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WINE TASTING AND CRITIQUE: BIAS, ERRORS, MISCONCEPTIONS AND THEIR INFLUENCE ON THE MARKET

José Luiz Borges

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ABSTRACT

Tasting is an important tool for evaluating wines, as it exerts a decision-making role at the various stages of production and distribution chains of consumption.

Tasting is also the instrument of wine critics and of wine contest judges. Assessment of specialized critics and the results obtained in wine contests exert great influence over wine market. The outcome of these evaluations, nevertheless, has revealed poor accuracy, precision and reproducibility. Still, the wine market is strongly influenced by such results.

This thesis introduces a revision on anatomical and physiological knowledge of the sense organs involved in the sensory evaluation of wines. The chemical basis for the origin of wines organoleptic characteristics regarding their appearance, aroma and oral sensations is also analyzed.

Based on this knowledge, the causes of errors, deviations and inaccuracy in wine tasting are then discussed, as well as how these factors contribute to illusory results at wine contests and to the assessment made by skilled critics, which is often dissociated of consumer's perception. The influence on the market and wine prices of the evaluation performed by specialized critics and awards obtained in contests have been focused in this analysis as well.

Some options of wines assessment are herein proposed, in order to meet the needs of regular consumers.

ACKNOWLEDGEMENTS

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INTRODUCTION

Sensory analysis is a useful tool in the food and beverage industry for product development, testing quality and establishing marketing strategies[1,2,3]. On the other hand, in the wine industry, tasting is the basis of all activities, from the viticultural practice to wine service at table and to its consumption. In the words of Émile Peynaud, tasting is a means of knowledge, and getting to know the wine better improves its production, storage, control and ultimately allows us to better enjoy it[4].

The world consumption of wine, in both producing and traditional consuming countries, has decreased considerably in the second half of the twentieth century. Moreover, new consumer markets, especially Asians, have emerged, importing large quantities of wine. In the last decade, there has been a slight overall increase in consumption. Other recent wine market trends are the relative rise in consumption of quality wines, with a consequent decrease in the consumption of wine in bulk and the increase in price per unit sold[5,6,7].

The expansion of the global market for fine wines has led to a greater accessibility to this product, with the growth in the number of uninformed consumers, or even naive ones. This phenomenon paved the way for the emergence of influential wine critics, whose tasting notes play an important role in the global wine market[8]. In a population of wine buyers, the higher the proportion of naive consumers with respect to

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[1] Adriano G. Cruz et al. Sensory analysis: relevance for prebiotic, probiotic, and synbiotic product development. Compr Rev Food Sci Food Saf.2010; 9(4):358-73.
[2]Montserrat Riu Aumatell. Sensory analysis in quality control: the gin as an example. [cited 2013 Dec]. Available from: http://www. intechopen. com/download/get/type/pdfs/id/23744.
[3]Maria Iannario et al. Sensory analysis in the food industry as a tool for marketing decisions. Adv Data Anal Classif. 2012; 6(4):303-21
[4]Émile Peynaud and Jacques Blouin. *O gosto do vinho*. São Paulo: Martins Fontes; 2010.
[5]Glyn Wittwer and Jeremy Rothfield. Projecting the world wine market from 2003 to 2010. Australas Agribus Rev. 2005; 13:paper 21.[cited 2013 Dec]. Available from: http://www. agrifood. info/review/2005/Wittwer_Rothfield. html.
[6]International Organization of Vine and Wine.World vitiviniculture situation in 2012.In: XXXVIth World Congress of Vine and Wine Bucarest, 3rd June 2013. [cited 2013 Dec]. Available from: http://ebookbrowsee. net/oiv-world-vitiviniculture-situation-in-2012-pdf-d502699851.
[7]International Organization of Vine and Wine.Statistical report on world vitiviniculture 2012.[cited 2013 Dec]. Available from: http://www. oiv. int/oiv/info/enizmiroiv report.
[8] Karl Storchmann, Alexander Mitterling and Aaron Lee. The detrimental effect of expert opinion on price-quality dispersion evidence from the wine market.AAWE Working Paper.Economics. 2012; 118.[cited 2013 Dec]. Available from: http://www. wine-economics. org/aawe/wp-content/uploads/2012/10/AAWE_WP118. pdf.

