

Food sensory evaluation throughout the time

Alice Vilela

Resumo

Há milhares de anos que os humanos usam os sentidos para avaliar os alimentos. Dado que muitas fitotoxinas e metabólitos bacterianos têm gosto amargo ou ácido, a humanidade provavelmente usou a avaliação sensorial desde antes que o Homo sapiens fosse considerado “humano”. À medida que a civilização se desenvolveu e o comércio e a venda de mercadorias se tornaram comuns, começou a surgir a necessidade da realização da avaliação sensorial dos alimentos. Os métodos de degustação, foram aplicados pela primeira vez na Europa, com o objetivo de controlar a qualidade de cervejarias e destilarias. Nos USA, durante a Segunda Guerra Mundial, surgiu a necessidade de produzir alimentos de qualidade que não fossem rejeitados pelos soldados do exército. A partir dessa necessidade surgiu a análise sensorial como base científica. Tradicionalmente, a indústria alimentar via a avaliação sensorial no contexto da empresa como sendo realizada pelo “expert” (N = 1) que através de anos de experiência era capaz de descrever os produtos e estabelecer padrões de qualidade desde a matéria-prima até ao produto final. Exemplos de tais “especialistas” incluem o mestre-ervejeiro, o enólogo, os provadores de café (baristas) e chás. Hoje em dia, os testes internos de consumidor, proporcionam à empresa uma alternativa barata para a obtenção de informações valiosas sobre as vantagens e falhas dos seus produtos. Portanto, a procura por possibilidades de fazer esse tipo de teste aumentou

Palavras-chave: Cientista sensorial, consumidor, análise de dados sensoriais.

Abstract

Humans have used their senses to evaluate food for several thousands of years. Given that so many phytotoxins and bacterial metabolites are bitter and sour, humanity had probably used sensory evaluation since before Homo sapiens were human. As civilization developed and the trading and selling of goods became a commonplace, the first seeds of food sensory testing as we know it was planted. Tasting methods, as a form of sensory analysis of foods, were applied for the first time in Europe, a long time ago, to control the quality of breweries and distilleries. In the United States, during World War II, it arose from the need to produce quality foods that were not rejected by army soldiers. From this need the methods of application of the tasting appeared, establishing the sensorial analysis as a scientific basis. The food industry traditionally viewed sensory evaluation in the context of the company “expert” (the N of 1) who through years of accumulated experience was able to describe company products and set standards of quality by which raw materials would be purchased and each product manufactured and marketed. Examples of such “experts” include the perfumer, flavourist, brew-master, winemaker, and coffee and tea tasters. Nowadays, small scale internal consumer tests provide a company with a cheap way to get valuable information regarding the advantages and flaws of their products. Therefore, the demand for possibilities to do this kind of test has increased.

Keywords : Sensory scientist, consumer choices, sensory data analysis.

INTRODUCTION

There is a class of scientists who specialize in the analysis of the sensory qualities of merchandises – the colour, sound, smell, taste, and feel of things. The original name for this area of research was "organoleptic", and the person who performed the analysis the "Organoleptician"¹.

It is difficult for us to understand how people, in the past, perceived their world in sensory terms. Can we ever reach an understanding of what smells meant to 18th century Parisians? Maybe, if we read the book "Perfume: The Story of a Murderer" - a 1985 literary historical fantasy novel, by the German writer Patrick Süskind, we get an idea! The novel explores the sense of smell and its relationship with the emotional meaning that scents may have! Or, can we ever uncover the meanings of taste in a pre-refrigerator age? The historian Mark M. Smith places these questions in his article "The explosion of sensory history"². Of the many sectors of consumer products industries (food/beverage, personal care products, pharmaceutical, fabrics, and clothing...), it was on the food and beverage sectors that grew the interest in sensory evaluation³. Its origins, can be traced back to the 1930s when the Arthur D. Little industrial consulting firm, in the U.S., devised a "Flavour Profile Method" and "Hedonic Index" for use by commercial food and beverage companies, and the first panel on "Flavour in Foods" was presented at the 1937 meeting of the American Chemical Society⁴.

