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Portable solutions for quality control of beers: a review

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Abstract

Brazil is one of the top five market leaders in beer production. The quantity of establishments legally registered is expected to increase in the coming years. The quality of beer is measured by a complex set of sensory characteristics that include appearance, aroma, taste, and texture. It is also composed of more than 800 chemical compounds originating from different raw materials. The evaluation of the product quality of this process is extremely necessary in order to guarantee customer security and satisfaction. Although human and chemical analyses can be considered complex, there is a tendency to use artificial intelligence technology for precise and cheaper evaluation. Sensory training technologies for evaluators and electronic nose technologies have the purpose of facilitating the recognition of on-and-off characteristics of beer. There were found and discussed one review article, four patents, seven commercial products concerning aroma sensory training kits, and the top 10 technology areas screened with the Orbit® platform. Eight research articles were also highlighted about electronic nose technology, one commercially available, and the top 10 technology areas based on Orbit® platform data. The advent of such technologies represents a step forward in improving quality assurance, but electronic nose technologies do not replace human evaluators yet, because human recognition is a decision factor in releasing a product to market shelves.

Keywords: portable; technology; sensory; beer; quality.

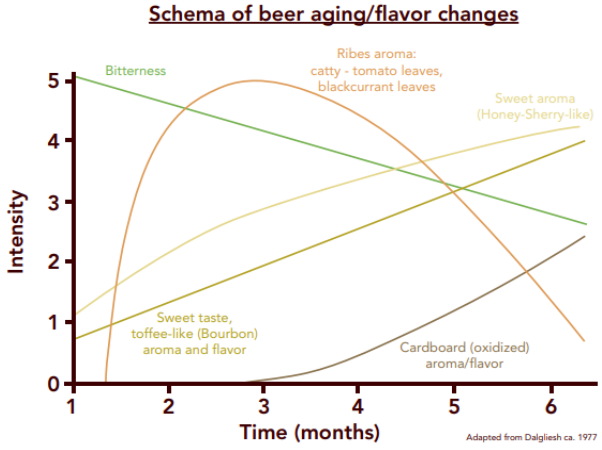
Practical Application: A study upon portable solutions concerning beer quality control with patent and scientific article overview.

1 INTRODUCTION

Beer is the result of the fermentation process by yeasts using wort, which is made from water, cereal, and hops. A study performed by Statista® with data updated in January 2023 showed that the beer market is expected to reach around US$ 50 billion in South America by 2027, which represents 8% of the worldwide expectation and also has an annual growth rate of 6.14% from 2023 to 2027 (Statista, 2023).

Brazil is one of the top five market leaders. In 2021, 14 billion liters of beer were sold, bringing the market up by R$77 billion. According to the 2021 directory produced by the Brazilian Ministry of Agriculture, more than 89% of establishments were legally registered when compared with 2020, which is a huge increase even with the pandemic's global economic impacts. There was also an increase of more than 1% in registered products compared with 2020, as well as an impact of the global pandemic (Brasil, 2021).

The quality of beer is measured by a complex set of sensory characteristics that include appearance, aroma, taste, and texture. These indicators build a specific sensory profile, and understanding how that profile can deteriorate with age is critical to the delivery of a consistently fresh product. A beer's composition, exposure to oxygen, and temperature can affect its flavor stability. As a practical example, bitterness is a characteristic that decreases in intensity with time, while the aroma and taste of sweet and oxidized foods increase at the same time. Curiously, aromas such as tomato and blackcurrant leaves have a huge increase during the first 2 months but suffer a massive decrease from the third month, as shown in Figure 1 (Brewers Association, 2014).



Source: Brewers Association (2014).

Figure 1. Correlation of intensity of flavors by time.

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The ideal scenario is for the beer to leave the factory in its best condition, which means that a quality decrease may occur during the steps forward, such as transportation and distribution. That is the reason why all stakeholders should be familiarized with product characteristics in order to maintain product quality and freshness due to unexpected occurrences. The reputation of a craft brewer relies on the ability to consistently deliver the product under the same conditions among batches. The reason for this concern is that consumers are becoming more aware of the characteristics of a good beer product, as they are interested in distinguishing aromas and flavors in order to learn about the different beer styles. It is noted that these flavor and aroma must be monitored and managed by careful control in distribution, during warehousing and storage, and in the delivery of packaged goods or during bar dispensing to the consumer's glass (Brewers Association, 2014). In the same scenario, monitoring and careful control ought to happen with a alcohol-free beer product (Muller et al., 2019).

