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Viewpoint

Electronic and bioelectronic tongues, two promising analytical tools for the quality evaluation of non alcoholic beer

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Authentication of the flavor of non alcoholic beer and control of its quality according to the present standards is an actual challenge in brewery. Electronic and bioelectronic tongues, which *could be* known as the taste sensors, are the advanced and emerging analytical technologies simulating the taste detection modality of the human tongue by means of electrochemical sensors or biosensors array. Although, application of electronic tongue has been reported for alcoholic beers but no work on the flavor sensory evaluation of non alcoholic beer by use of bioelectronic tongue has been published. Employment of electronic and bioelectronic tongues can reduce some problems in quality control of non alcoholic beers. Recently published works show a promising perspective for the fulfillment of this goal. This paper discusses and concludes that these analytical tools have a high potential application in brewery to monitor the flavor of non alcoholic beer in the immediate future.

Taste substances are getting through the biological membrane of gustatory cells in the taste buds of tongue. Taste is perceived when the information on taste substances is transduced into an electrical signal, which is transmitted along the nerve fiber to the brain (Chandrashekar, Hoon, Ryba, & Zuker, 2006; Toko, 2006). Electronic and *probably* bioelectronic tongues are known as two promising tools for the taste assessment of the foodstuffs (Di Natale *et al*., 2000; Escuder-Gilabert & Peris, 2010; Toko, 1998; Vlasov, Legin, & Rudnitskaya, 2008; Vlasov, Legin, Rudnitskaya, D'Amico, & Di Natale, 2000; Winquist, Holmin, Krantz-Rülcker, Wide, & Lundström, 2000). The concept of the electronic tongue is based on the organization principles of the human taste sensory system. Electronic tongues are the analytical systems that operate by coupling an array of sensors with a chemometric data processing stage (Vlasov, Legin, & Rudnitskaya, 2002; Winquist, 2008; Rudnitskaya & Legin, 2008). As such these systems can be designed to perform quantitative multi determinations, to identify substances of varieties, or to counterbalance interference effect. To mimic the human sense of taste, which is the objective of the artificial taste system, would be just another possible application, which probably required specific design for the sensors and for the data treatment. Artificial taste systems and electronic tongues, therefore, are not equivalent; the former is a specific application of the latter.

As mentioned above, an electronic tongue includes an array of cross-sensitive (or partially selective) chemical or

biochemical sensors and pattern recognition and chemometrics for the analyzing their complex output (Ciosek & Wroblewski, 2007; Mohapatra & Panigrahi, 2006; Rodriguez-Mendez *et al*., 2008). Recently the concept of biosensor array has been considered in food quality and safety characterization as documented by Gutés, Céspedes, Alegret, and del Valle (2005). This work dealt with the application of single amperometric biosensor to the detection of phenols in the mixture. Voltammograms recorded using these biosensors were processed using artificial neural network (ANN), which allowed simultaneous determination of different phenols. Therefore, this biosensor can be considered as a "virtual" electronic tongue. If an array of biosensors is exposed to food, each biosensor recognizes one or groups of analytes as well as the quantity of a specific analyte present in the sample, and then with chemometric tools, accurate characterization of the sample could be achieved. Biosensor array to food quality characterization is a novel and emerging idea and there are few reports in the literature on the application of bioelectronic tongue. For instance, Solna *et al*. (2005) implemented a bioelectronic tongue for the characterization of wastewater samples. Application of some chemometric tools were considered for reduction of the data dimensionality and identification of the samples studied. This biosensor array was exploited to recognize four different wastewater samples (untreated, alarm, alert and normal) from chemithermomechanical pulp mill. HRP-modified and bare platinum sensors included at the bioelectronic tongue array showed the most convenient responses (Tonning *et al*., 2005).

