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Review Article

A Review on Evolutionary Trends in Sensory Profile Analysis of Alcoholic Beverages

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ABSTRACT

The alcoholic beverage industry is continuously growing and evolving. The industry constantly working to meet the consumer's palatability preferences and for this, the most valuable tool required is the know-how of alcoholic beverages' impact on consumers' senses. Different sensory evaluation methods are extensively used in the wine, beer, and distilled spirits industries for product development and quality control. Hence, this review is focused on the different sensory evaluation methods adopted by the alcoholic beverage industries and how they continue to lead the way in sensory evolution through the advancement of biomimetic technology.

Keywords- Sensory evaluation, alcoholic beverages, senses, analytical tools

INTRODUCTION

One of the most significant tasks of the beverage industry is to figure out how alcoholic beverages impact consumers' senses. The five common senses of humans determine their perception of a specific beverage and they can only get the advantages of delightful drinking if their senses accept it. As a result, customer reaction as seen via the five senses is regarded as an important indicator of beverage acceptance. For example, the sound of opening a beer can create an expectation regarding the product's freshness. Similarly, the presentation of good quality brandy in a cheap polystyrene container will not only ruin its expected quality but also the sensory quality (sight and touch) and the same goes for color like strawberry flavor in red drinks [53]. Among all the senses the most significant ones are the chemical senses for appreciating our drinks. These include taste, smell and chemesthesis (prickle, texture and temperature). Taste detects compounds present in beverages using chemosensors present in the mouth; olfaction detects compounds emitted by drinks in the oral cavity and throat to the nose and chemesthesis mediates information about the irritants through nerve endings in the skin [14].

Sensory evaluation is a scientific approach for eliciting, measuring, analyzing, and interpreting responses to items via the senses of sight, smell, touch, taste, and sound. Precision, accuracy, and sensitivity are all important in sensory evaluation, to minimize false-positive outcomes [32]. Humans are usually used as test subjects in judging alcoholic beverages for their sensory profile. To conduct an efficient sensory evaluation, the analyst must first understand the study's aim, then determine a suitable experimental design, recruit panelists which are most suited for the task, prepare and display the samples properly, and accurately interpret the results. A sensory evaluator should always check if the sensory method is being used correctly and if any errors were introduced at any point throughout the experiment [10]. However, the sensory liking of individuals for a specific drink varies from person to person and region to region depending on culinary culture. Due to the possible biases of consumers and the expenditures involved, more precise techniques are required for consumer acceptance of the product at the international level.

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Therefore, the studies involving sensory attributes of alcoholic beverages and their measurement matrixes are gaining importance in international food research and development. A large number of researchers have attempted to construct strong tools for physical measurements to replace human subjective assessment with objective evaluation to eliminate the uncertainty and imprecision that exists in sensory evaluation. The conventional sensory panels are now being replaced by newer updated techniques and instrumental measurements [54]. Novel software programs like Fizz and Comp-sense etc. are now available for sensory analysis. Also, novel analytical tools/systems viz., Electronic nose (E-nose), Electronic tongue (E-tongue) and

Computer Vision systems (CVS) are being used in the food, beverage and pharmaceutical industries for evaluation. These E-Systems essentially mimic the human taste and olfactory systems. They are rapid, consistent, economic, and non-destructive. The sensors produce electronic signals on non-selective interactions with the flavor molecules/compounds that are indeed references to the quality or the chemical composition of the material. However, in computer vision systems, the mode of operation has its basis of human vision and image analysis to deduce the quality features. The data on colors and flavours extracted by E-Systems is then analyzed using multivariate data analysis to generate patterns in the data for conclusions [64].