Beer is composed of more than 800 chemical compounds originating from different raw materials (e.g., malt, yeast, water, and hops), and many of them are formed during maturation and storage. Sensory evaluation of beer is a complex job that often comes down to a number of panelists and the terminologies they would use to describe the appearance of one property. Sensory analysis consists of choosing the method, evoking a response to stimuli, selecting the samples, quantifying the response, statistical analysis, and interpretation (Habschied et al., 2022). As a practical example, the way hops are addicted to the must can sharply change the final beer sensory profile (Gomes et al., 2022).

A lexicon is a collection of standardized sensory vocabulary for product development using sensory descriptive analysis methods, along with each attribute's descriptions and references to preparation instruction. It is widely used as a relevant communication tool among sensory panels and scientists, product developers, marketing professionals, and suppliers across countries or cultures for several purposes, such as quality control, product development, research on varietals, and shelf-life studies. Moreover, the lexicon plays a major role in describing the sensory attributes of products consistently due to differences in perception, background knowledge, and culture among sensory panels (Asih et al., 2021).

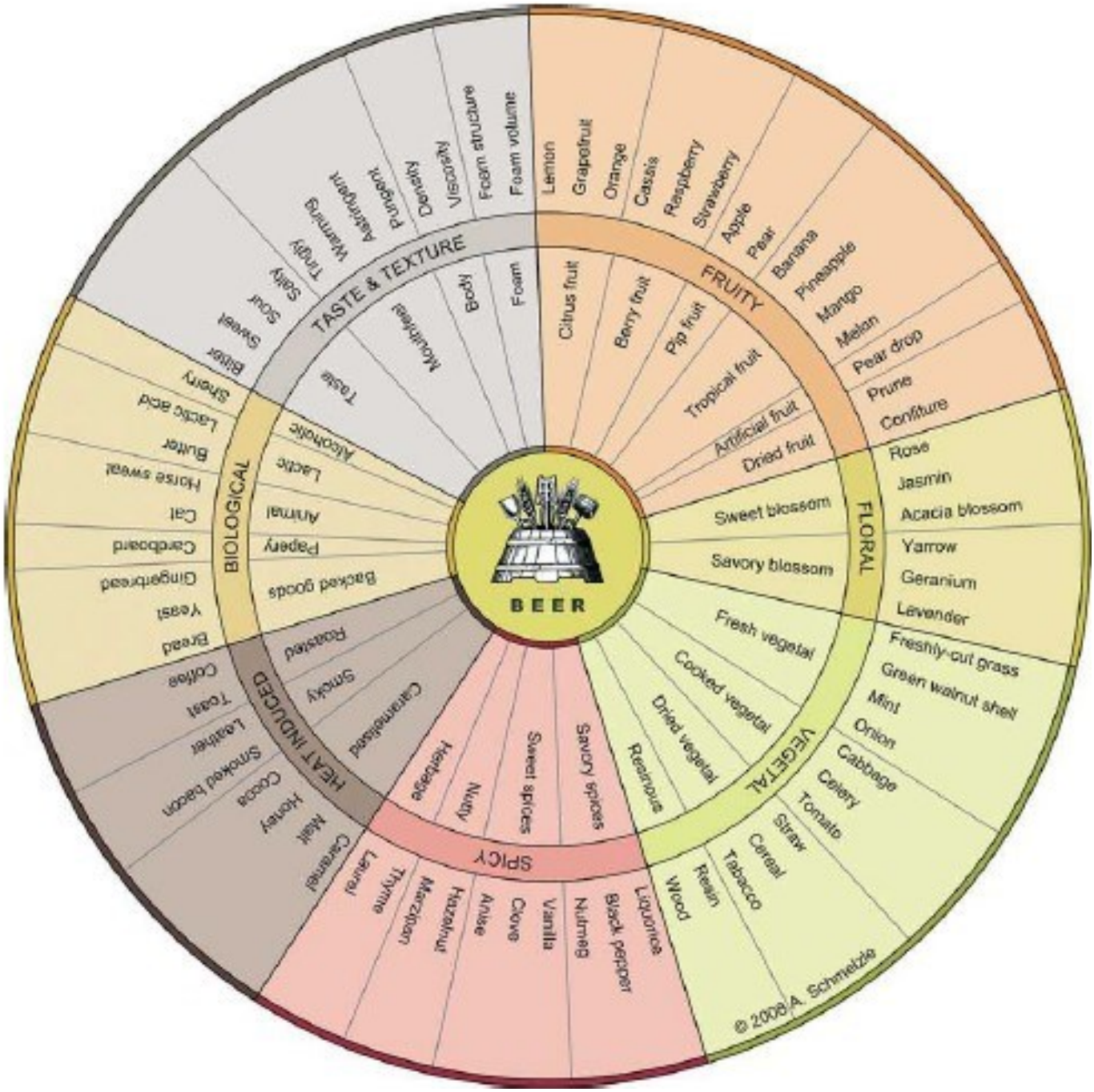
Specific sensory wheels have been developed as tools for assessing the sensory attributes of beverages in order to establish a common terminology among evaluators. Sensory wheels can characterize products based on a lexicon that comprises an organized technical list of the most likely representative attributes to describe, from raw materials and commodities to processed finished products, as is beer. The procedure to generate a lexicon is based on collecting a specific product frame for reference, then listing descriptive words that comprise aroma, flavor, taste, mouthfeel, and trigeminal sensations (tingly, warming, and astringent), reviewing references and examples of those terms, and assembling representative attributes in a final list (Schmelzle, 2009; Silvello et al., 2020).

