Digital Agriculture Food and Wine

Digital Agriculture, Food, and Wine deals with the implementation and integration of digital data, sensors, technology, and tools on agricultural applications from the farm to consumers. These technologies can range from big data, sensor technology, sensor networks, remote sensing, robotics, unmanned aerial vehicles (UAV). Data processing is performed using new and emerging technologies, such as computer vision, machine learning, and artificial intelligence, among others. The latest advances made by the Digital Agriculture Food and Wine Sciences group (DAFW) from The University of Melbourne deals with crop monitoring/decision making, assessment of quality of produces, non-invasive sensory analysis for consumer perception assessment, and animal stress and welfare assessments.

1. Introduction

The increasing demand from consumers for more premium/high-quality food and beverages, and the fact that the traditional methods to assess these products tend to be time-consuming, not affordable especially for small producers and, in some cases, their need for large laboratory space, raise the need for the development of novel techniques based on emerging technologies to ease the assessment of food and beverage quality traits from farm to consumers. The application of emerging technologies related to artificial intelligence has shown to be effective in the reliable, cost-effective, and rapid prediction of the most critical quality traits to offer products that may satisfy consumers needs.

2. Datas

Traditional methods to assess different quality traits in food and beverages from farm/vineyard to palate such as physicochemical parameters, sensory profile, and consumer acceptability tend to be costly with equipment that requires large space and special installation as well as specialized personnel to operate it. Hence, the results are not readily available to producers, which hinders the ability for near real-time decision making for the management of crops, raw material, or processing methods to improve the quality of final products [1][2][3].

For the viticulture and winemaking industries, despite keeping records from past vintages and accumulating data from operations and management practices plus physicochemical parameters and sensory descriptors of berries and wines [4], there have been minimal attempts to analyze these records using emerging technologies such as data mining and machine learning [5]. The majority of recent studies have focused on the use of robotic platforms and unmanned aerial and terrestrial vehicles to acquire remote sensing data to gather information to be used for decision-making related to irrigation scheduling, pest, and disease detection or yield estimation, among others [6][7][8][9][10]. Examples of some studies on wine are the implementation of machine learning modeling in a vineyard from vertical vintages and weather and water balance data to obtain aroma profiles and physicochemical parameters [11] and sensory profile according to changes in seasonality, showing that quality traits from wines can be characterized and modeled [5]. Near-infrared spectroscopy has been used to measure berries and used to develop machine learning models to predict berry cell dead and living tissue as well as sensory descriptors of the final product (wine) [12].

At the farm level, in the animal industry, emerging technologies such as machine learning have been implemented in a robotic dairy farm, by analyzing and modeling data from four years of weather parameters including temperature-humidity index to assess milk productivity/yield and quality traits such as fat and protein content [13].

In the brewing industry, the quality of beers produced in every batch is usually assessed using traditional techniques that provide results days or even weeks later, and by a master brewer tasting the product and confirming if it has the same sensory characteristics as usual [14][15][2][16]. However, this is not efficient and does not provide reliable, objective, and accurate results. Therefore, artificial intelligence techniques have been developed to assess beer quality within minutes by using an electronic nose to detect volatile compounds translated into aromas using machine learning, in any stage of

the brewing process [3], and an automatic robotic pourer, RoboBEER (The University of Melbourne, Parkville, Vic, Australia), coupled with computer vision analysis to assess color and foam-related parameters in bottles beers [17]. Data obtained from the latter has been used to develop machine learning models to predict the type of fermentation [17], sensory profile [15], physicochemical parameters, aromas [18], consumers acceptability [19], and proteins [20] of the final product.

Other emerging technologies such as the use of remote/non-invasive biometrics to acquire more information from consumers by assessing physiological and emotional responses when evaluating the acceptability of food and beverages have been developed along with a Bio-Sensory Application (The University of Melbourne, Parkville, Vic, Australia) to display the sensory questionnaire and record videos to capture the consumers responses, which are then analyzed using computer vision algorithms [21][22]. These techniques have been applied to assess different products, such as beer [14][23], chocolate [24], labels [25], and insect-based snacks [26]. Similar techniques to assess physiological responses have been adapted to assess any signs related to stress that may be associated with the end products (i.e., milk, meat).