During the 1940s-1950s, sensory evaluation received additional motivation through the U.S. Army Quartermaster Food and Container Institute, which supported research in food acceptance for the armed forces⁵. For the military, in combat, the importance of flavour and acceptability for a particular product were recognized. It was not enough to present to the military, food-products with an adequate level of nutrition. This aspect of food did not guarantee food acceptance by military personnel⁶. For instances, a number of studies were published on "Browning" – As to the objectives of the conference, those immediately apparent were: To report the status of Quartermaster Corps contract research on browning; to evaluate research progress; and to assess the value of the different approaches selected by the various investigators in attempting to understand the mechanisms and control of browning ⁷ and

¹ Howes, D. *The Science of Sensory Evaluation: An Ethnographic Critique*. Adam Drazin and Susanne Kuechler, eds., *The Social Life of Materials*, published by Bloomsbury Academic, 2015: 81-97 <https://www.bloomsbury.com/us/the-social-life-of-materials-9781472592668/>

² Smith, M.M. "The explosion of sensory history", *In Looking Bach*, vol 23, 2010: 860- 863.

³ Stone, H. and Sidel J.L. *Sensory Evaluation Practices*. Orlando: Academic Press, 1985.

⁴ Howes, 2015.

⁵ Sidel, J.L., Stone, H. "The role of sensory evaluation in the food industry", *Food Quality and Preference*, vol 4, Issues 1-2, 1993: 65-73. [https://doi.org/10.1016/0950-3293\(93\)90314-V](https://doi.org/10.1016/0950-3293(93)90314-V).

⁶ Sidel and Stone, 1993.

⁷ Quartermaster Food and Container Institute for the Armed Forces (U.S.). *Contributions of browning research to ration item stability; a conference on the status of browning reaction research and a review of its contributions to stabilized packaged rations*, conference held 1 February 1952 at the Quartermaster Food and Container Institute for the Armed Forces, Chicago, Illinois, Research and Development Division, Office of the Quartermaster General, 1952.

also about “Color in foods”⁸. So, Funds were assigned to studies of the problems of identifying what foods were more or less preferred as well as the more fundamental issue of the measurement of food acceptance.

After the war, a new impulse was made in sensory science and sensory history. The White Sands Proving Ground became the centre of V2 rocket research, and the nearby Holloman Aeromedical Field Laboratory and the associated Wright-Patterson Air Force Base Aero-Medical Laboratory began working on to what would become known as the “Project Mercury”, the first U.S. space program. Soon, scientists found that the exploration and conquest of space by humans would require more than merely surviving, like a fly, a monkey or a mouse. Once the man was “up there”, enclosed in a spacecraft alone or together with other courageous humans, a question raised. What would they have for lunch?⁹. In space, every aspect of metabolism becomes a problem! Food scientists calculated that 5 pounds a day per person, or 1 ton a year is the amount of food needed¹⁰ for a man to survive in space. Given this, the conclusion was “reduce everything to its essences, the most basic form”: nutrient pellets, titrated to meet, precisely, the body’s needs, to sustain bare life and function.

Lieutenant Colonel David Simons, a medical officer, was the first human to dine in space-equivalent conditions (over 100,000 feet up, above 99 per cent of the earth’s atmosphere). Dr Simons had been one of the designers of the experiments that rocketed animals into near-space. He and his co-workers, at Holloman and Wright-Patterson, developed a scheme to lift a human to the upper limits of the atmosphere using a giant, helium-filled balloon. This work was named the project “Man High”¹¹.

Beatrice Finkelstein, research nutritionist, and dietitian at Wright AFB Aero Medical Laboratory was the scientist responsible for designing Dr Simons’ low-residue diet (Figure 1 A)¹². In a series of experiments at Wright AFB, Finkelstein confined human subjects within a sensory deprivation chamber to examine “the means they employ to defend themselves against the effects of isolation.” The test subjects spent 72 hours alone in a pitch-dark, soundproof room. The room had a cot, a chair, a chemical toilet, and a refrigerator. The refrigerator held little Tupperware-style containers of food, lids marked with tactile symbols, which indicated their contents. Subjects could palpate the lids in the dark, and select the substance of their meals (Figure 1 B).