2. The five senses of man

The characteristics of five senses that detect the properties of food and beverages and used for sensory evaluation:

Sight

Color, size, shape, texture, consistency, and opacity are all factors that the eyes take into account while determining the first quality of food. The rods and cones on the retina transform the light that enters the lens of the eye into neural impulses that flow to the brain via the optic nerve. Color may be used to determine freshness, dilution strength, and the degree to which the beverage has been fermented. Color is used to determine the appeal and acceptance of an item. Visual cues might influence a person's decision, similarly, tint can also elicit specific mental expectations. Color might be misleading also [4]. Changes in hue might hide the quality of food. For example, simply changing the color of a beverage may greatly improve its appeal. Even little visual features like neighboring or background colors, as well as the relative proportions of opposing color regions, might influence a customer's perspective. The purity of liquids and the shine, dullness, roughness, or smoothness of a surface elicits assumptions about the beverage [11].

Smell

Sense of smell also plays a role in determining the quality of product. Smell of a beverage gives a sense of its aroma which determines the perception of drinks. The sense of smell creates an infinite number of potential tastes when it is combined with other senses important for drink perception. The receptors of sense of smell are located in the nose and occupy 4-5 cm^2 in each nostril. Temperature also affects the volatility of scents, as aroma is carried by volatile molecules in the form of gas. Hence, it is simpler to detect hot beverages than cold ones. Hot tea, for example, is considerably easier to detect than iced tea. The olfactory epithelium in the nasal cavity detects lighter molecules in one of two ways that can be volatile in nature i.e. either directly via the nose or after entering the mouth and flowing retro-nasally, or toward the back of the throat and up into the nasal cavity [2]. Depending on hunger, human beings' sensitivity to scents varies. Satisfaction, mood, attention, the existence or absence of respiratory illnesses, and gender are all factors to consider. Because different people perceive odours differently, detecting a novel aroma from a beverage necessitates the use of a broad panel to obtain reliable findings.

Taste

Taste, or a person's sense of gustatory input, is the most significant component in their meal choices. The sense of taste is mostly organized in the oro-sensory area. It is viewed as the total group of sensory receptors present in our lips, palate, tongue, soft palate and areas in the upper throat. Material must be dissolved in water, oil, or saliva in order to be tasted. The papillae of the tongue contain taste buds. Taste buds are found in two kinds of papillae. Taste buds are found in the mushroom-like fungi that form papillae on the tip and sides of the tongue, as well as the circumvallate papillae at the rear of the tongue [42]. Healthy adults have between three thousand to ten thousand taste buds in the oral cavity. The taste cells in the taste buds are continuously regenerated by mitotic division. Taste receptors that cannot penetrate the taste cell membrane interact with taste receptor proteins located in the cell membrane. Earlier only four basic tastes were recognized viz., sweet, sour, salty, and bitter but a fifth taste 'umami' was added later [26]. In humans, the umami receptor is specific for glutamate and aspartate. The human receptor for sweet taste is a single heterodimeric T1R2/T1R3 receptor [35], salty flavor is detected by the taste buds by permeating sodium ion through apical ion channels and thereby depolarizing the taste cells in the taste buds, sour taste transduction is mediated by multiple pathways, including transport of H^+ through proton sensitive channels and cross membrane diffusion of undissociated acids. the receptors of bitter taste are also the members of GPCR family and they have been named as T2Rs and their twenty-five types have been identified from the human genome analysis [23], the receptors for umami taste is T1R1 and T1R3 which are members of class C GPCRs.

Sound

Another sense that is used to assess beverage quality is sound. Sizzling, bursting, bubbling, squeaking, dripping, exploding, and sputtering are all sounds that may convey a lot about a drink. Because the majority of these sounds are influenced by water content, their features reveal the freshness and maturity of a product. The sounds consumers hear before tasting influence both the sensory and hedonic expectations for the beverage [55]. Vibrations in the nearby medium, generally air, are heard as sound. The vibrations are transferred by the middle ear's tiny bones, which cause hydraulic action in the inner ear's fluid, the cochlea. The cochlea is a spiral canal lined with cilia that delivers neural signals to the brain when stimulated.

Touch

The sense of touch conveys texture perceptions to us via skin or mouth sensations. The texture is a multi-sensory experience: first, we visualize then we touch, which can be received directly through the fingers or indirectly through drinking utensils; and the third is mouth feel. Mouth feel is felt by the tactile nerve cells on the tongue; teeth and palate. Texture also comprises tactile feel qualities, which are assessed by tactile nerves on the surface of the skin of the lips, hands, or tongue as geometric features or moisture properties. Because the lips, tongue, face, and hands have a higher surface sensitivity, minor changes in particle size, temperature, and chemical qualities may be detected easily across food products.