3. Applications

Emerging technologies based on artificial intelligence can be applied to any field. In the food and beverage industry, techniques based on robotics, sensors, supervised machine learning modeling, and computer vision have been applied [2].

Specifically, in viticulture and enology, these technologies have been developed to aid in the assessment and prediction of wine quality traits to satisfy consumers demands. Among the approaches that have been developed to assess or predict wine, quality is the construction of artificial neural network models using weather and water balance data until harvest to predict the wine aroma profile, physicochemical components [11], sensory profile, and color with high accuracy [5]. Furthermore, near-infrared (NIR) spectroscopy data from berries has been used to predict berry cell dead and living tissue, and sensory profile of wines [12]. NIR has also been used to develop models to predict smoke contamination in berries and wine. On the other hand, an electronic nose has been developed to detect smoke taint in berries and wines and predict specific glycoconjugates related to smoke [27].

These modeling techniques have also been applied i) to assess aroma profiles in cocoa plantations based on aerial photogrammetry, canopy architecture and machine learning [28]; ii) to assess big data related to environmental factors affecting dairy cow stress and milk productivity and quality [13]; iii) use of remote sensing and machine learning to assess crop water status [6]; iv) use of robotics and remote sensing to assess the intensity of beer sensory descriptors [15], consumers acceptability [19], type of fermentation [17], proteins [20] and other physicochemical parameters [18], v) use of biometrics (physiological and emotional responses) from consumers to assess acceptability of beer [14][23], and insect-based snacks [29], vi) use of a portable electronic nose coupled with machine learning to assess aromas in beer [3], and vii) use of near infra-red spectroscopy and machine learning to assess physicochemical parameters and sensory descriptors of beer [18][30], and physicochemical parameters in chocolate [31], among others.

References

1. Lu Wang; Da-Wen Sun; HongBin Pu; Jun-Hu Cheng; Quality analysis, classification, and authentication of liquid foods by near-infrared spectroscopy: A review of recent research developments. *Critical Reviews in Food Science and Nutrition* **2016**, *57*, 1524-1538, 10.1080/10408398.2015.1115954.

2. Claudia Gonzalez Viejo; Damir Dennis Torrico; Frank R. Dunshea; Sigfredo Fuentes; Emerging Technologies Based on Artificial Intelligence to Assess the Quality and Consumer Preference of Beverages. *Beverages* **2019**, *5*, 62, 10.3390/beverages5040062.

3. Claudia Gonzalez Viejo; Sigfredo Fuentes; Amruta Godbole; Bryce Widdicombe; Ranjith R Unnithan; Development of a low-cost e-nose to assess aroma profiles: An artificial intelligence application to assess beer quality. *Sensors and Actuators B: Chemical* **2020**, *308*, 127688, 10.1016/j.snb.2020.127688.

4. Lamy, J.L.. Business of Winemaking; Board and Bench Publishing:: San Francisco, CA, USA, 2015; pp. ..

5. Sigfredo Fuentes; Damir D. Torrico; Eden Tongson; Claudia Gonzalez Viejo; Machine Learning Modeling of Wine Sensory Profiles and Color of Vertical Vintages of Pinot Noir Based on Chemical Fingerprinting, Weather and Management Data. *Sensors* **2020**, *20*, 3618, 10.3390/s20133618.

6. Maria Romero; Yuchen Luo; Baofeng Su; Sigfredo Fuentes; Vineyard water status estimation using multispectral imagery from an UAV platform and machine learning algorithms for irrigation scheduling management. *Computers and*

Electronics in Agriculture **2018**, *147*, 109-117, 10.1016/j.compag.2018.02.013.

7. Salvador Gutiérrez; María P. Diago; Juan Fernández Novales; Javier Tardaguila; Vineyard water status assessment using on-the-go thermal imaging and machine learning. *PLOS ONE* **2018**, *13*, e0192037, 10.1371/journal.pone.0192037.

8. Suyash S. Patil; Sandeep A. Thorat; Early detection of grapes diseases using machine learning and IoT. *2016 Second International Conference on Cognitive Computing and Information Processing (CCIP)* **2017**, *2016*, 1-5, 10.1109/ccip.2016.7802887.

9. Jerome Treboux; Dominique Genoud; Improved Machine Learning Methodology for High Precision Agriculture. *2018 Global Internet of Things Summit (GIoTS)* **2018**, *2018*, 1-6, 10.1109/giots.2018.8534558.

