Editorial: Special Issue “Implementation of Digital Technologies on Beverage Fermentation”

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In the food and beverage industries, implementing novel methods using digital technologies such as artificial intelligence (AI), sensors, robotics, computer vision, machine learning (ML), and sensory analysis using augmented reality (AR) has become critical to maintaining and increasing the products’ quality traits and international competitiveness, especially within the past five years. Fermented beverages have been one of the most researched industries to implement these technologies to assess product composition and improve production processes and product quality. Therefore, this Special Issue (SI) is focused on the latest research on the application of digital technologies on beverage fermentation monitoring and the improvement of processing performance, product quality and sensory acceptability. This SI consists of 13 publications with different applications related to product quality assessment using a low-cost electronic nose (e-nose) coupled with ML modelling as rapid methods to assess beer quality traits [1], for fault detection in beer [2] and to evaluate the success of amelioration techniques in smoke-tainted wines [3]. Furthermore, a study on the use of a low-cost ultrasonic sensor and ML to assess alcohol concentration in the beer fermentation process was published in [4]; the use of computer vision analysis to evaluate foam stability in beer using a three-dimensional (3D) camera was reported in [5], and morphological assessment of Saccharomyces cerevisiae yeast during fermentation was shown in [6]. Some methods based on liquid chromatography were reported to assess different chemical compounds in fermented beverages, such as the use of liquid chromatography coupled with electrospray ionization and quadrupole time of flight tandem mass spectrometry (LC-ESI-QTOF-MS/MS) for the characterization of phenolic compounds in herbal tea [7] and high-performance liquid chromatography with fluorescence detection (HPLC-FLD) to analyze biogenic amines in sparkling wine [8]. Different methods were used for the sensory analysis of fermented beverages, such as the use of focus groups with semi-trained panelists to assess the sensory descriptors of kombucha [9] or the use of AR to evaluate the acceptability of yogurt samples in different environments [10]. On the other hand, some applications for monitoring, optimization and improvements during processing have been presented, such as a robotic system, TeeBot, developed for fermentation and sampling [11]. Different techniques have been proposed for the optimization of beer fermentation accounting for parametric uncertainty [12], and a simulation of a closed system to was used to assess the effect of time and temperature on the respiration rate measured as consumed oxygen in olive fermentation used to extract oil [13].

Due to the expertise requirements and the time-consuming and costly nature of traditional methods to assess the quality traits of fermented beverages, novel rapid, reliable and cost-effective methods have been developed involving digital technologies. The use of different sensors coupled with ML and AI has shown to be effective predictive methods along the production line. A low-cost and portable e-nose has been developed and integrated with artificial neural networks (ANN) to accurately predict the type of fermentation...
in beer (97%); consumer acceptability towards carbonation, bitterness, aroma, flavor and overall liking of beer (R = 0.95); different color and foam-related parameters (R = 0.93) [1]; and to assess the presence and level of faults (95%), as well as the specific off-flavors/off-aromas found in beer (>96%) [2]. The same e-nose showed to be highly accurate (>90%) at assessing the effectiveness of smoke taint amelioration techniques using activated carbon and enzymes [3]. A different approach for the use of sensors was presented using an ultrasonic sensor along with long short-term memory neural networks (LSTM) as a cost-effective method to predict alcohol during the fermentation process of beer with high accuracy (R² = 0.94) [4]. Computer vision is very convenient for developing non-invasive, contactless methods for assessing physical measurements. For instance, researchers have developed different approaches to determine foam in beer, one of the most important indicators of its quality. These consisted of measuring 13 different color- and foam-related parameters in beer using an automatic robotic pourer and computer vision algorithms [1], and foam stability in beer was assessed using a 3D camera based on measuring the distance between the camera and the beer [5]. On the other hand, Guadalupe-Daqui et al. [6] used automated computer vision to assess yeast (S. cerevisiae) morphological changes, which are related to yeast health and stress that, at the same time, has an impact on the quality of fermented products such as beer.

Sensory analysis of food and beverages is also important to determine the product’s quality and consumers’ acceptability. Therefore, researchers have developed novel methods applied to fermented beverages. Torrico et al. [10] designed sensory sessions to test different environments using mixed reality with AR headsets. Compared with the regular testing setting in individual booths, significant interactions between samples and the environment were found.

Monitoring and optimizing the production process of fermented beverages is also necessary to reduce time and improve product quality; researchers have developed a TeeBot automatic robotic sampler to monitor the fermentation of either 96 samples of 100 mL or 384 samples of 30 mL, which aids in minimizing the labor and time required for this part of the process [11]. Bhonsale et al. [12] presented three different approaches to optimize the temperature profile of beer fermentation, accounting for parametric uncertainty, which is usually not considered. The authors found that the second-order polynomial chaos was the best approach for high-quality beer manufacturing by maximizing the alcohol concentration and fermentation time.

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