Utilization of these analytical tools has shown promising results, a valuable review paper on application of such instruments is found in literature (Zeravik, Hlavacek, Lacina, & Skladal, 2009). Sensitivity improvement has been of interest to the researchers working on taste quantification and many technological and computational techniques are being employed for this purpose (Ciosek, Kraszewska, & Wroblenski, 2009; Gutiérrez, Gutés, Céspedes, del Valle, & Muñoz, 2008; Liyama, Ezaki, & Toko, 2009; Lorenz, Reo, Hendi, Worthington, & Petrossian, 2008; Mimendia *et al*., 2010; Rodriguez-Mendez, Gay, & de Saja, 2009; Winquist, Krantz-Rulcker, & Lundstrom, 2008; Woertz, Tissen, Kleinebudde, & Breitkreutz, 2010). At present, usage of nanotechnology in biosensor preparation is under consideration to enhance selectivity and sensitivity as well as biosensor performance (Darder *et al*., 2009; Lima, Hernandez, Carvalho, Carvalho, & da Silva, 2009; Rodriguez-Mendez & de Saja, 2009; Siqueira, Caseli, Crespilho, Zucolotto, & Oliveira, 2010; Apetrei *et al*., 2011).

According to the literature, electronic and bioelectronic tongues, also known as the taste sensors, based on the different measuring concepts including potentiometry, voltammetry, etc were developed. This is worth mentioning that discrete biosensors have been applied to selective detection of food components such as ethanol, sugars, etc, that contribute to some taste characteristics as well. However, no applications of bioelectronic tongues to the assessment of the taste or quality of food have been reported. Nonetheless, electronic tongue has shown to be promising tools for assessment of foodstuff flavor while bioelectronic tongue *might be* used for this purpose.

Nowadays, there are big demands in the food industry for the quality control of the product in process lines and development of new food products (Apetrei *et al*., 2007; Gay *et al*., 2010).

Sensorial quality of non alcoholic beer is the primary method for the consumer to express his preferences (Ghasemi-Varnamkhasti, Mohtasebi, Ahmadi, Rodriguez-Mendez, Siadat, M., & Razavi, 2009; Ghasemi-Varnamkhasti, Mohtasebi, Siadat, & Balasubramanian, 2009). A non alcoholic beer has a restricted final alcohol by volume content lower than 0.5%. Non alcoholic beers can tender some opportunities that can be addressed by marketers. This is true in particular in a context where more firm regulations are likely to ban or restrict alcoholic beverage from classical usage situations. A list of profits for the non alcoholic beers are: (a) no constraint for sale by hours and by places of consumption; (b) no warning on labels for sensitive consumer subgroups such as pregnant women; (c) health benefits of beer can be promoted; (d) no social judgment for heavy drinking out of the home; (e) no excise duty or a reduced one is charged; (f) export and distribution are made possible in countries where the sale of alcoholic beverages is banned for religious reasons; (g) a wider domestic potential market which can hold members of religious groups which forbid, discourage, or restrict consumption of alcoholic beverages; (h) a non alcoholic beer can be targeted at non-traditional domestic market segments such as younger people, females or those who like the taste of beer but not the alcoholic content; (i) fewer calories than the regular beer varieties may attract potential consumers who are sensitive about weight issues (Porretta & Donadini, 2008).

Apart from these merits, marketers have to pay particular attention that non alcoholic beers have been criticized because they have a different flavor fingerprint against regular beers. General taste in non alcoholic beer is stated to be almost poor and mild due to a very low intensity of the most descriptors generally associated with beer, and to a special lack of complexity and balance which this is attributed to the absence of alcohol. Aqueous solutions of alcohol could cause a warming sensation which, on swallowing, continues in the throat and on into the stomach; this sensation is generally pleasing to man. Ethanol is a recognized flavor potentiator. It enhances sweetness in beer and plays a dual role in alcoholic beverage. It is well known that in non alcoholic beer, some flavors are not enhanced due to lack of alcohol, the others are suspended or their flavor characters are altered as well. In a consequence, flavor monitoring of non alcoholic beer sounds to have a great importance to the brewing industry, since sensory properties are important factors in the determination of consumer liking. The flavor attributes of beer are critical to its overall acceptance by consumers. There are few practical options for the substantial elimination of

components from beer during production, which limits the opportunities for remedial action. This means that, for product consistency, a fine degree of control is mandatory. This is particularly relevant to beer flavor, where the typical dynamic range of flavor perception varies from sub-ppt (low picomolar) to high-ppm (high millimolar) concentrations.

