

# **Brix and chips: IT in the training and research winery of the Robert Mondavi Institute at UC Davis**

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**Abstract:** The Department of Viticulture and Enology of University of California at Davis has recently been endowed with a new training and research (T&R) winery. The heart of the winery is the fermentation room which houses close to 170 fermentation tanks of various sizes. The high-tech fermentation tanks raise fermentation control to a new level. Each is equipped with digital sensors that were purpose-designed by a team of engineers led by a distinguished inventor and CEO of a semiconductor producing firm who also is a wine enthusiast. The sensors on a chip closely monitor fermentation and wirelessly transmit measurement data, e.g. data on Brix, to the winery's computers and into the cloud. In this paper we briefly introduce the winery and we then illustrate digital fermentation monitoring using monitoring of color and phenols in red wine fermentation as an example. We close our contribution with reflections on the transferability into practical enology of the digital sensors.

## **1 Introduction**

In a modern university the applied sciences, like agriculture, enology, and other food sciences, serve mainly three functions: teaching, research, and the transfer of useful research results into industry. Moreover, two principles have proven their worth in applied research and teaching: (i) research and teaching, are best carried out in conjunction, and (ii) some applied research is best conducted not in a laboratory but on a scale that approximates the scale of operations in practice. The actual scale of such applied research is thereby often a compromise between several considerations, such as closeness to operational scales that prevail in practice, need for parallel experiments conducted by students, and costs. Moreover, such operational scale experiments often also serve demonstration purposes.

The Department of Viticulture and Enology of University of California at Davis has recently been endowed with a new training and research (T&R) winery that raises digital fermentation control to new levels. In our paper we briefly provide some general

information on the new winery, and we describe its fermentation control based on digital sensors using a specific application that was recently reported in the research literature [SH14]. We then discuss the potential value of the T&R winery for practical enology.

## **2 The T&R winery**

The T&R winery is part of a teaching and research complex which consists of the winery, a brewery, and a food-processing facility. All three facilities are embedded in the Robert Mondavi Institute. The winery covers an area of 1,160 m<sup>2</sup> - nearly the area of an Olympic-sized swimming pool. Less than half of that area is occupied by the fermentation room, which houses 152 small fermentation tanks of 200 liters capacity and 14 larger tanks of 2,000 liters capacity each. Besides offices, a lab, and several cellaring rooms for bottles and barrels, the winery also has a "Schatzkammer" for special wine collections, a classroom with large windows towards the fermentation room, and, something that is rarely seen in other teaching and research wineries, a special room for the computers that process, store and make accessible the data captured by the sensors that are embedded in the fermentation tanks. Many of the data are, however, stored in the cloud and are accessible there for staff and students. The T&R winery is used by staff of the Dept. of Viticulture and Enology and by MSc-students of enology. At present, the number of students in a MSc-cohort is about thirty.

Prof. Roger Boulton, the godfather of the winery, is proud of the winery's status as the world's first LEED Platinum winery. LEED stands for Leadership in Energy and Environmental Design, a rating system for the design, construction and operation of "green" buildings that was developed by the U.S. Green Building Council (USGBC). Features of the winery that have contributed to its LEED status are the capture of carbon dioxide from all fermenters, the use of solar power for hot water generation, and the thorough insulation of the building, which has drastically reduced energy requirements for air-conditioning, even on Davis' hot summer days.

Even though the winery is operated as part of the public university system of the State of California, its construction was privately funded in full. A major donor was Robert Mondavi, the legendary Oakville wine promoter whose name the institute bears.

## **3 Digital fermentation monitoring**

Wine fermentation is a highly complex process in which yeast cells convert sugar into CO<sub>2</sub> and alcohol, and during which a large but unknown number of aromas are generated or transferred from the grapes to the wine [BO12]. Fermentation has been described as chaotic, comparable to the weather or the stock market [FL94]. Chaotic complexity may have contributed to the evolution of considerable diversity in wine making processes that range from the laissez-faire of "natural" wine making, through moon-calendar guided biodynamic wine making, to high-intervention wine making. Improvements in wine

fermentation that enhance the market value of a wine, or that reduce wine production costs, are not achieved by poetically waxing about the wonders of natural wine making, or by adhering to moon calendars, or by stubbornly clinging to ancient wine making traditions. Rather, progress in wine making, as in the production of any other food and beverage, depends on the ability of producers to acquire knowledge of the scientific laws of enology and to turn this knowledge into superior production skills and products. This is why students of wine making are usually educated in scientific research and training facilities, and not in wine ashrams or wine museums.