The aroma wheel (Figure 2) offers a sensory language that allows expression of the diversity of beers using comprehensible attributes familiar from daily life, which not only makes it understandable for amateurs but also provides experts with a sufficiently large vocabulary and provides communication among each other in the same language (Schmelzle, 2009).

A sensory kit is a set of non-food-grade aromatic liquids made from a single or a mixture of synthetic compounds or by aroma extraction and placed in a glass vial for olfactory system training, known as an aroma kit, or food-grade encapsulated compounds for both olfactory and gustatory system training, known as a flavor kit. Generally, an aroma kit is used by sniffing the vial, whereas a flavor kit is used by dissolving the capsules into any liquid, which can both smell and drink (Asih et al., 2021). Most of the methodologies for olfactory training concern training sessions for panelists, posterior discussions, and descriptive analysis. This kind of dynamic usually takes more than a week and includes costs for the panelists. The use of sensorial kit training can make the process of learning faster because of the exposure to the isolated scent or flavor (Gonzalez Viejo & Fuentes, 2020).

The evaluation of the product quality of this process is extremely necessary. Many people may think only the visual characteristics of the product are enough to verify the quality, but there are several parameters that have to be evaluated before releasing a batch to market shelves. All the processes in food or beverage chain production have to be verified and evaluated using some quality metrics established by legislation (Reitenbach, 2016). The Associação Brasileira de Normas Técnicas (Technical Standards Brazilian Association) is responsible for technical standardization in Brazil, providing inputs to Brazilian technological development, which influences and manages trade, industry, and the provision of services in Brazil. In addition, the institution is linked to the International Organization for Standardization (ISO), which manages and defines these standards worldwide. ABNT norms govern the industry and control the quality and effectiveness of the products sold (ABNT, 2022). Due to the standardization and training established by the rules for the production of a catharina sour beer in an innovative way, Ghesti et al. (2023) described the profile of the beer according to the analysis of a panel of tasters, which sensorily assessed and described their characteristics following the descriptions of a universal language on the subject.

Brazilian technical standard number 11132 concerns the methodology of sensory analysis to monitor the performance of a quantitative sensory panel. To this end, it provides guidelines for assessing the overall performance of a quantitative descriptive panel and the performance of each panel member and is applicable to validating the training of individual assessors or panels as well as monitoring the performance of established panels. The methods specified are for monitoring and assessing the ability of a panel and its raters to discriminate between products, the agreement between raters on the same panel, and the repeatability of those raters in their intensity scores. A panel of evaluators can be used as a tool to identify sensory attributes of products and assess the intensity of those attributes. Performance is a measure of a panel's or rater's ability to make reliable and valid attribute assessments across all products being evaluated. It can be evaluated at a given time, typically after a training period (validation), or tracked over time (monitoring) (ABNT, 2022).



Source: Schmelzle (2009).

Figure 2. Beer aroma wheel for communication with the consumer.

To have a satisfied consumer, it is essential for brewers to be able to produce their beer varieties repeatedly in the same quality and free from defects, consistent with all previous batches with a corresponding sensory profile. For craft breweries, it is a challenge to keep the same quality production because they usually do not have the possibility of process monitoring like breweries with a 24/7 production, but it takes too long to analyze raw materials and semi-finished products in an external laboratory and therefore to react to changes in composition with recipe adjustments (Bastgen et al., 2019; Habschied et al., 2022).

Human and chemical analyses can be considered complex; hence, they are done in batches and cost time and money. However, early detection or continuous monitoring using a fast analysis can avoid waste and save money and time. An e-nose is a technology that could be able to analyze and extract the chemical information of the organic volatile compounds in beer and correlate their organoleptic qualities (Santos et al., 2017).

The definition of the electronic nose was proposed in 1994 by Gardner as "an instrument which comprises an array of electronic chemical sensors with partial specificity and an

appropriate pattern recognition system, capable of recognizing simple or complex odors." The e-nose device has the advantages of low cost and portability for making *in situ* and online measurements. The goal of an e-nose is to identify an odorant sample and estimate its concentration using a signal processing and pattern recognition system. It is necessary to create a database of expected odorants by presenting the samples to the sensors. In addition, the most common application of the e-nose is in beer, and it is used to differentiate beer styles and different alcoholic beverages (Santos et al., 2017).