the informed ones, the greater the effect of the scores assigned by critics in pricing. Moreover, a similar effect occurs when a wine receives a second revision grade given by the same critic or another one. In this case, the re-evaluation grade receives a higher weight by consumers, affecting final price[9]. The effect of high grades on the price of the wine seems to be higher than that related to lower grades[10]

However, inconsistency and poor reproducibility observed in wine competitions, tasting panels and analysis made by opinion-forming critics lead to questioning the validity of tasting as a method of evaluating wines[11,12]

This thesis has the purpose of reviewing the anatomical and physiological bases of sensory evaluation and the chemical origins of wine organoleptic properties. In addition, the causes of limitations, biases and errors of wine tasting will be discussed as well as their repercussions in the specialized critique of wine and in its market.

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[9]Michael Gibbs, Mikel Tapia and Frederic Warzynski. Globalization, superstars, and reputation: theory and evidence from the wine industry. J Wine Econom. 2009; 4(1):49-64. Available from: http://www. wine-economics. org/journal/details-content/volume-4-2009-no-1/.

[10]Héla Hadj Ali, Sébastien Lecocq and Michael Visser. The impact of gurus: parker grades and en primeur wine prices. [Revised, June 2007; cited 2013 Dec]. Available from: http://ermes. u-paris2. fr/doctrav/0718. pdf.

[11]David Derbyshire. Wine-tasting: it's junk science. The Guardian,The Observer. 2013 Jun 23.[cited 2013 Dec]. Available from: http://www. theguardian. com/lifeandstyle/2013/jun/23/wine-tasting-junk-science-analysis.

[12] Richard E. Quandt. On wine bullshit: some new software? J Wine Econom. 2007. 2(2): 129-35.

ANATOMY AND PHYSIOLOGY OF THE SENSE ORGANS

The sense organs constitute our interface with the environment. Through them we perceive the signals of the outside world, which are processed in the upper layers of the brain, thus becoming a cognitive reality. The evolution of such organs has allowed the survival of the human species. Without olfaction, how could one manage to escape in time from a fire in the house or even detect deteriorated food? Vision has allowed us to observe the enemy from afar and the sense of touch warns us immediately about hot or sharp objects that could cause injuries. The sensorial mechanisms also receive hedonic stimuli.

The nerve pathways that carry different sensory stimuli to the cerebral cortex are integrated in an area called the orbitofrontal cortex. This area, in addition to sensory integration, is likely responsible for enhancing affective values, decision-making processes and the mediation of hedonic experience[13]. This integration between vision, olfaction and taste, whose primary biological function is to optimize search for proper foods, can also lead to errors of judgment. Thus, our senses may be misleading, requiring a careful analysis based on experiential knowledge of the information brought by them.

The organs of sense, whose anatomy and physiology are described below, are those involved in both hedonic and technical tasting of wines.

1. Vision

The eye is a sophisticated optical instrument developed by natural selection under evolutionary pressures of over millions of years. This sensory organ allows us to capture a range of the light spectrum, the visible radiation and is one of our important interfaces with the structural organization of the world.

The beam of light emitted or reflected by objects goes through the transparent anterior membrane of the eye, the cornea, until it reaches the crystalline lens. This

[13]Morten L. Kringelbach. The human orbitofrontal cortex: linking reward to hedonic experience. Nat Rev Neurosci. 2005;6:691-702.

structure resembles a lens and it is deformable by the action of the muscles on which it is fixed. When going through crystalline lens, the light undergoes refraction controlled by the change in the shape of this lens. This process sends the focus of the light beam onto the retina, a nervous tissue located in the posterior part of the eye[14].