⁸ Quartermaster Food and Container Institute for the Armed Forces U.S.) *Color in foods*, a symposium sponsored by the Quartermaster Research and Development Command, U. S. Army Quartermaster Corps, Oriental Institute, Kenneth T. Farrell Edts. University of Chicago, November 3-4, 1953.

⁹ Berenstein, N. “Eating at 100,000 Ft.: Man High and the Origins of Space Food”. 2018. Retrieved from: <http://nadiaberenstein.com/blog/2018/3/8/eating-at-100000-ft-man-high-and-the-origins-of-space-food>, accessed 6th June 2019.

¹⁰ Ibid.

¹¹ Ibid.

¹² Berenstein, 2018.

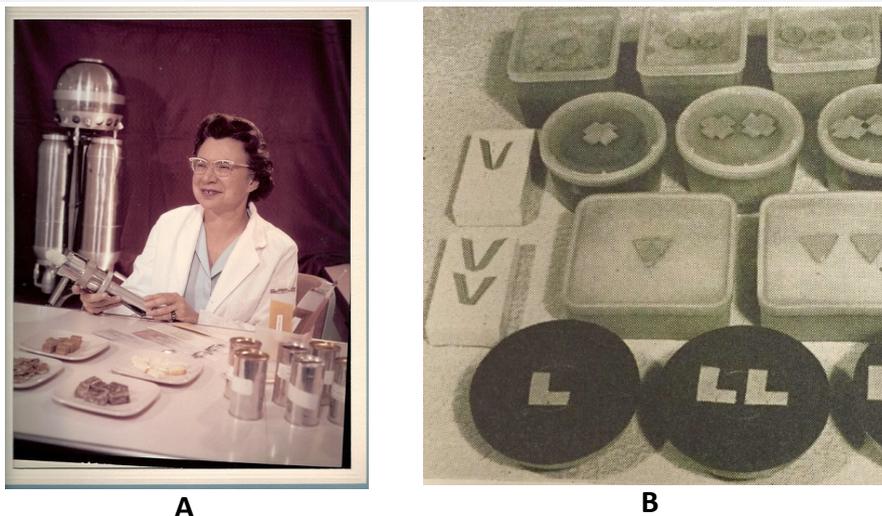


Figure 1: (A) Beatrice Finkelstein in her research lab; (B) Small Tupperware-style containers and system of coding various food-groups.

In her report, Finkelstein wrote “The significance of food during these trials has varied (...) Some subjects have spent excessing amounts of time eating, nibbling or counting food; others have become angry at the food or overly fond of it. (...) While some snacked continually, others stuck to a routine of three or four meals a day. Brownies, ordinarily a favourite, lost savour; in contrast, canned orange juice, which usually rated low, was enjoyed. All meat tasted the same (...)”¹³. Moreover, she concluded: “Evidence is strong that food is used as a tool to obtain personal satisfaction”. For those alone and in the dark in conditions meant to mimic the stress and isolation of high-altitude spy flights, or voyages into space, food was one of the only available comforts.

All these issues were apparently forgotten during the 1960s and early 1970s due to implementation of the U.S. federal government program “War on Hunger”. The government’s desire to feed the starving and undernourished met with frustration when product after the product was rejected by the target consumers, primarily because no one troubled to determine whether the sensory properties of these products were acceptable to the targeted groups¹⁴.

Mainly due to government’s successes and failures in sensory evaluation, the food industry began to provide support for this developing science and various studies were custom-built to find out how to make the food more acceptable¹⁵.

THE EVOLUTION OF THE “SENSORY SCIENTIST”

¹³ Ibid.

¹⁴ Sidel and Stone, 1993.

¹⁵ Pangborn, R.M. “Sensory Evaluation of Food: A Look Forward and Back”. *Food Technology* 18, 1964: 1309-1324.

The title of “*Organoleptician*” has since been dropped, and replaced by “Sensory professional” or “Sensory scientist”. The sensory evaluation of food products remains central to the practice of these professionals of the “sensory science”, but the scope of the products studied has expanded significantly to include everything from personal care to household cleaning¹⁶.