10. Ron Berenstein; Ohad Ben Shahar; Amir Shapiro; Yael Edan; Grape clusters and foliage detection algorithms for autonomous selective vineyard sprayer. *Intelligent Service Robotics* **2010**, *3*, 233-243, 10.1007/s11370-010-0078-z.

11. Sigfredo Fuentes; Eden Tongson; Damir D. Torrico; Claudia Gonzalez Viejo; Modeling Pinot Noir Aroma Profiles Based on Weather and Water Management Information Using Machine Learning Algorithms: A Vertical Vintage Analysis Using Artificial Intelligence. *Foods* **2019**, *9*, 33, 10.3390/foods9010033.

12. Sigfredo Fuentes; Eden Tongson; Juesheng Chen; Claudia Gonzalez Viejo; A Digital Approach to Evaluate the Effect of Berry Cell Death on Pinot Noir Wines' Quality Traits and Sensory Profiles Using Non-Destructive Near-Infrared Spectroscopy. *Beverages* **2020**, *6*, 39, 10.3390/beverages6020039.

13. Sigfredo Fuentes; Claudia Gonzalez Viejo; Brendan Cullen; Eden Tongson; Surinder S. Chauhan; Frank R. Dunshea; Artificial Intelligence Applied to a Robotic Dairy Farm to Model Milk Productivity and Quality based on Cow Data and Daily Environmental Parameters. *Sensors* **2020**, *20*, 2975, 10.3390/s20102975.

14. Claudia Gonzalez Viejo; Sigfredo Fuentes; Kate Howell; Damir D. Torrico; Frank R. Dunshea; Integration of non-invasive biometrics with sensory analysis techniques to assess acceptability of beer by consumers. *Physiology & Behavior* **2019**, *200*, 139-147, 10.1016/j.physbeh.2018.02.051.

15. Claudia Gonzalez Viejo; Sigfredo Fuentes; Damir Dennis Torrico; Kate Howell; Frank R. Dunshea; Assessment of Beer Quality Based on a Robotic Pourer, Computer Vision, and Machine Learning Algorithms Using Commercial Beers. *Journal of Food Science* **2018**, *83*, 1381-1388, 10.1111/1750-3841.14114.

16. Lees, M.; Rogers, P.; Campbell, D.; Pecar, M.; Sudarmana, D.; Intelligent Systems for the Brewery based on Real-Time Measurement of Biological Parameters.. *In Proceedings of Proceedings of the 9th Australian Barley Technical Symposium* **1999**, *1999*, 2.8, .

17. Claudia Gonzalez Viejo; Sigfredo Fuentes; Guangjun Li; Richard Collmann; Bruna Condé; Damir Dennis Torrico; Development of a robotic pourer constructed with ubiquitous materials, open hardware and sensors to assess beer foam quality using computer vision and pattern recognition algorithms: RoboBEER. *Food Research International* **2016**, *89*, 504-513, 10.1016/j.foodres.2016.08.045.

18. Claudia Gonzalez Viejo; Sigfredo Fuentes; Beer Aroma and Quality Traits Assessment Using Artificial Intelligence. *Fermentation* **2020**, *6*, 56, 10.3390/fermentation6020056.

19. Claudia Gonzalez Viejo; Damir Dennis Torrico; Frank R. Dunshea; Sigfredo Fuentes; Development of Artificial Neural Network Models to Assess Beer Acceptability Based on Sensory Properties Using a Robotic Pourer: A Comparative Model Approach to Achieve an Artificial Intelligence System. *Beverages* **2019**, *5*, 33, 10.3390/beverages5020033.

20. Claudia Gonzalez Viejo; Christopher H. Caboche; Edward D. Kerr; Cassandra L. Pegg; Benjamin L. Schulz; Kate Howell; Sigfredo Fuentes; Development of a Rapid Method to Assess Beer Foamability Based on Relative Protein Content Using RoboBEER and Machine Learning Modeling. *Beverages* **2020**, *6*, 28, 10.3390/beverages6020028.

21. Sigfredo Fuentes; Claudia Gonzalez Viejo; Damir D. Torrico; Frank R. Dunshea; Development of a Biosensory Computer Application to Assess Physiological and Emotional Responses from Sensory Panelists. *Sensors* **2018**, *18*, 2958, 10.3390/s18092958.