3. Scales frequently used in the sensory analysis by panelists

3.1 Category scales:

The earliest technique of scaling is category scaling, which entails selecting discrete response choices to represent increasing sensation intensity in terms of degrees of like or preference. The hedonic scale, which evaluates the level of like or hate for sensory aspects of beverages, is the most often used category scale in sensory testing [30, 58]. Consumer panels benefit from category scales because of their simplicity and they are easier to tabulate than line markers. An example of such a scale is hedonic scale for children [3, 34].

3.2 Line scales

The other scales for sensory rating are line scales. Graphic ratings or visual analog scales are other names for line scales. With line scales, the sensory panelists reaction is recorded as the distance between the mark and one of the scale's ends, generally the "lower" end. Line scaling varies from category scaling because in this scaling, the person's options appear to be more open and less constrained. For Quantitative Descriptive Analysis (QDA), [57] advocated using line scaling, which was then a relatively new way to describing the intensities of all the major sensory qualities. One of the example of line scale is the scale given by [33].

3.3 Estimation scales

There are also estimation scales for Magnitude and in Physicochemical investigations Magnitude estimation scaling is a common approach. In this panelists give numbers to their sensations in accordance to how powerful each one feels. Ratios between numbers in the analysis are designed to indicate the magnitude ratios of sensations that have been experienced. If sample X is assigned a value of 10 for sweetness and sample Y seems three times as sweet, Y is given a magnitude estimate of 30.

The magnitude estimate approach is offered in two forms. In one way, the panelist is provided a standard stimulus with a set value as a reference, and all subsequent stimuli are scored concerning the reference. In this technique, 0 values are OK, but they should not be used as a reference. In the second version, the panelist is allowed to pick any number for the first sample because there is no standard stimulus. After then, all samples are assessed about the initial intensity. As the panelists chose various ranges of numbers in the second variant, the data must be adjusted to put all panelists within the same range and this adds a stage to the analytical process. Panelists are advised to avoid slipping back into old patterns of just utilizing category scales that they are familiar with. People want to remain with a method that they are acquainted with; therefore this might be a significant problem with the panelists that are already trained and follow a different scaling approach [16].

4. Sensory analysis and evaluation of alcoholic beverages

When one makes a beverage, it is giving its consumers a sensory experience. While our senses of sight, hearing, taste, and touch may appear to be subjective, they can all be quantified with the right tools, procedures, and controls. Sensory testing is a valuable tool in the development of a successful beverage. The more one knows about how a tool works the better he'll be able to use it and apply the data to improve the product [56]. Qualitative 'sensory analysis', often known as a sensory assessment, combines a scientific approach with how people use their senses to evaluate consumer goods.

It allows us to go from subjectively expressing how a beverage looks, tastes, smells, sounds, and feels to objectively measuring, quantifying, and assessing its characteristics [38]. Sensory analysis may be used at many phases of the development and scaling of a beverage to enhance decision making and raise the likelihood of success.

Sensory assessment allows the beverage maker and supply partners to communicate more easily and quickly during the formulation process [39]. Using a common vocabulary to describe taste profiles and textures simplifies the process of getting to an ideal formulation e.g., one will have greater luck creating a distinct strawberry seltzer taste if phrases like "sweet strawberry with green undertones" rather than just "strawberry" are used.

There are different methods for analyzing the sensorial profile of beverages which includes building lexicons, triangle test and flavor wheels.

1. A trained descriptive flavor analysis panel can characterize a sample's flavor using words. Even without formal training, anybody may begin to learn the lexicon, which is a collection of standardized words for describing a product's sensory characteristics. There may be an established Flavour Wheel vocabulary to refer to, depending on the type of beverage. Dr. Morten Meilgaard's beer flavor wheel, for example, organizes and defines beer taste vocabulary [22].