However, the food industry traditionally viewed sensory evaluation in the context of the company “expert” (the N of 1) who through years of accumulated experience was able to describe company products and set standards of quality by which raw materials would be purchased and each product manufactured and marketed. Examples of such “experts” include the perfumer, flavourist, brew-master, winemaker, and coffee and tea tasters¹⁷.

Sensory professionals have also effort to expand their role within the companies they worked for, seeking to convince management that the application of sensory evaluation techniques is crucial to every stage of product development, from product conception to product consumption. They usually use the language of driving, as in “*sensory properties drive consumer acceptance and emotional benefits*”¹⁸, and it has had the desired effect.

The science of sensory evaluation can be integrated into the “aesthetic-industrial complex” context and It is one of the “sciences of subjectivity” which, as Shapin (2012)¹⁹ suggests, “are world-making”.

Nevertheless, one crucial question can be made: what sort of world are these sensory scientists making out of our senses? Can it be really proven as an exact science?

The science of sensory evaluation rests on a vital paradox: “*Most sensory characteristics of food can only be measured well, completely, and meaningfully by human subjects*” as opposed to scientific instruments. But it is considered necessary that human subjects behave as much like scientific instruments as possible: “*When people are used as a measuring instrument, it is necessary to control all testing methods and conditions to avoid errors caused by psychological factors*”²⁰.

Meilgaard and collaborators (2010)²¹ affirm that the key to sensory analysis is: “*(...) to treat the panellists as measuring instruments. As such, they are highly variable and very prone to bias but they are the only instruments that will measure what we want to measure so we must minimize the variability and control the bias by making full use of the best existing techniques in psychology and psychophysics (...)*”.

¹⁶ Howes, 2015.

¹⁷ Sidel and Stone, 1993.

¹⁸ Howes, 2015.

¹⁹ Shapin, S. “The Sciences of Subjectivity”. *Social Studies of Science*, 42, 2012: 170-184.

²⁰ Howes, 2015.

²¹ Meilgaard, M., Carr, B.T. and Civille, G.V. *Sensory Evaluation Techniques*, 3rd edition. Boca Raton, FL: CRC Press, 2010.

The controls techniques mentioned by Meilgaard and co-workers²² include:

1. Standardization of the test conditions, e.g. constant single lighting conditions, temperature, humidity, test station design;
2. Elimination of all disturbance variables (sounds, odours, light-stimuli, the exertion of persons, uncomfortable sitting position);
3. Ensuring that “irrelevant” sensory factors, such as the size of the samples, do not interrupt on the panellists' judgment;
4. Train panellists to evaluate products “monadically” (to assess one sensory characteristic at a time);
5. Isolating one panellist from another by having them perform their tasks in individual booths or cubicles (Figure 2);
6. Instructing the panellists not to discuss samples before evaluation (since this might create expectations);
7. Instructing the panellists to work in silence, since “comments or noises” made out loud can influence sensory judgments.



Figure 2. Individual booths or cubicles and sample deliver system²³.

Moreover, now, several industries are working on “Sensory equipment” from tasting cabins to sample preparation rooms (Figure 3)²⁴.

²² Ibid.

²³ Thiemt. *Special equipment for sensory product control*. Retrieved from <https://thiemt.com/legacy/laboratory/sensory-labs/general-information/>, accessed 25th May 2019.

²⁴ Ibid.



Figure 3 - The backside of the test cabin acts as a wall unit of the preparation room. The samples preparation and coding, such as the presentation takes place right here. The materials of the ceilings, walls, and floors should be odourless and olfactory inert, such as the furnishings.