Intelligent sensory technology has been successfully applied in quality assessments of alcoholic beverages in terms of variety and geographical origins, monitoring production processes, detection of frauds and adulterations, discrimination of years of aging, distinction of brands and types, aroma analysis, detection of spoilage and off-flavors, and monitoring of the production process (Wang et al., 2022). Future trends inevitably include the development and implementation of different computer sciences, digital analytical methods, and artificial intelligence (AI) into food and beverage safety and analytics, although human senses will always be irreplaceable concerning sensory analysis because it is a complete experience and evaluation (Habschied et al., 2022). AI is becoming vital for sensory and consumer science due to its ability to efficiently explore and correlate data from instrumental and human testing to produce solutions that benefit the food industry, particularly consumers (Nunes et al., 2023).

This paper aims to list and compare some of the technologies based on detecting molecules produced by the brewing process, including sensorial training kits for panelists and electronic nose technology.

2 METHODOLOGY

The theoretical reference survey stage was carried out by research in the article database Google Scholar, patent databases such as Espacenet, Patentscope, Google Patents, the Instituto Nacional da Propriedade Intelectual (INPI) Brazilian patent platform, and Orbit®, and Google for current products on sale. It was a qualitative and quantitative study of existing portable technologies that are related to quality control by organoleptic characteristics concerning aromas.

As a second stage of the work, a qualitative comparison of information between publications of the same type was carried out. Comparison of indicators of the publications surveyed resulting from the first stage, such as year of publication, type of technology, and conclusions for the scientific articles and the year of deposit, country of origin of the authors, and abstract for the patents (Chart 1). For the commercial products in Brazil, they were listed and compared by supplier, use, price, and cost benefits.

Finally, the third stage consisted of explanatory writing about the results collected in order to expose the learning acquired during the discussion.

The global patent database Orbit®, a Questel® new portal for patent, design, and legal professionals looking for a comprehensive coverage, was also used.

The terms used for the Orbit® research were different because there were no relevant results provided by the platform using the keyword chosen for the scientific articles and patent research (Chart 2). The search term settings were default: title, abstract, object of invention, advantages, and independent claims.

Chart 1. Terms used for scientific articles and patent research.

Beer olfactory training
Beer sensory training
Aroma kit for sensory training
Electronic nose
Portable olfactory sensory training kit beer
Olfactory sensory training kit beer
Sniffin sticks beer aromas

3 RESULTS AND DISCUSSION

3.1 Patents

In what concerns the intellectual property, such technologies do not always guarantee protection with legal support. This is due to the artificially produced aromas not having novelty and inventive activity, which are requirements for the protection of knowledge under a Brazilian patent. However, the product can become a patent if it has an innovative design and is consequently functional by means of how the aroma is released and how the technology works in a practical way (Brasil, 1996).

A product is considered protectable in cases in which it presents novelty, inventive activity, and industrial application. Novelty is anything new when compared with the already existing knowledge, which is also known as the state of the art, until the day before the patent deposit. Inventive activity is a characteristic that must be noticed by an expert in the corresponding area of the invention. The subject must not be obvious to the evaluator's concern. It is considered an industrial application whenever the invention can be reproduced by any industry in the area (Brasil, 1996). Applied to this theme, some examples are listed in Chart 3.

Using the same Boolean operators as the scientific article research, Chart 3 represents the relevant patents found. In this sample space, the oldest year of deposit was 1999, while the most recent was 2021. The United States has presented more patents. All patents presented are relevant to the concern of the technology and functionality of aroma training based on the abstract and respective claims of each invention.

No relevant patents were found in the INPI database due to the lack of arguments for protection in Brazilian legal terms and also due to the common cases of trade secrets in the Brazilian food industry. Lamas, Mello e Ghesti (2022) studied such cases in Brazil motivated by the secrecy sharing requested by public

Chart 2. Terms used for the Orbit® research.

aroma AND detection AND beer
electronic AND nose AND beer

Chart 3. Patents prospected in relation to keywords and patent databases.

