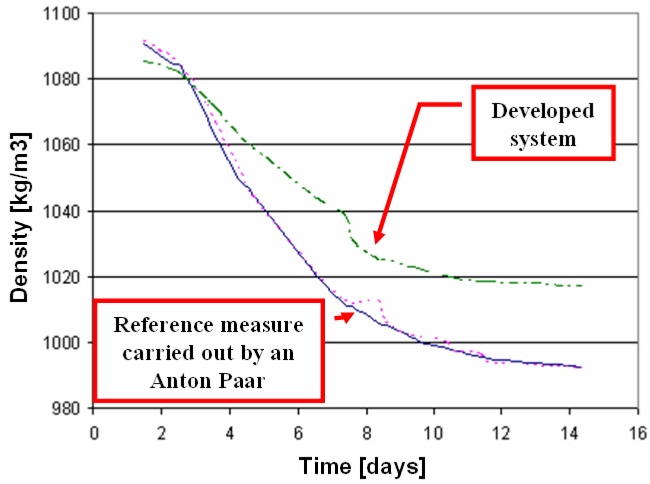

Fig. 10. Comparison of the developed system result with the utilized reference instrument (Anton Paar). The obtained measures do not follow the density changes due the crystals deposited in the fiber surface.

4. CONCLUSIONS

The obtained results show the good performance of the sensors to measure density in simple sugar dissolutions. Nevertheless, due to the complexity in the fermentation process, this system presents serious disadvantages because the sub-products deposited in the fiber surface. This fact is due to the reaction of the potassium and the tartaric acid that are produced in the fermentation process. Notice that it was necessary to get a system to be installed in a real process because the experiences in the laboratory with little quantities of grape juice (one or two liters) have not demonstrate this problem because of the concentrations of sub-products were not enough to be precipitated in the surfaces.

Therefore, this continuous measurement method is not practical. Thus, it is convenient to submerge the sensor only the necessary time to do the measure and, after this, cleaning it with water.

At this point other methods are being considered to achieve a better solution.

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