THE EVOLUTION OF THE “SENSORY TESTS” AND DATA ANALYSIS

Nowadays, there are three kinds of tests used in sensory evaluation procedures. “Discriminative tests”, used to determine if a difference exists among samples. “Descriptive tests”, employed to identify and quantify sensory characteristics (descriptors) that are important in a product. “Affective” or “hedonic tests”, used to measure how much a panellist (or just a simple consumer) likes a product sample. The variability of responses is controlled through the use of standardized questionnaires and standard numerical scales²⁵ as well as through statistical analysis²⁶. The results of the experiments, and the plotting of such results in the form of graphs and tables. Only results which are “statistically significant” are considered “meaningful.” In other words, while sensory evaluation experiments are concerned with assessing the qualities of products, it is the quantification of sensation that counts. Averages are usually calculated so that any trace of the “subjective associations” of individual panellists can be eradicated from the overall picture of a product's sensory qualities²⁷. The degree of sensory restriction to which the sensory professional is subjected allows the reproducibility of the results that are “precise and consistent”²⁸.

²⁵ Stone, H., Bleibaum, R. and Thomas, H. *Sensory Evaluation Practices*, 4th Edition. San Diego, CA, Academic Press, 2012.

²⁶ Meilgaard et al., 2010.

²⁷ Stone et al., 2012.

²⁸ Poste, L., Mackie, G. A., Butler, G. L., Larmond, E. *Laboratory Methods for Sensory Analysis of Food*. Ottawa, Agriculture Canada, 1991.

Many of the papers published in the field are concerned with the development of “sensory lexicons”. The construction of these vocabularies (a group of words, commonly called a lexicon), is essential both for standardization and communication among sensory professionals working in different countries, and the communication of product sensory attributes to the consumers. Sensory lexicons are applied using descriptive sensory analysis techniques. They provide a source list to describe products (wine, bread, beer, coffee, chocolate). Over the years, descriptive lexicons represented in wheel form, have been developed for wine²⁹ (Figure 4 A), beer³⁰ and spirits³¹, among others alcoholic beverages like Pink Port Wines³² and chocolate (Figure 4 B).



Figure 4 – (A) An example of the wine aroma wheel³³, first developed by Nobel and co-workers³⁴; (B) An example of the chocolate aroma and flavour wheel and a chocolate tasting plate³⁵.

Characteristics of flavour lexicons to be used in food/beverages products sensory profiles have been discussed by Lawless and Heymann³⁶. And, according to the authors, a vital characteristic of a good flavour lexicon is that it must be discriminative, as well as, descriptive, if possible. For a descriptive language to be discriminating, it must be able to differentiate the products for which it was developed. One example is the work performed by Vilela and co-workers³⁷. The work aimed to develop

²⁹ Noble, A.C., Arnold, R.A., Masuda, B.M., Pecore, S.D., Schmidt, J.O., Stern, P.M. “Progress Towards a Standardized System of Wine Aroma Terminology”. *American Journal of Enology and Viticulture*, 35, 1984: 107-109.

³⁰ Meilgaard, M. C., Dalgliesh, C. E. and Clapperton, J. F. “Beer Flavor Terminology”. *Journal of the Institute of Brewing*, 85, 1979: 38-42. doi:10.1002/j.2050-0416.1979.tb06826.x

³¹ Lee, K.M., Paterson, A., Piggott, J.R., Richardson, G.D. “Origins of Flavor in Whiskies and a Revised Flavor Wheel: a Review”. *Journal of the Institute of Brewing*, 107, 2001: 287-313. doi:10.1002/j.2050-0416.2001.tb00099.x

³² Monteiro, B., Vilela, A., Correia, E. “Sensory profile of pink port wines: Development of a flavor lexicon”. *Flavor and Fragrance Journal*, 29, 2014: 50-58. doi:10.1002/ffj.3178.

³³ Aromaster / aromaster.com [CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0/>)], accessed 26th May 2019.

³⁴ Noble et al., 1984

³⁵ <https://www.slideshare.net/sveinmagnus/fine-chocolate-tasting>, accessed 26th May 2019.

³⁶ Lawless, H.T., Heymann H. *Sensory Evaluation of Food: Principles and Practices*. Chapman & Hall, New York, 1998.