Patent	Year of deposit	Country	Relevance
WO2017204590 /EP346652A1 – Aroma-releasing module and aroma-releasing container comprising the same	2019	Korean Republic	Aroma-releasing module technology and its use in order to decrease material waste in sensory training
CN102323385A – Method for measuring smell threshold of volatile flavor compound and application thereof	2011	China	Use of a Tedlar bag as a new method for measuring the smell threshold of a volatile flavor compound Effective improvement of the accuracy of an objective measurement result and accurate reference basis for artificial smell identification for learning machines
CA2337155 – Sensor arrays for the measurement and identification of multiple analytes in solutions	1999	Canada	A sensor array technology for the rapid characterization of multi-analyte fluids (electronic tongue)
WO2011001156A1 – Aroma training apparatus and method	2009	United Kingdom of Great Britain and Northern Ireland	New aroma identification kit technology and method of identifying aroma

organs, which shows the paradoxical lack of knowledge to deal with trade secrets and technology transfer. This also explains why there is no commercial registration for these technologies.

It is not compulsory that the technologies shown in Chart 3 be used in training panelists for sensory analysis of beer, but it seems that they can be used with such a final objective. These are inventions that have the possibility of being used for sensory learning and vocabulary stimulation, in addition to saving material and training time. The register CA2337155 is a Canadian patent comprising an electronic tongue, which is a set of sensor arrays that has the same objective of reducing material and time expenditure.

Figure 3. Aroma Sensory Training®.

3.2 Commercial products

FlavorActiV's GMP (Pharmaceutical Good Manufacturing Practice) Flavor Reference Standards is a sensory kit comprising encapsulated compounds that can be dissolved into any liquid to impart the aroma, taste, and mouthfeel of a specific positive or negative flavor for taster training, calibration, and quality control purposes. This product is sold by FlavorActiV, a UK company that provides sensory tools and training for the global beverage industry.

As for the aroma training kits, most of them are aimed at identifying unwanted aromas (the off-flavors) and consequently indicating quality, but some need to be replaced each time they are used. In this aspect, the Aroma Sensory Training®, developed by Science of Beer Institute scientists, presents an advantage due to zero waste of water and resources because the aromas are kept in the respective vials because the structure is designed for shorter training and efficient lexicon apprenticeship. The Aroma Sensory Training®, as shown in Figure 3, is a kit that contains different aromas belonging to the main olfactive families that were selected for olfactory sensory training using beer aromas based on its sensory wheel, has the best beneficial cost among all presented here because it can be used more than once, is an orthonasal application, and has a 3-month expiration date (Science of Beer Institute).

As for the other sensorial training kits, the methodologies aim to dilute the content of the vial in 1 L of beer that will be discarded after the sensorial analyses. The vial's contents usually compound the beer off flavors, the unwanted aromas and tastes from beer production, and the aim is to make human recognition faster and more obvious if compared with a sample that can proceed to market shelves. The Sensorial Kit off-flavors, Off-Flavors kit (basic), Off-Flavors Kit, and Aroxa Beer Uno Sensory Kit represent such methodologies. The only exception is the hops sensory analysis kit, which is an aroma sensorial training designed in order to make the recognition of hops easier. Chart 4 correlates such products with their respective suppliers, uses, prices and each cost benefit.

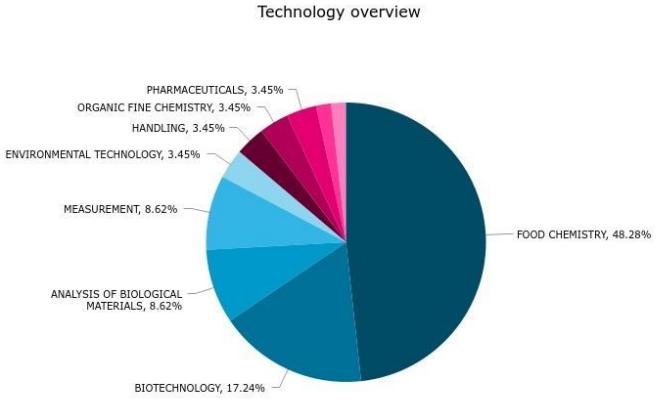
As for the Orbit® platform, the results using "aroma AND detection AND beer" presented 43 patent families, in which the top 10 technological domains are presented in Graph 1.

Graph 1 division is based on the International Patent Classification (IPC) codes contained in a patent set being analyzed. The IPC codes have been grouped in the top 10 technology fields, which are represented here.

Food chemistry is the major technology area with 48%, followed by biotechnology with 17%. The other areas cannot cover half of the total area. Food chemistry also represents the food industry, which is the industry involved in this study due to the aforementioned need for small businesses to assert robust quality control in order to guarantee a safe and desirable product.

Chart 4. Commercial products.