2. Another sensory evaluation that is frequently used by expanding beverage firms is the triangle test which allows a customer to blindly detect any variations among samples, [17]. In a triangle test, panelists are given three samples, one of which is unique and the other two are identical. The panelists are instructed to recognize and report the different sample. This sort of test can be done to evaluate if there are any discernible alterations in the product over time during shelf-life testing. It may also be used to guarantee that manufacturing runs are consistent.

3. Flavor wheels give a more precise representation of the spectrum of flavors found in various distillates. Their shared terminology is meant to make tasting and describing procedures easier. A standardized procedure with objective criteria improves the accuracy of sensory descriptions while also increasing the panelist's competence [45].

   Three concentric rings make up the flavour wheel. These are divided into numerous flavour groups based on color, such as 'fruity,' 'flowery,' 'herbal,' and so on. Some of these categories are divided into subcategories in the inner circle, such as 'stone fruit,' 'berries,' 'citrus,' 'exotic,' and so on. The outer circle has 65 distinct qualities, each of which is distinguished by a flavour reference. They serve as a point of reference for the distinct flavours of the various distillates and aid in the creation of a flavour profile for each spirit. Flavour wheel has been successfully applied for different beverages. Some of which are described as:

1. Three concentric rings make up the basic flavour wheel for Gin. Vegetable, spicy, fruity, floral, off-flavours, and taste are the six flavour categories divided by color. These categories are separated into sub-categories in the inner circle, such as herbs, woody, and so on. The outer circle has 58 distinct qualities that may be easily identified using olfactory references. They contribute to producing a distinct flavour character for each gin by providing hints to the fragrance variety of the various distillates.

2. Kirsch's flavour wheel is also made out of three concentric rings. Fruity, floral, vegetable, spicy, roasted, off-flavours, and taste are the seven flavour groups (separated by color) in these circles. Whereas in plum and Mirabelle prune distillates, three concentric rings make up the flavour wheel and fruity, flowery, vegetable, spicy, fatty, roasted, off-flavours, and taste are the eight flavour groups (separated by color) in these circles. Among these categories all wheels are separated into sub-categories in the inner circle, such as stone fruit, berries, citrus, and so forth. The outer circle has 65 distinct qualities, each of which is defined by a flavour reference. They demonstrate the wide range of flavours and tastes found in various distillates and aid in the creation of unique flavour profiles for each kind.

3. In partnership with the Swiss Fruit Association, Agro scope created a flavour wheel to better identify the diversity of Swiss apple juice and cider. The use of common terminology makes describing and tasting easier. A systematic method based on objective criteria improves the accuracy of sensory descriptions and the panelist's competence. Agro scope also created a whiskey taste wheel to better define the Whisky-diversity generated in the alpine area. A systematic method based on objective criteria improves the accuracy of sensory descriptions and the panelist's competence.

5. Sensory quality concerns and issues in the alcoholic beverage industry

The majority of alcoholic beverage makers test their products for taste. Some organizations, usually the bigger ones, have a sensory group/department that is in charge of the entire sensory programmers employed in the QC departments of the manufacturing facilities. The sensory group will convey standard operating procedures as needed, perform and monitor panel training, and analyze outcomes for remedial measures in these situations [46]. Other firms do sensory testing on a and when needed basis, with evaluations tailored to the requirements of a certain circumstance. On this issue, it's important to remember that many well-known alcoholic beverage firms have been making products for far longer than modern structured sensory procedures have been bought into use.

In reality, the United States Bottled-in-Bond Act, of 1897 was established to safeguard whiskey drinkers from illegal and often deadly blended whiskey manufacturing. The Bottled-in-Bond Act is seen as a forerunner of the 1906 United States Food and Drug Act. Even though the Act provided no clear guidelines for sensory quality, whiskey branded as Bottled-in-Bond became renowned as the good stuff because it provided certainty to the customer. According to a study [40], the original Seagram firm was one of the first corporations in any sector to use sensory techniques developed by the United States Army Quartermaster Corps in the 1940s. Seagrams was one of, if not the largest, distilled spirits firms in the world throughout the 1900s. The Seagram's brand is still alive and well, although it is now owned by Diageo.