22. Claudia Gonzalez Viejo; Sigfredo Fuentes; Damir D. Torrico; Frank R. Dunshea; Non-Contact Heart Rate and Blood Pressure Estimations from Video Analysis and Machine Learning Modelling Applied to Food Sensory Responses: A Case Study for Chocolate. *Sensors* **2018**, *18*, 1802, 10.3390/s18061802.

23. Claudia Gonzalez Viejo; Sigfredo Fuentes; Kate Howell; Damir Torrico; Frank R. Dunshea; Robotics and computer vision techniques combined with non-invasive consumer biometrics to assess quality traits from beer foamability using machine learning: A potential for artificial intelligence applications. *Food Control* **2018**, *92*, 72-79, 10.1016/j.foodcont.2018.04.037.

24. Damir Dennis Torrico; Sigfredo Fuentes; Claudia Gonzalez Viejo; Hollis Ashman; Nadeesha M. Gunaratne; Thejani M. Gunaratne; Frank R. Dunshea; Images and chocolate stimuli affect physiological and affective responses of

consumers: A cross-cultural study. *Food Quality and Preference* **2018**, *65*, 60-71, 10.1016/j.foodqual.2017.11.010.

25. Damir Dennis Torrico; Sigfredo Fuentes; Claudia Gonzalez Viejo; Hollis Ashman; Paul A. Gurr; Frank R. Dunshea; Analysis of thermochromic label elements and colour transitions using sensory acceptability and eye tracking techniques. *LWT* **2018**, *89*, 475-481, 10.1016/j.lwt.2017.10.048.

26. Fuentes, S., Wong, Y.Y., and Gonzalez Viejo, C.; Non-invasive biometrics and machine learning modeling to obtain sensory and emotional responses from panelists during entomophagy. *Foods* **2020**, *In press*, In press, .

27. Fuentes, S., Tongson, E., Summerson, V., and Gonzalez Viejo, C.; Advances in Artificial Intelligence (AI) to Assess Smoke Contamination in Grapevines and Taint in Wines due to Increased Bushfire Events. *Wine and Viticulture Journal* **2020**, *35*, 26-29, .

28. Sigfredo Fuentes; Gabriela Chacon; Damir D. Torrico; Andrea Zarate; Claudia Gonzalez Viejo; Spatial Variability of Aroma Profiles of Cocoa Trees Obtained through Computer Vision and Machine Learning Modelling: A Cover Photography and High Spatial Remote Sensing Application. *Sensors* **2019**, *19*, 3054, 10.3390/s19143054.

29. Fuentes, S., Wong, Y.Y., and Gonzalez Viejo, C.; Non-invasive biometrics and machine learning modeling to obtain sensory and emotional responses from panelists during entomophagy. *Foods* **2020**, *In Press*, In Press, .

30. Claudia Gonzalez Viejo; Sigfredo Fuentes; Damir D. Torrico; Kate Howell; Frank R Dunshea; Assessment of beer quality based on foamability and chemical composition using computer vision algorithms, near infrared spectroscopy and machine learning algorithms. *Journal of the Science of Food and Agriculture* **2017**, *98*, 618-627, 10.1002/jsfa.8506.

31. Thejani M Gunaratne; Claudia Gonzalez Viejo; Nadeesha M Gunaratne; Damir D. Torrico; Frank R. Dunshea; Sigfredo Fuentes; Gunaratne; Gonzalez Viejo; Thejani M. Gunaratne; Thejani M. Gunaratne; et al. Chocolate Quality Assessment Based on Chemical Fingerprinting Using Near Infra-red and Machine Learning Modeling. *Foods* **2019**, *8*, 426, 10.3390/foods8100426.

32. Thejani M Gunaratne; Claudia Gonzalez Viejo; Nadeesha M Gunaratne; Damir D. Torrico; Frank R. Dunshea; Sigfredo Fuentes; Gunaratne; Gonzalez Viejo; Thejani M. Gunaratne; Thejani M. Gunaratne; et al. Chocolate Quality Assessment Based on Chemical Fingerprinting Using Near Infra-red and Machine Learning Modeling. *Foods* **2019**, *8*, 426, 10.3390/foods8100426.