Product	Supplier	Use	Price	Cost benefit
Aroma Sensory Training	Science of Beer Institute	Aroma kit for sensory education and training	R$ 800.00	R$ 50.00 per vial
Sensorial Kit Off-Flavors	Brau Flavors	Capsules and small glass vials, containing the most varied types of unwanted aromas in a beer, which must be diluted in 1 L of beer	R$ 929.99	(20 vials) R$ 46.4995 per vial
Hops Sensory Analysis Kit – HOP AROMA STANDARD	Barth Haas Group	Training in the sensory identification of hops, in their aromas and characteristics	R$ 398.13	R$ 33.1775 per vial
Off-Flavors Kit (basic)	Dr. Flavour	Kit containing 11 parameters to be analyzed in beer, training, 11 vials to be diluted in 1 L of beer	R$ 480.00	R$ 43.64 per vial
Off-Flavors Kit – Self-Training Pack – 20 Flavors	Insumos do vale	Kit with 20 vials of different off-flavors to be diluted in 100 mL of beer.	R$ 149.90	R$ 7.495 per vial
Aroxa Beer Uno Sensory Kit	Mr. Malt	Kit with 10 vials of different off-flavors for dilution in 100 mL of beer	€ 164.70 R$ 870.27	R$ 87.00 per vial
GMP Flavor Standards	Flavor ActiV	54 vials with different flavors for dilution in a beer	–	€ 65 per vial R$ 343.46 per vial



Graph 1. Result for technology overview by the key words "aroma AND detection AND beer."

The living patents are protected in China, Japan, Europe, the Korean Republic, France, India, Denmark, and Great Britain national offices, which are the top countries; some are indeed presented in Chart 3. China has 16 patent families, whereas Japan has five, which are the top two countries leading the ranking in the number of patent families.

3.2 Scientific articles

The only research article that dealt with a sensory training beer kit was a review from 2021, in which the state of the art of the lexicon, sensory wheel, and kits as training tools for panelists were mentioned (Asih et al., 2021). The lack of original studies about sensory training beer kits reinforces the previously mentioned cost of money and time, which directly influences the methodology's choice.

The research was executed on electronic nose technologies in order to exhibit a future but not distant tendency in the quality control area, as presented in Chart 5.

In this sample space, the studies found were published within the past 23 years. This shows how recent the use of electronic noses is and also how promising the technology is for predicting the coming years of quality control advances.

All studies mentioned in Chart 5 show the need for standardization for sample evaluation and product quality prediction, which are met by electronic nose technology, so that the result generated by the analysis is not biased by human influence, making the error as small as possible. Therefore, it is necessary to train the technology qualitatively for the recognition of a pattern to be studied quantitatively.

The way this recognition is performed presents a limitation of this technology, which is experimental machine learning. If the qualitative presentation suffers any interference, the result will also suffer; consequently, Voss et al. (2019) reported a difficulty in detecting alcohol, which is a volatile compound, among all the volatile compounds present in beer.

The electronic nose technology, in combination with machine learning methods such as SVMs, presents higher levels of efficiency in pattern recognition, which can decrease the error of the presented results and increase the predictability of long-lasting quality. FOX 2000 is a four-sensor e-nose commercialized by Alpha M.O.S presented in González-Martín et al. (2000), but there are no records for its use for evaluation in beers. The same company now commercializes the HERACLES electronic nose, a more up-to-date version of the same technology. The only result found at the INPI with the operators "electronic and nose" in Portuguese was a patent

Chart 5. Scientific articles about E-nose.