6. Current sensory methods in the alcohol beverage sector

Different tests (duo-trio, paired comparisons, triangle, and the like) are frequently employed in quality control since the purpose is to maintain a standard quality beverage from one production to the next. These tests are more likely to be carried out by a quality analyst (QA) or corporate sensory group with their own trained panelists and sometimes need more time and a greater number of

For quality control evaluations, simple go-no-go comparison tests with lower panel sizes (3–6 panelists) are more typical. In these tests, the sample is compared to a similar product's reference standard, and the panel determines if the given sample is comparable to the reference sample or not. The product is approved for usage if the panel finds it to be equivalent. If it is not authorized, a decision must be made on what remedial action is necessary. What is similar is a crucial part of this form of analysis. Comparable usually indicates that consumers are expected to recognize or accept the product in the package as typical or indicative of the expected product. This method of testing necessitates that the panelists have some experience with a typical or representative product and then use their best judgment to determine if slight, sometimes inherent variances result in the product being similar. Corrective action includes mixing off the unapproved product in tiny amounts with permitted batches and retesting to confirm that the resulting blend is not impaired in quality [21].

Apart from this an optional choice is made for more processing of product, such as by filtering. Multiple sample comparison tests are also commonly used by quality control regions. When many manufacturing samples of the same product are available, these tests are valuable; generally, 3 to 5 goods are compared to a reference. The mentioned test can be done as a scaled test with ANOVA findings or as a ranking of samples for the difference using Friedman analysis [39]. Because these tests frequently require 8 to 12 panelists, their usage may be limited by the number of panelists available.

In the alcohol beverage business, descriptive analysis approaches are less popular. These analysis methods are used by some major beer and wine industries, to describe product taste profiles. The results of descriptive testing on a product's taste profile can be utilized to teach panelists in recognizing and intensifying key product qualities. This information may also aid sensory personnel in determining the sensitivities of certain persons on QA/QC panels to distinct taste components, which may impact their conclusions. According to research, trained sensory panel results might be useful as predictors of customer acceptability, albeit such predictions would have to be made on a product-to-product basis. It's worth repeating that a QC/QA test isn't usually meant to determine overall acceptance or liking, but rather to check that item satisfy agreed-upon standards of typicality and representativeness [24].

7. Analytical tools for sensory evaluation of alcoholic beverages

In the scientific literature, the central integration of taste, smell and trigeminal is often referred as flavour [14]. Commonly, taste is often confused with flavour and hence it is important to use sensitive devices to get the correct inputs. In which biomimetic techniques play a key role by mimicing or adapting to biological systems for the development of more precise technologies (Fig. 1).

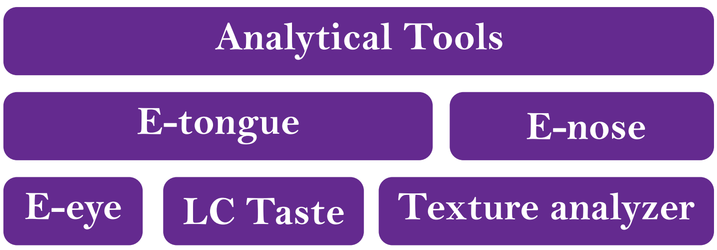

Fig. 1: Different analytical tools used in beverage industry

7.1 E-Nose technology in sensory analysis

The E-nose is an olfactory device that is constructed of an array of heterogeneous gas sensors that respond to the vapors and volatiles/ vapours of the tested sample. It comprises an array of non-specific sensors built with a range of chemical elements each detecting and measuring different attributes [12]. There are three materials of which the various sensors are made of viz., the metal oxides, intrinsically conducting polymers and the conducting polymers composites. The detection of the gases is also done using other sensors like quartz microbalance (QMB) sensors, optical sensors and surface acoustic wave sensors.