The retina is a projection of the central nervous system outside the skull, and it is the only noninvasively observable part of this system. It is a 0.5 mm thick layer, which coats the inner posterior surface of the eyeball. Interestingly, the retina of vertebrates is "inverted" in the sense that the photosensitive segments of the receptor neurons are facing the outermost region of the eye. Because the retina is in the posterior part of the eye, the light beam arriving frontally through the lens must pass through the entire retinal thickness to stimulate the receptor cells. Its structure is organized into three layers where neuronal bodies are found. These layers are separated by two interfaces where the synaptic connections between different retinal neurons are observed. The receptor cells are located adjacent to the ocular pigment epithelial layer, which is rich in melanin, allowing it to absorb reflections of light, preventing them from returning to the photoreceptors and blurring the image. Furthermore, the retinal pigment epithelial layer provides a continuous flow of retinal (vitamin A) to the photoreceptors where its fixation to the opsin molecule occurs. There are two types of receptor cells which are sensitive to light, rods and cones which convert light energy to electrical activity. The cones are responsible for daytime vision and distinction of colors and brightness. The rods, in turn, are responsible for vision in dim light and the distinction of light and dark. Most mammals have cones which are sensitive to wavelengths of light corresponding to the visible green and red colors. Primates, in turn, have three types of cones: those sensitive to the range of light wave, which we decode as red; those sensitive to green; and those that respond to blue[15]. This particular sensitivity of the cones is due to its photoreceptors, i.e. proteins called photopsins. There are three types of photopsins whose maximum response corresponds to three ranges of light wavelengths. According to its photopsin, there are cones, which are sensitive to short wavelengths of about 420 nanometers, the S-cones (blue). The cones, which are sensitive to waves of medium length, in the range of 530 nm, are the M-cones (green) and cones sensitive to long

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[14]Helga Kolb. Gross anatomy of the eye.In: Kolb H, Fernandez E, Nelson R, editors. Webvision: the organization of the retina and visual system. [Last Updated January 25, 2012]. Available from: http://webvision. med. utah. edu/book/part-i-foundations/gross-anatomy-of-the-ey/

[15]Helga Kolb. Photoreceptors. In: Kolb H, Fernandez E, Nelson R, editors. Webvision: the organization of the retina and visual system. [Last Updated January 25, 2012]. Available from: http://webvision. med. utah. edu/book/part-ii-anatomy-and-physiology-of-the-retina/photoreceptors/.

waves are the L-cones (red), which respond to the range of approximately 560 nm.[16] The gradient sensitivity of the cones together allows the detection of a wavelength range of about 380 to 780 nm, i.e. visible light. If red and green receptors are equally stimulated, we see yellow, and if the three types of cones are stimulated homogeneously, we see white[17]. The three cones, acting together, distinguish 200 shades, 20 saturation levels and 500 levels of brightness. The combination of these parameters provides 2,000,000 gradations of colors[18].

The second types of photosensitive cells, rods, also have a light reactive pigment, rhodopsin, formed from a precursor and vitamin A. The degradation of rhodopsin by light energy causes excitation and response of the rods, which are responsible for seeing white, black, and bright/dark.

The receptor cells are connected to other neurons, called bipolar, which in turn, make connection to the ganglion neurons, which conduct stimulation out of the retina. The signal emitted by various cones is assembled by horizontal cells, which determine how many cones converge to a ganglion cell. Regarding the rods, this convergence role is played by the amacrime cells located near the retinal surface, near the ganglion cell layer. The cell bodies of the bipolar and horizontal cells form the inner nuclear layer of the retina. This layer is separated from that of photoreceptor cells by the outer plexiform layer, where the synapses among neurons of the two layers are located.

The inner nuclear layer is separated from the ganglion cells layer by the inner plexiform layer, where the synaptic connections occur. The axons gathered from the ganglion neurons form the optic nerve. The stimulus is then driven back to the front by these cells which merge to the optic nerve. The electrical impulses generated are organized and transmitted to the brain by the optic nerve[19].