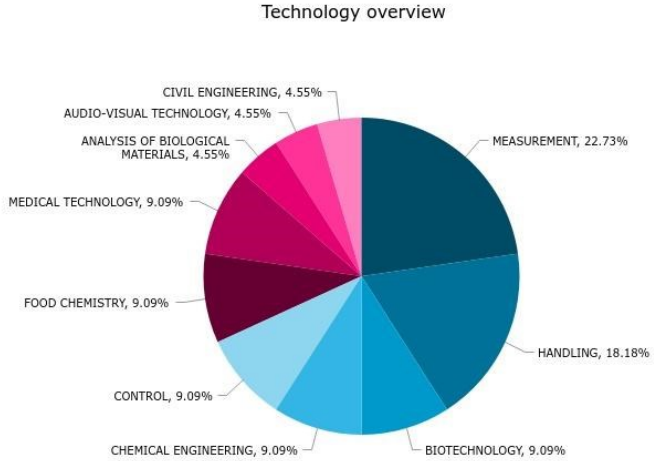
Title	Publication	Technology	Relevance
Low-Cost Methods to Assess Beer Quality Using Artificial Intelligence Involving Robotics, an Electronic Nose, and Machine Learning	2020	E-nose composed of nine different gas sensors for volatile aromatic compounds	Accuracy of 97% in identifying beer fermentation, consumer preference, acceptance, physicochemical, and colorimetric analysis Use of a non-invasive technology robotic pourer RoboBEER to evaluate foam, color, and carbonation
A Prototype to Detect the Alcohol Content of Beers Based on an Electronic Nose	2019	E-nose composed of metal oxide semiconductor (MOS)	Use of MOS electronic nose to detect alcohol content in beers. The device can be used to classify and differentiate types of beverages with close alcohol levels, but it is desired to train the device with samples more compatible with the beverages to be tested.
Time Series Feature Extraction for Machine Olfaction	2019	TruffleBot e-nose	Classification of the odors of three similar beers at >98% accuracy
A deep feature mining method of electronic nose sensor data for identifying beer olfactory information	2019	Convolutional neural network (CNN) combined with a support vector machine (SVM) model	Beer classification performance of 96.67% was presented by the system. It is an effective tool for high-precision intelligent identification of beer olfactory information.
Electronic nose sensors data feature mining: a synergetic strategy for the classification of beer	2018	E-nose sensors data feature mining in combination with SVM	The analytical method can be used as a reliable tool for accurate identification of beer olfactory information.
Mining Feature of Data Fusion in the Classification of Beer Flavor Information Using E-Tongue and E-Nose	2017	E-tongue and e-nose technologies	It obtained the important evaluation of each variable and the correlation behavior by observing the classification tendency of the model. The classification accuracy rate is 88% in all three methods tested.
From simple classification methods to machine learning for the binary discrimination of beers using electronic nose data	2014	Electronic nose based on MOS	Classification of alcoholic and non-alcoholic beer samples in a fast and reliable way with 100% accuracy
Differentiation of products derived from Iberian breed swine by electronic olfactometry (electronic nose)	2000	FOX 2000 Alpha M.O.S Electronic Nose comprising six MOS sensors	The use of a commercial e-nose in the Iberian swine breed showed satisfactory results in justifying the quality and consequent price of the products derived.
Desenvolvimento de nariz eletrônico para detecção de compostos voláteis na cerveja	2016	E-nose combined with probabilistic neural network (PNN) analysis	The percentage of accuracy for the equipment is almost double compared with the trained panel and tends to be much closer to 100%, which represents a real gain in the reliability of the sensory analysis of beer.

with the same technology but used to monitor the air quality of closed spaces.

On the Orbit® platform, there were found 15 patent families using "electronic AND nose AND beer" as keywords. Some of the most relevant graphs for this study are shown in Graph 2.

Graph 2 shows the top 10 technology patents-related areas. Representing the larger area is measurement, followed by handling, biotechnology, chemical engineering, and related areas. Electronic nose technology has the purpose of measuring the components in beer that human senses cannot detect and it is a cheaper alternative to quality control.

The top country or continent competitors within the patent-related keywords are China, Europe, and the United States, with three patent families each, followed by Canada (two patent families), Australia, Denmark, Spain, and France, each with one patent family.



Graph 2. Result for technology overview by the keywords "electronic AND nose AND beer."

4 CONCLUSION

Such technological innovation has a huge impact on the beer quality market, as the verdict will not be biased by human variation, such as individual repertoire, gender, age, and sensory fatigue. As displayed, Brazil has and will have a continuous annual growth in the number of craft breweries and products, which can make room for failure if rules are not followed and processes are not monitored correctly. That is the reason all batches of beer to be commercialized must always be inspected, following the good manufacturing practices provided by legislation. Sensory training technologies for evaluators and electronic nose technologies have the purpose of facilitating the recognition of most aromas and flavors provided during the production process. Both training panelist kits and electronic noses represent a relevant advance in sensory science and, more importantly, in the guarantee of quality products in a healthy way and also in a sensory experience way. The advent of technologies involving AI is a trend in many areas because the capacity for refined recognition is a disruptive innovation in quality control studies. Despite the innovation, it is important to emphasize the irreplaceable role of human evaluators because machines do not yet have the ability to recognize if the presence or the absence of a component is a positive or negative factor. The release of the product to the market only happens after a sensorial evaluation carried out by professionals in the area, and that is why there is still the investment of time and money in portable technologies that help in the sensorial training of new panelists.

REFERENCES

Asih, N. E., Ramadhanty, K. P., Ramandias, J., Azkarama, F., & Sunarharum, W. B. (2021). Lexicon, sensory wheel and kit as sensory communication tools: a review. *IOP Conference Series: Earth and Environmental Science*. IOP Publishing. https://doi.org/10.1088/1755-1315/924/1/012027

Associação Brasileira de Normas Técnicas (ABNT) (2022). *Análise sensorial: Metodologia. Diretrizes para a avaliação do desempenho de um painel sensorial descritivo quantitativo*. ABNT. Retrieved from https://www.abnt.org.br/

Bastgen, N., Ginzel, M., & Titze, J. (2019). Precision of a small brew house by determining the repeatability of different brews to guarantee the product stability of the beer. *Beverages*, *5*(4), 67. https://doi.org/10.3390/beverages5040067

Brasil (1996). *Lei nº 9.279, de 14 de maio de 1996*. Regula direitos e obrigações relativos à propriedade industrial. Retrieved from https://www.planalto.gov.br/ccivil_03/leis/l9279.htm

Brasil (2021). Ministério da Agricultura, Pecuária e Abastecimento. *Anuário da cerveja*. Ministério da Agricultura, Pecuária e Abastecimento.