Perhaps the biggest remaining quality challenge for the brewers is the achievement of flavor stability. The factors determining flavor robustness in non alcoholic beer are extremely complicated. Achieving flavor stability is a major challenge, especially as what happens for the beers between packaging and consumption that is often out of the control of the brewer. It has even been suggested that the aged character should be maximized in beer before it leaves the brewery, namely no further flavor change will occur.

Considering the several limitations of traditional analytical procedures to evaluate taste in non alcoholic beer, such as the sensorial analysis by means of a trained panel of experts, alternative techniques should be provided. Electronic and bioelectronic tongues could simulate the taste detection modality of the human tongue by means of sensors array, but overcoming the variability of human perception (Ghasemi-Varnamkhasti, Mohtasebi, & Siadat, 2010; Scampicchio, Ballabio, Arecchi, Cosio, & Mannino, 2008).

To date, no research has been reported on the flavor evaluation of non alcoholic beer by use of electronic and bioelectronic tongues, which is probably due to low interest to non alcoholic beer from consumption view points. In recent years, employing advanced technologies in brewing process (i.g in fermentation stage), the quality and the taste of non alcoholic beers have been fairly improved in such a way the consumption of such product has been of great interest to the consumers. This means the necessity of employment of electronic and probably bioelectronic tongue for the quality evaluation of non alcoholic beer to enhance more its quality and solve the remaining problems in taste and flavor. However, only few publications have been dedicated to the flavor assessment of alcoholic beer using electronic tongue as reported in literature (Lvova, Paolesse, Di Natale, & D'Amico, 2006; Toko, 1996). More recently, the promising results have been reported in the case of non alcoholic beer (Arrieta, Rodriguez-Mendez, de Saja, Blanco, & Nimubona, 2010; Polishin *et al*., 2010; Rudnitskaya *et al*., 2009). They correlated the taste perception attributes with sensory panel and measured by electronic tongue with very promising results for a number of beer samples. The majority of the beer samples studied by these authors were alcoholic beer even though few non alcoholic beer brands are seen in their work. So, flavor evaluation of non alcoholic beer has a high potential to be studied by means of electronic and bioelectronic tongues since the information obtained on flavor could give an insight into process control in non alcoholic beer production. Consequentially, a brewer can check the non alcoholic beer production line that whether flavor attributes of the non alcoholic beer processed are within the categories accepted or not. Also, non alcoholic beer production manager could decide about the items contributing to the beer flavor quality.

Conclusion

Brewers focus on those chemical and physical properties which have a significant contribution on the final flavor quality of non alcoholic beers. However, the brewers' descriptions of the similarities and differences of diverse non alcoholic beer tastes are still very subjective and imprecise. Sensory taste profile could be helpful in clarifying and objectifying these descriptions. These methods are time consuming and require complex and expensive provisions. However, there is a promising direction for the development of biomimetic sensor array systems (Del Valle, 2010; Riul, Dantas, Miyazaki, & Oliveira, 2010). During last decade, few reports have been published in the bibliography dealing with the application of electronic tongues in flavor monitoring of alcoholic beer. More recently, few works have been published on analysis of non alcoholic beer using electronic tongue. Up to now, no research has been published on the flavor evaluation of non alcoholic beer by means of bioelectronic tongue. It is unlikely that application of bioelectronic tongue would give insights into beer production control as responses of the systems are likely to be non-selective in such medium as beer. On the other hand, bioelectronic tongue would be useful tool for process control.

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