³⁷ Vilela, A., Matos, S., Abraão, A.S., Lemos, A.M., Nunes, F.M. “Sucrose Replacement by Sweeteners in Strawberry, Raspberry, and Cherry Jams: Effect on the Textural Characteristics

strawberry, raspberry, and cherry jams with more acceptable nutritional profile, but maintaining their sensory characteristics in comparison with the traditional formulation with sucrose. Sucrose was replaced by fructose, sorbitol, or fructooligosaccharides (FOS), given the potential low glycemic index and the reduced calories in the case of sorbitol and FOS, and enrichment with dietary fibre, in the case of FOS. After sensory lexicon development sensorial and application of quantitative descriptive analysis test, the authors found that the sweeteners used interfered, significantly, in the parameters measured. For exemplification, the sensory profile, and the strawberry jam sensory attributes, prepared with different sweeteners (osmotic dehydration agents), can be seen in Figure 5, a spider graph, one of the most used type of graph for sensory profile presentation.

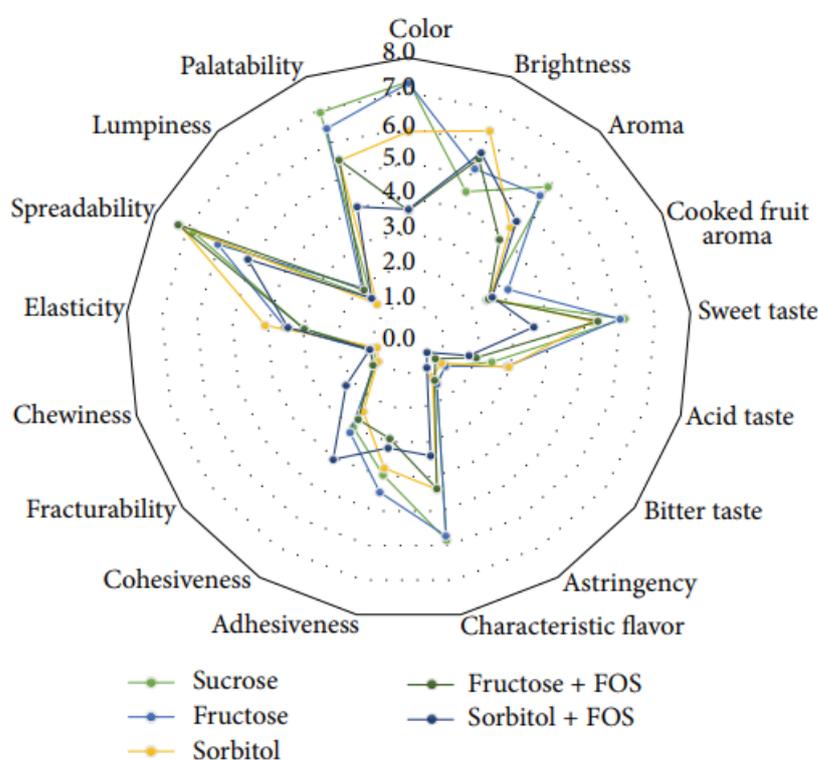


Figure 5: Sensory profile of strawberry jams prepared with five different OD agents or combinations of two. Adapted from Vilela et al.³⁸

Another interesting data analysis and representation is CATPCA (as Categorical Principal Components Analysis). In a work performed by Monteiro and co-workers³⁹, the applicability of sensory techniques in the Pink Port Wine sensory evaluation was studied. The work aimed to differentiate between five Pink Port Wine brands, positioned on the Portuguese market. The authors, with the Porto Cruz company's help, were the work was performed, selected and trained a group of panellists by using

and Sensorial Profile—A Chemometric Approach". *Journal of Food Processing*, vol. 2015, Article ID 749740, 2015: 14 pages. <https://doi.org/10.1155/2015/749740>.

³⁸ Vilela et al., 2015

³⁹ Monteiro et al., 2014.

discriminative tests. Then the identification and selection of descriptors was performed and finally, the establishing of the wines sensory profile, using the developed sensory lexicon, and non-parametric multivariate analytical techniques such as CATPCA. Interestingly, from the five brands studied, three of them were very similar in terms of attributes, while the other two presented different sensory characteristics. The two-dimensional CATPCA explained more than 87% of the total amount of initial variance and a scatter plot, with each attribute and each wine plotted along with Principal component 1 and Principal component 2 was obtained (Figure 6)⁴⁰.