The processes using mass spectrometry and ultra-fast gas chromatography for detection are also included under the term electronic nose. The data from the array of sensors of E-Nose is individually collected to analyze and classify the information. Post processing techniques like Principal Component Analysis (PCA), Functional Discriminate Analysis (FDA), Cluster Analysis (CA), Linear Discriminate Analysis (LDA), Fuzzy Logic or Artificial Neural Network (ANN) are used by the system. The former techniques are based on linearity while the ANN is regarded as a nonlinear method [51].

Another important aspect is the sample handling system used in the beverage industry for exposing the sensor arrays of e-nose to the volatile compounds present in the headspace. Specific techniques like Dynamic Headspace (DHS), Purge & Trap (P&T) and Solid-Phase Micro Extraction (SPME) are used in case of samples like wine [8].

Besides the sample handling, the pre-processing of the samples is also crucial as in case of the analysis of the alcoholic products like beer and wine. The pre-processing steps like alcoholization and dehydration indeed ensure better detection and classification of aromas by the e-nose [49]. Nowadays electronic noses are commercially available in the market and find a range of applications.

The E-nose has various successful applications in the beverage industry and research has focused on the measurement of various aspects like off flavours, freshness, contamination and adulteration for the process analysis. However sometimes the technology may be deficient of the sensitivity (masked by other compounds that are not relevant to aroma) or in case of few beverages the presence of temperature drifts and water vapours may render the quality evaluation process ambiguous. [25].

Wine as a commercial product differs in flavours and aromas due to the variations in the production methods. The e-noses have an important application in wine quality assurance. The quality of wine is largely affected by the biochemical process of the yeast and enzymes. High contents of aromatics and the organic acids can be detrimental to the final wine flavour. An electronic nose has been employed to determine the wine defects or spoilage due to 4-ethylphenol concentrations over desirable limits [9].

The most common flavours and aromas used in the qualitative and quantitative analyses comprise of Ethyl octanoate, 2,4,6-Trichloroanisole, Ethanethiol, 1-Hexanol and Ethylacetate. The same has been assessed for wine quality using tin oxide electronic nose sensors followed by data analysis using PNN, LOO and PCA algorithms. Other applications like the difference in aging processes, products, and sensorial descriptions have also been performed in various studies using similar technology [47].

Today, we have a variety of gas sensors available. However, currently, only four of them are used in commercialized products i.e.: Metal Oxide Semiconductor (MOS), Quartz Crystal Microbalance (QCM), Bulk acoustic wave (BAW) and Metale-Oxide e-Semiconductor Field-Effect Transistor (MOSFET) [5]. The hybrid E-nose technologies use a combination of the above, e.g., hybrid MOS and MOSFET is the most common and also various combinations of MOS, QCM and MOSFET are available in commercial systems. Such combinations offer advantage of different transducers and at the same time a choice of chemical sensors.

Table 1: Fusion technique applications for quality evaluation E-nose and E-tongue

1	Black tea flavour perception	[6]
2	Classification of vinegar having different marked ages	[19]
3	Discrimination of Chinese liquors	[41]
4	Classification of black tea	[7]
5	Flavour analysis of liquids	[20]
6	Strawberry juices characterization	[48]

A novel combination of E-nose, CVS and E-tongue is known as the multi-sensor data fusion system and is used for flavour perception of many beverages (Table 1). This fusion system has been also employed by [44] for testing of Chinese rice wine. The results from the data processed by different sensors and analysed by PCA and Multi-Layer Regression (MLR) and ANNs/MLR models showed that the novel model is indeed superior to traditional data fusion. Also, the shortcomings of the individual E-nose, E-tongue and CVS can be countered by employing data fusion techniques. These essentially use the cross sensitivity of different data (smell, taste, colour) to yield a new pattern. Such combinations of artificial senses thus increase the overall effectiveness, offer good accuracy, and limits the errors due to the failure of individual much information is available on different aspects.

