Food Control 71 (2017) 383–392

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Development of a robotic and computer vision method to assess foam quality in sparkling wines

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ARTICLE INFO

Article history:
Received 23 March 2016
Received in revised form
30 June 2016
Accepted 17 July 2016
Available online 20 July 2016

Keywords:
Automatic pourer
Soluble protein
Effervescence
Bubble
Image analysis
Carbonated beverage

ABSTRACT

Quality assessment of food products and beverages might be performed by the human senses of smell, taste, sound and touch. Likewise, sparkling wines and carbonated beverages are fundamentally assessed by sensory evaluation. Computer vision is an emerging technique that has been applied in the food industry to objectively assist quality and process control. However, publications describing the application of this novel technology to carbonated beverages are scarce, as the methodology requires tailored techniques to address the presence of carbonation and foamability. Here we present a robotic pourer (FIZZeyeRobot), which normalizes the variability of foam and bubble development during pouring into a vessel. It is coupled with video capture to assess several parameters of foam quality, including foamability (the ability of the foam to form) drainability (the ability of the foam to resist drainage) and bubble count and allometry. The foam parameters investigated were analyzed in combination to the wines scores, chemical parameters obtained from laboratory analysis and manual measurements for validation purposes. Results showed that higher quality scores from trained panelists were positively correlated with foam stability and negatively correlated with the velocity of foam dissipation and the height of the collar. Significant correlations were observed between the wine quality measurements of total protein, titratable acidity, pH and foam expansion. The percentage of the wine in the foam was found to promote the formation of smaller bubbles and to reduce foamability, while drainability was negatively correlated to foam stability and positively correlated with the duration of the collar. Finally, wines were grouped according to their foam and bubble characteristics, quality scores and chemical parameters. The technique developed in this study objectively assessed foam characteristics of sparkling wines using image analysis whilst maintaining a cost-effective, fast, repeatable and reliable robotic method. Relationships between wine composition, bubble and foam parameters obtained automatically, might assist in unraveling factors contributing to wine quality and directions for further research.

1. Introduction

Computer vision and automated process control have been widely used in the food industry to manage production of and to assure the maintenance of product safety and quality (Ma et al., 2014). However, the wine industry has not yet extensively incorporated these novel technologies, most likely due to a lack of training in the fundamentals of tailored developed technology. Most of the applications to increase quality of wines are found in the viticulture process by using remote sensing and precision technology so as estimate yield (Diago et al., 2012); assessment of

Abbreviations: t_1, maximum volume time; V_f, foam volume; C_v, collar velocity; h, collar height; F_v, foam velocity; D_r, drainability; W_f, percentage of wine in the foam; t_c, collar time; L_f, average foam lifetime; E, foam expansion; h_c, collar initial height; S_b, small bubbles; Q, flow rate; C, method traditional; A., autolysis; T, Transfer method; A, 9–24 months of autolysis; B, +24 months of autolysis.

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http://dx.doi.org/10.1016/j.foodcont.2016.07.020
0956-7135/

biotic and abiotic stresses (De Bei et al., 2011; Fuentes, Poblete-Echeverría, Ortega-Farias, Tyerman, & De Bei, 2014); to evaluate grape quality (Hall, Lamb, Holzapfel, & Louis, 2002); and to monitor grapevine phenology (Herzog et al., 2014). The available literature shows applications in wines for process control focused on monitoring the alcohol content (Oikonomou, Raptis, & Sanopoulou, 2014), malolactic fermentation (Gennaro et al., 2013), quantification of free sulfur dioxide (Monro et al., 2012) and polyphenols (Photinon, Chalermchart, Khanongnuch, Wang, & Liu, 2010). Other technological applications have been developed for quality control by using electronic tongues (Gutiérrez et al., 2011) and noses (Aleixandre et al., 2015). There is, consequently, an evident lack of computer vision and sensing technology applied to assist process and quality control during winemaking. The opportunities are vast and strengthened by the interest of the wine industry in modernizing the methods of and guaranteeing the image of high-quality producers.

Sparkling wines are wines presenting carbonation obtained from the introduction of carbon dioxide (CO_2) by either artificial injection during the bottling process, or by a second alcoholic fermentation that occurs in bottles or pressurized tanks (Jackson, 2009). When the second alcoholic fermentation is realized in bottles, it is named either: method traditional, *méthode Champenoise* or bottle fermented; when the second alcoholic fermentation in performed in pressurized tanks, the process is called transfer method. Subsequently, the sparkling wines obtained by the method traditional and transfer method are left in contact with lees (dead yeast cells), a process known as autolysis, to develop the flavor and aroma characteristics. The quality of sparkling wines due to the presence of carbonation, is primarily assessed by analyzing the bubble and collar dynamics (the latter assessed as the row of bubbles at the edge of the glass), which are formed during the pouring and drinking process (Liger-Belair, 2005). Therefore, the assessment of sparkling wine is highly influenced by the quality of the foam produced during the release of CO_2 upon bottle opening and subsequent wine appreciation.