In the natural and applied sciences new knowledge often arrives in the wake of new instruments for measurement. Miniaturized digital sensors are such new instruments and, by using digital sensors the T&R winery has raised fermentation monitoring and control to a new level. Each of the fermentation tanks is equipped with sensors that were purpose-designed by a semiconductor producing firm whose CEO also is a winery owner. The sensors on a chip closely monitor fermentation and wirelessly transmit measurement data, e.g. data on must temperature and Brix, to the winery's computers and into the cloud. Moreover, a digital sensor has been developed that allows online monitoring of color and total phenolics during fermentation of red wine [SH14].

Color, mouth-feel, and astringency are important quality attributes of red wines. Color results from extracting during fermentation color pigments from the grape skins. Mouth-feel, astringency, and bitterness of a wine are closely related to the presence of phenolic compounds that are extracted during fermentation from grape skins and from grape seeds.

For phenolic measurements either chromatography or spectroscopy are usually used. Color measurements are usually made using spectroscopy. Both measurement methods require taking samples manually on a regular schedule, refrigerated sample storage, and taking the measurements sometime after sampling. The measurement intervals – not the sampling intervals - may be longer than pump-over intervals and pump-over may occur even after desired levels of color and phenolics extraction have been attained or exceeded.

To allow inline measurement of color and phenolics in real-time during an ongoing fermentation a sensor on a chip was built. The sensor consists of a quartz transmission flow cell, UV and visible light LEDs for light of different wavelengths, photodiodes, analog to digital converters, printed circuit board, microcontroller, power supply, graphical user interface and USB interface. In total, the sensor is composed of more than 30 elements, most of which are available from electronic equipment suppliers.

The sensor was used to measure the evolution of color and total phenolics during fermentation in the T&R winery's research fermenters of grapes of various varieties. Measurements taken by the sensor were compared with measurements taken conventionally and both types of measurements correlated highly, for color as well as for total phenolics.

## 4 Discussion

Monitoring data are valuable for fermentation management when the data can be processed by decision routines or heuristics that enable wine makers to better control fermentation. This suggests that fermentation monitoring data need to be combined with fermentation process models that in turn can be embedded into decision models or fermentation management heuristics. Neither process nor decision models exist at this time, but research on such models is under way. Moreover, both digital data capture and decision heuristics would have to be integrated into winery work flows to assure continued adoption. Finally, the cost of digital sensors, which are at present custom-made and priceless, would have to fall to a level where their use becomes economical. Given that digital sensors are a capital investment which incurs fixed costs, their use is more likely to be economical when they are imbedded in large fermentation tanks.

New technologies regularly incur revenge effects, which are “ironic unintended consequences of ... ingenuity” and which happen “because new structures, devices and organisms react with real people in real situations in ways we could not foresee” [TE97]. A typical revenge effect of new methods of measurement and quantification is the “McNamara fallacy”, that is the human tendency to attach more weight and attention to things that can be quantified than to things that cannot, but that may be more important. In wine production, where many wine attributes that determine the wine experience by a drinker cannot be measured, the consequences of this fallacy may be comparable to the fallacy of reducing female beauty to the measurements of bust, waist, and hip.

## 5 Closing remark

Still, beauty is in the eye of the beholder and wine is more a good than it is an art form. While no one set of measurements will ever capture the many dimensions of fine wine, this new tool will allow winemakers to more consistently produce wines of specific extraction levels. Like other advances in the science of winemaking, on-line measurement of color and phenolics should result in better wines at reduced prices, thus benefiting wine drinkers across the globe.

## References

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