7.2 E-tongue, E-eye, and other technologies employed in sensory analysis

7.2.1 Electronic tongue (E-tongue)

Taste is a key organoleptic characteristic that determines whether or not a product is acceptable for oral intake. It is known as the Cinderella of the senses. The "Electronic Tongue," which was first described in 1995, is seen as a potential tool for quantitative and qualitative analysis of multicomponent matrices. When utilized in conjunction along with human taste evaluation data, an electronic tongue or taste sensor is a trained tool for screening the flavour qualities of formulations in a short timescale. For the electronic tongue to work, test compounds must have sufficient aqueous solubility. Co-solvents such as ethanol can be used to increase the solubility of test compounds, allowing the instrument's application to be expanded. Three types of E- tongue, or taste sensors, have been created in recent years like impedance spectroscopy and voltammetry.

[29] demonstrated the first gustatory sensors based on the

potential of various types of PVC membranes for altering the taste quality parameters like bitterness, saltiness, etc., into electrical signals. A second electronic tongue based on impedance spectroscopy was reported by [50], in which super molecular sheets of conducting polymer were used to make sensors. A third type was also created in which metallic electrodes were used as working and stainless steel electrodes were used as normal ones [62].

The main parts of an electric sensor system are diverse sensor types interconnected to an amplifier, a sample table, an arm, and data recording to a computer. This technology simulates the interaction of chemicals with unique taste properties of taste receptors. Sensors represent the taste buds, which interact with these chemicals at the surface causing possible alterations. The signals obtained are used to compare the computer-recorded actions that correlate at the physiological level to the neutral network. The information gathered can then be matched to human memory or associated with pre-existing taste patterns using an existing matrix of sensor responses. For amperometric signal detection, potentiometry is perhaps the most commonly used, and materials used are noble metals, oxide glasses, and Chalcogenide. The E-tongue has wide use in the sensory perception of beverages in industries (Table 2).

Table 2: Applications of sensors in E-tongue

Work done	Type of E-tongue sensor	Reference
Beer types	Potentiometric and voltammetric Sensors	[27]
Coffee bitterness	Potentiometric Sensors	[63]
Beer and wine analysis	Potentiometric Sensors	[43]
Detection of adulteration in cherry tomato juices	Potentiometric Sensors	[28]
Commercial beer styles	Voltammetric Sensors	[13]
Discriminate type and brand recognition of orange beverage and Chinese vinegar	Commercial e-tongue	[37]
Sensory attributes of liquors	Commercial E-tongue	[36]

7.2.2 Electronic eye (E-eye)

The electronic eye is a computer vision system that converts analog visuals to digital images. To avoid subjective deviation of human eyes, the E-eye collects pictures of things using image sensors rather than human eyes and applies a computer simulation criterion to recognize the image. A promising method of recognizing the exterior qualities of food is the computer vision system, a novel artificial perception tool. The system of computer vision adequately handles food texture, size, color, and shape as compared to previous detecting methods. More significantly, this system for food detection is reliable imitation technology that is efficient, convenient, simple to use, non-destructive, and can evaluate greater nuances than the human eye.

The electronic eye in the food sector employs optical sensor technology to collect digital images of tested substances and then utilizes the technology of imageprocessing to detect information about the character of food quality from an image-linked process and build a food quality detection model. The electronic eye makes thorough assessments of a product's attributes using high-resolution camera images under-regulated illumination circumstances in a confined cabinet (shapes and colors). E-eye can assess the entire sample as viewed by the customer, or it can highlight certain aspects.

The electronic eye goes through a process that involves picture capture, processing, and analysis. A camera collects the reflected light from the measured item and converts it to electrical analogue signals. The target characteristic information is then extracted, the regions of interest are selected, and the pictures are divided into background and target images using a computer processing system.

The image segmentation procedure could be carried out via region-based segmentation, edge-based segmentation or thresholding or to retrieve the chemical information containing region. Color information is used to create analytical parameters, as well as quantitative or qualitative analytical data is collected through pattern recognition, multivariate analysis, and single calibration [15, 61].

For physical parameters impacting Indian black tea wherein in one such study [1] investigated computer vision systems identification and evaluated tea color as a quality-related feature. PCA was used to examine the color of brewed tea, the texture, size, and shape of tea grains gathered by machine vision technology, and other physical features. When the photos of Indian black tea were evaluated, the findings revealed that grade-level distinctiveness and significant metrics were attained.