Brewers Association (ed.) (2014). *Best Practices Guide to Quality Craft Beer: Delivering Optimal Flavour to the Consumer*. Brewers Association. Retrieved from https://www.brewersassociation.org/educational-publications/best-practices-guide-to-quality-craft-beer/

Ghesti, G., Carvalho, I., Carmo, T., & Suarez, P. A. Z. (2023). A newer source of microorganism to produce Catharina Sour beers. *Food Science and Technology*, *43*, e102022. https://doi.org/10.1590/fst.102022

Gomes, F. de O., Guimarães, B. P., Ceola, D., & Ghesti, G. (2022). Advances in dry hopping for industrial brewing: A review. *Food Science and Technology*, *42*, e60620. https://doi.org/10.1590/fst.60620

González-Martín, I., Pérez-Pavón, J. L., González-Pérez, C.; Hernández-Méndez, J., & Álvarez-García, N. (2000). Differentiation of products derived from Iberian breed swine by electronic olfactometry (electronic nose). *Analytica Chimica Acta*, *424*(2), 279-287. https://doi.org/10.1016/S0003-2670(00)01106-5

Gonzalez Viejo, C., Fuentes, S. (2020). Low-cost methods to assess beer quality using artificial intelligence involving robotics, an electronic nose, and machine learning. *Fermentation*, *6*(4), 104. https://doi.org/10.3390/fermentation6040104

Habschied, K., Krstanović, V., & Mastanjević, K. (2022). Beer Quality Evaluation: A Sensory Aspect. *Beverages*, *8*(1), 15. https://doi.org/10.3390/beverages8010015

Lamas, F. C., Mello, L. R., & Ghesti, G. F. (2022). Tratamento do segredo industrial na transferência de tecnologia dos produtos estratégicos de defesa: questionamentos a partir da lei de acesso à informação. *Cadernos de Prospecção*, *15*(3), 792-805. https://doi.org/10.9771/cp.v15i3.46143

Muller, C., Neves, L. E., Gomes, L., Guimarães, M., & Ghesti, G. (2019). Processes for alcohol-free beer production: a review. *Food Science and Technology*, *40*(2), 273-281. https://doi.org/10.1590/fst.32318

Nunes, C. A., Ribeiro, M. N., Carvalho, T. C. L., Ferreira, D. D., Oliveira, L. L., & Pinheiro, A. C. M. (2023). Artificial intelligence in sensory and consumer studies of food products. *Current Opinion in Food Science*, *50*, 101002. https://doi.org/10.1016/j.cofs.2023.101002

Reitenbach, A. F. (2016). *Desenvolvimento de nariz eletrônico para compostos voláteis da cerveja*. Doctoral Thesis, Universidade Federal de Santa Catarina.

Santos, J. P., Lozano, J., & Aleixandre, M. (2017). Electronic noses applications in beer technology. *Brewing Technology*, *177*. https://doi.org/10.5772/intechopen.68822

Schmillen, A. (2009). The beer aroma wheel. *Brewing Science*, *62*, 26.

Science of Beer Institute. *Aroma Sensory Training®: Guide Manual*. Science of Beer Institute. https://doi.org/10.29327/5194321

Silvello, G. C., Bortoletto, A. M., & Alcarde, A. R. (2020). The barrel aged beer wheel: a tool for sensory assessment. *Journal of the Institute of Brewing*, *126*(4), 382-393. https://doi.org/10.1002/jib.626

Statista (2023). *Consumer Market Insights, Alcoholic Drinks*. Beer, South America. Statista. Retrieved from https://www.statista.com/outlook/cmo/alcoholic-drinks/beer/south-america#global-comparison

Voss, H. G. J., Mendes Júnior, J. J. A., Farinelli, M. E., & Stevan Jr., S. L. (2019). A prototype to detect the alcohol content of beers based on an electronic nose. *Sensors*, *19*(11), 2646. https://doi.org/10.3390%2Fs19112646

Wang, A., Qiu, J., Cao, R., & Zhu, H. (2022). Application of intelligent sensory technology in the authentication of alcoholic beverages. *Food Science and Technology*, *42*, e32622. https://doi.org/10.1590/fst.32622