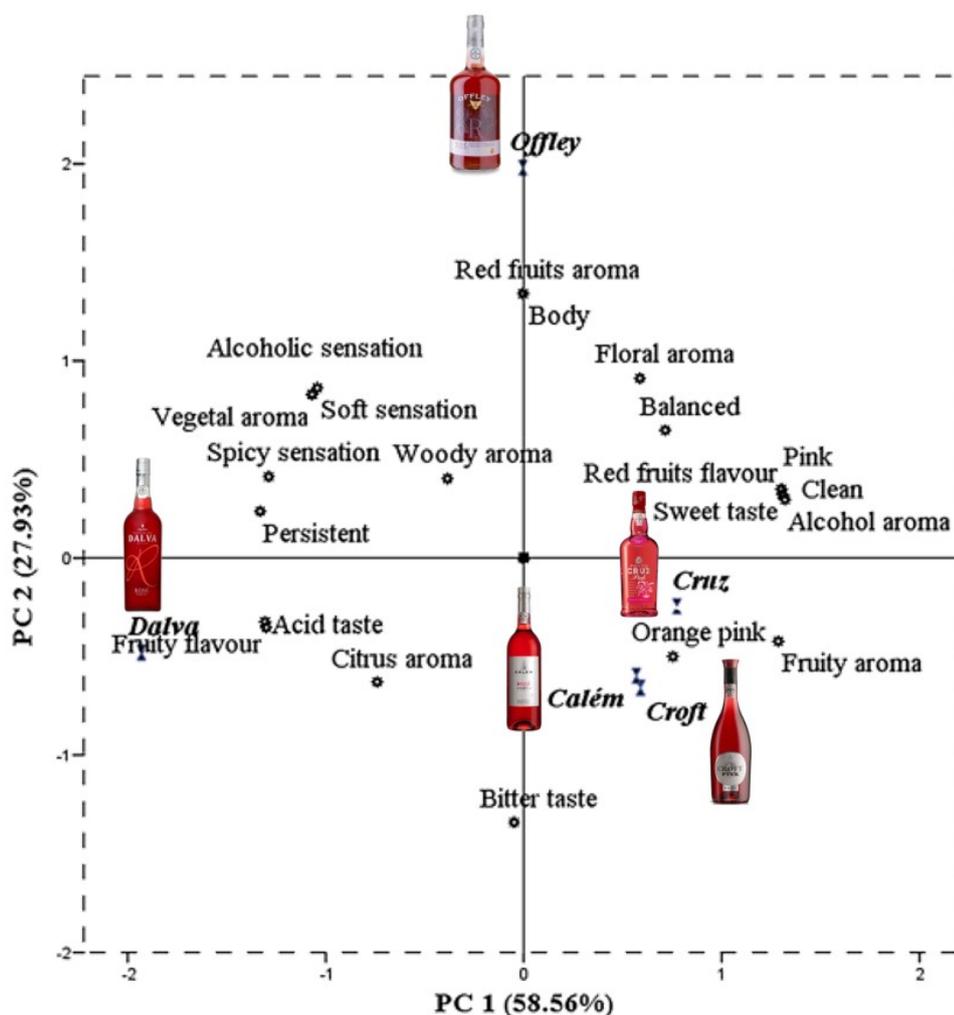


Figure 6. Principal components loadings and scores of the sensory attributes and wines for PC1 and PC2, after CATPCA analysis. Adapted from Monteiro et al.⁴¹

In 2018, Vilela and co-workers⁴², published a study on three Vinho Verde monovarietal wines from the grape varieties, Alvarinho, Loureiro, and Arinto. The “sensory lexicon” developed by the trained

⁴⁰ Ibid.

⁴¹ Monteiro et al., 2014.

panellists could be used by marketers allowing the articulation of flavour perceptions to consumers. Moreover, a second-order factor analysis statistical model (SEM) was developed for each grape-variety wine, based on the data-set of the sensory attributes, allowing a new perspective on the sensory characterization of these wines (Figure 7). This work also shows that Structural Equation Modelling (SEM), is a good statistical tool to be used in sensory analysis data treatment, once SEM explicitly considers the measurement errors associated with the variables under study, and can encompass two sub-models, according to the relational structure between the variables: a measurement model and a structural model that allowed as to characterize the monovarietal wines according to their main sensory descriptors.