The E-eye performs repeatable shape and color assessments under-regulated settings and ensures traceability of product via data storage, regardless of product consistency or texture. Hence it provides a visual evaluation that is objective and dependable. In a single acquisition of the entire product, the equipment assesses both color and form data. It defines the percentage, color distribution, surface fluctuations, and, information of area, circularity, as well as a surface ratio ranging from maximum to minimum thus providing an in-depth analysis. Further, the test needs a minimal amount of sample. So it is ideal for regions that are complicated and non-uniform. The size of the sample is mostly an issue thanks to the broad measuring surface, which also allows many samples to be evaluated in one study making it an easy and fast study. However, System components' calibration and selection of are essential considerations for achieving greater efficiency in specific applications. Poor or uneven illumination, for example, has a substantial impact on capturing a high-quality image. As a result, measurements become more unreliable, and the signal's instrumental resolution suffers. Furthermore, it is influenced by operational and environmental factors.

7.2.3 LC Taste®.

Symrise (Holzminden, Germany), broadcasted the release of their patented LC Taste analytical method/system, which assists the company's analysts in identifying chemicals with high taste masking potential. This breakthrough technology permits business analysts to "identify and screen non-volatile compounds and non-volatile masking systems for taste dosage activity on negative tastants, utilizing patented extraction and preparation processes," according to the company [59]. In this, the mechanical studies and human taste testing on flavoring and aroma components could be done at the same time. It is a quick and effective "taste screening" solution that works in combination with Symrise's IFC (Integrated flavour concept) for flavour development. All major parts of a multisensory experience may be addressed using the IFC development platform, including taste, flavour release, aroma, visual impression, trigeminal perception and texture. One of the many effective uses of this technique is the use of newly created technologies to conceal bitter components in tea. Key flavouring elements like maltol, vanillin as well as FuraneolTM, capsaicinoids, sucrose, taste enhancers, sugar, bittering agents and amino acids/peptides are all recognized by the LC TasteTM user.

7.2.4 Texture analyzer

Fresh and processed food texture qualities are critical in determining product quality and acceptance. Crunchiness as well as the crispness of celery and potato chips, for example, is crucial for a quality, and industrial processing has invested much in measuring these attributes. It is critical to assess the textural characteristics of food items to ensure product quality and consistency. Subjective and objective approaches are used to assess these characteristics. According to [18] the food industry has adopted empirical approaches because they are quick, economical, and correspond to organoleptic qualities assessment by their sensory evaluation. The characteristics assessed by these tests, on the other hand, are poorly defined, instrument-dependent, and lack an absolute standard. TPA, which is meant to mimic the motion of chewing, is a commonly used technology in the food business. With sensory analysis, TPA test might have a strong connection, but its findings cannot be compared to those obtained using other methods.

The engineering technique entails stress-strain testing and the determination of well-defined mechanical qualities including stiffness, firmness, hardness, and yield. "Texture analyzers" are devices that distort the food sample by pushing, crushing, twisting and squashing it to quantify food texture in a scientifically repeatable manner and provide standardized assessment techniques. TPA was first performed with a Texturometer, which uses a probe to simulate molar teeth. Even though the placement of the food and the lower molar is upside down, the probe movement simulates chewing, and two successive bits are taken. The resultantforce–time curve may be used to objectively determine texture properties like as hardness, adhesiveness, and cohesiveness [31].

Conclusion

Sensory evaluation methods are extensively used in the wine, beer, and distilled spirits industries for product development and quality control and the alcoholic beverage industry continue to lead the way in sensory evolution through the advancement of biomimetic technology. Here, the biological systems being mimicked are specifically the biochemical response mechanisms for odour, sight, texture and taste. Sensory work requires many skills, but this is not always appreciated. Immense strides have been made in alcoholic beverage industry to improve sensory evaluation techniques but still, room for further improvements exists, which can be taken care of by continued training to the experts and the development of new biomimetic systems.

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Keshani Bhushan:
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