The use of image analysis for foam quality assessment has been previously reported by Sarker, Bertrand, Chtioui, and Popineau (1998). In their study, the process consisted of injecting pure nitrogen into a previously degassed wine sample and further analysis of images to characterize the foam properties. The use of gas injection to study foam characteristics has been introduced by Foulk and Miller (1931) and Bikerman (1938). Furthermore, the Bikerman method has been adapted or modified to standardize the procedure to uncover the effect of different compounds in food produces (Davis & Foegeding, 2007; Phillips et al., 1990; Robillard et al., 1993) and to study foamability and foam stability in wines (Maujean, Poinsaut, Dantan, Brissonnet, & Cossiez, 1990; Moreno-Arribas, Pueyo, Nieto, Martı;n-Álvarez, & Polo, 2000). A later development, which includes image analysis, as a methodology to evaluate sparkling wine has been reported by Cilindre, Liger-Belair, Villaume, Jeandet, and Marchal (2010).

Computer vision is the science and technology applied to the theory, design and implementation of algorithms that automatically process visual data to recognize objects and convey the information in numerical or other meaningful ways (Ikeuchi, 2014). A typical computer vision system includes: image acquisition, image processing and results delivered as meaningful information to assist product classification. The present study describes the development of a computer vision assisted method composed of a robotic pourer (FIZZeyeRobot) coupled with video capture to standardize image acquisition together with an automated image processing and analysis using customized algorithms. The results are conveyed in numerical and graphical forms using multivariate data analysis techniques representative of foam quality and product classification.

The aim of this study was to develop a fast, affordable, reliable and robust method for quality monitoring and control to be used in sparkling winemaking, which maintains the portability required for use in diverse environmental situations. By understanding the bubble and foam parameters and their relationship with quality, the technological process of sparkling wine production can be measured, benchmarked and regulated.

2. Experimental procedure

The development of a robotic and computer vision method to assess foam quality in sparkling wines was composed of several steps: video acquisition; video processing and analysis; quantification of foam quality parameters; and delivery of results in numerical and graphical form; a schematic representation of the process is shown in Fig. 1.

2.1. Video acquisition

2.1.1. FIZZeyeRobot (robotic pourer)

A robotic pourer, the FIZZ-eyeRobot, was developed to standardize the volume poured and to eliminate human error during wine pouring. The robotic pourer consists of a chamber to contain the wine bottle, raised and tilted by an electrically powered motor with a lift capacity of 5 kg (Fig. 1). The lifting mechanism is controlled using an Arduino Uno mini® programmable board (Arduino Inc., Rome. Italy). The customized code developed allows controlling the pouring process, either manually or automatically, by activating a switch. The automated pouring can be calibrated to the original position of the bottle before the pouring and then to allow it to be tilted up to 30° angle from the vertical. By pressing the activating button, the first pour of 50 ml of wine is delivered to the glass; if pressed again, the second pour of 50 ml is delivered, from the same bottle. The precise bottle size and mass can be entered into the Arduino® control program to ensure the accuracy of the pouring volume.

The pourer enclosure includes a video camera to capture the images at a rate of one per 0.5 s using an IPEVO View 2 camera of 2-megapixel resolution (IPEVO, Sunnyvale, CA. USA). The images were captured automatically using the Image Acquisition Toolbox® from Matlab®. The captured videos (.avi file format) were then processed using a customized code developed in Matlab ver2014b (Mathworks Inc. Matick, MA. USA).

2.1.2. Glass shape and washing

It has been shown that the shape of the glass influences the losses of dissolved CO_2 (Liger-Belair, Polidori, & Zeninari, 2012). To avoid variation in glass morphology, International Standard Wine Tasting Glasses (ISO wine glass) were used. Those used were Luigi Bormioli ISO wine tasting glasses, with a rim diameter of 46 mm, height of 155 mm, and a total volume of 215 mL. Cellulose fibers present in the glass can act as the primary origin of nucleation sites, which creates bubbles in the glasses presenting natural effervescence (Liger-Belair, Beaumont, Jeandet, & Polidori, 2007). Thus, to prevent random nucleation sites, the glasses were uniformly and mechanically etched to provide a continuous flow of bubbles and washed at 45 °C for 30 min and blow dried in a dishwasher (Bosch Group, Stuttgart, Germany).

2.1.3. Image processing and analysis

After the video capture and subsequently transference to a personal computer, the images were further analyzed by an automated code. The procedure implemented was, by analogy, similar to determining the concentration of a compound by spectrophotometric analysis: the concentration is estimated by