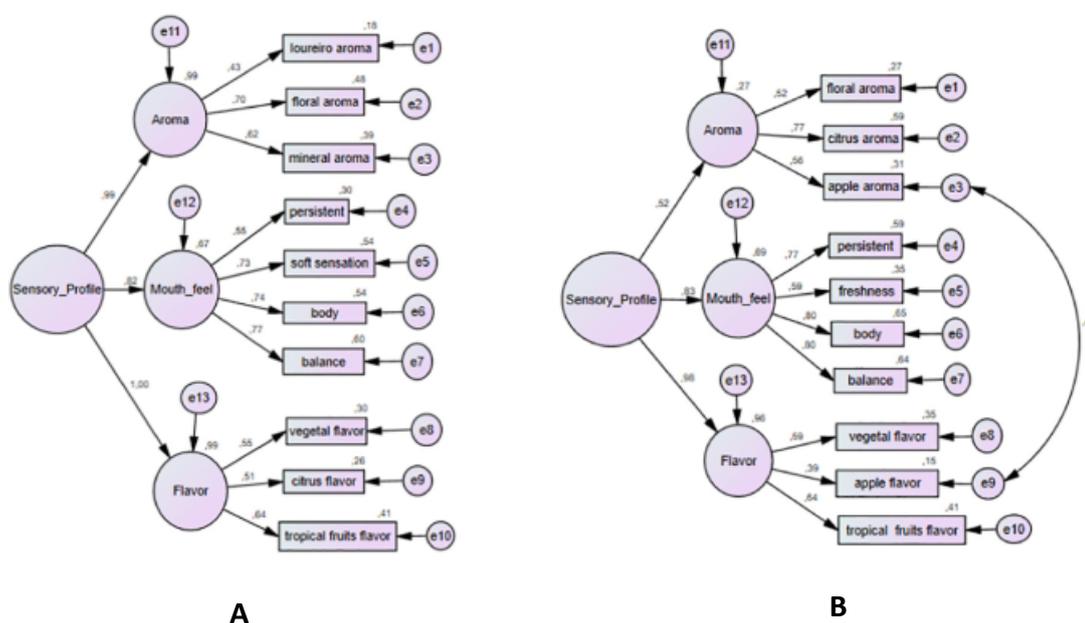


Figure 7 - Schematic representation and values of the standardized factor weights and the individual reliability of each of the items in the final second-order CFA model for the sensory profile of monovarietal Loureiro (A) and Alvarinho (B) wines. Adapted from Vilela et al.⁴³

FINAL REMARKS

Sensory evaluation involves the development and use of principles and methods for measuring human responses to food and beverages. This science depends on guidelines for the preparation and serving of samples under controlled conditions so that biasing factors can be minimized.

⁴² Vilela, A., Marques, C., Correia, E. "Structural Equation Modelling (SEM) applied to sensory profile of Vinho Verde monovarietal wines". *Food Research International*, Vol 111, 2018: 650-660. <https://doi.org/10.1016/j.foodres.2018.05.077>.

⁴³ Vilela et al., 2018.

Sensory perception is a learned and active practice and not a passive reflex. Sensations are held to arise “neither from the food/beverage nor from the consumer, but from the encounter between them”, that is, it is neither taste nor taster, but *tasting*.

Universal objectives and universal languages “lexicons” must be developed. As, also, new statistical methods, graphical representations, and data analysis must be studied, so that sensory experts and consumers can contribute, both, for a better food/beverage sensory quality evaluation.

Acknowledgements: We appreciate the financial support provided to the Research Unit in Vila Real [grant number PEst-OE/QUI/UI0616/2014] by FCT - Portugal and COMPETE.

SOBRE A AUTORA:

Alice Vilela

CQ-VR, Chemistry Research Centre, University of Trás-os-Montes and Alto Douro, School of Life Sciences and Environment, Department of Biology and Environment, 5001-801 Vila Real, Portugal.

avimoura@utad.pt