When the fibers that make up the left and right optic nerves reach the base of the diencephalon, in its path toward the posterior area of the brain, they partially cross to the opposite side. In humans, in the structure called optic chiasm, 60% of fibers cross to the contralateral hemisphere (decussation), while the others continue their way

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[16]James K Bowmaker and Herbert J Dartnall. Visual pigments of rods and cones in a human retina. J Physiol. 1980;298:501-11.
[17]Helga Kolb. How the retina works. Am Sci. 2003;91:28–35.
[18]Titus Vilis. The Physiology of the Senses Lecture 1: The eye. In:_______. The Physiology of the Senses: transformations for perception and action [Online Course; Revised 16/08/2012]. Available from: http://www. tutis. ca/Senses/L1Eye/L1Eye. pdf.
[19]Dale Purves et al. , editors. Vision: the eye. In:_______. Neuroscience. 3rd ed. Sunderland, MA: Sinauer Associates; 2004. p.229-58. Available from: http://www. cns. iisc. ernet. in/ns201_13/books/Neuroscience_Purves. pdf.

ipsilaterally. After the optic chiasm, the axons of ganglion cells begin to form the optic tract, which contains fibers from both eyes. This complex architecture makes the images originating from our right visual field be processed also in the left hemisphere of the brain and vice versa. The optic tract reaches the dorsal lateral geniculate nucleus. The neurons of the nucleus, in turn, through a portion of the so-called internal capsule optical radiation reach the primary visual cortex, known as Brodmann area 17, or V1 in the calcarine fissure of the temporal lobe. In this area, the stimulus generated by the light on the retina will be decoded, interpreted and integrated, converting sensation to perception and cognitive phenomenon. This retino-geniculo-striate route is the primary visual pathway[20].

As seen above, in primates, color vision is the result of a complex integration of stimuli received by the three types of cones. This type of vision in normal individuals is called trichromacy. The absence or non-operation of one or more cone leads to different forms of color blindness (dyschromatopsia). About 8% of men and 0.5% of women have congenital abnormalities of color vision[21]. It is known that specific genes determine the presence of each type of cones. The genes encoding the red and green pigments are located in adjacent regions of the chromosome X[22], which explains the differences in prevalence of congenital dyschromatopsias between men and women. Conversely, the gene for the blue pigment is at chromosome 7.

2. Olfaction

The sensory systems associated with the nose and the mouth are responsible for detecting chemicals in the environment. Thus, olfaction, taste and trigeminal tactile sensations are called chemical senses. The olfaction is important in the selection of food and for reproductive and maternal functions. The neuroendocrine regulation and emotional responses also undergo the influence of olfactory stimuli.

[20]Dale Purves et al. , editors. Central visual pathways.In:_______. *Neuroscience.* 3[nd]ed. Sunderland, MA: Sinauer Associates; 2004. p.259-82. Available from: http://www. cns. iisc. ernet. in/ns201_13/books/Neuroscience_Purves. pdf.

[21]Michael Kalloniatis and Charles Luu. Color perception. In: Kolb H, Fernandez E, Nelson R, editors. Webvision: the organization of the retina and visual system. [Copyright 2014].Available from: http://webvision. med. utah. edu/book/part-viii-gabac-receptors/color-perception/.

[22]Jeremy Nathans et al. Molecular genetics of inherited variation in human color vision.Science. 1986;232:203-10.

Olfaction allows one to identify a large number and variety of chemical substances from the external environment. It is estimated that human beings can sense about 10.000 to 100.000 chemical substances with different odors[23]. These "odorants", unlike sapid substances, should be small and volatile molecules that can be transported by air from the emission source to the olfactory system. This system, which is one of the oldest in the phylogeny of mammals, is characterized by exceptional sensitivity and high discriminatory power. This last quality is verified by the fact that minor changes in the molecular structure of an odorant may determine perceptions of different odors.

Transported by the inspired air, odorants reach the nostrils and nasal cavity. In this region, bone structures known as shells or turbinates direct the airflow to the rear and top of the cavity. In this region, a small area of the lining epithelium of the nasal cavity contains the endings of the olfactory sensory neurons. In humans, this area, i.e. the olfactory plaque, has 2-4 cm^2 and contains 10 to 20 million receptor cells. When the odorants reach the olfactory plate, they are dissolved in the mucus that covers the epithelium. In this mucus, odorant binding proteins[24] and some specific antibodies provide transport and presentation of the odorant to the sensory endings of the receptor neurons. The cell membrane of these structures houses the so-called G proteins-coupled receptors[25].These proteins are encoded by a large multigene family[26].It is known that humans have about 330 odorant receptors[27]while mice have approximately 1000[28]. These data suggest that between 1 and 2% of the human genome are genes dedicated to the production of these proteins. This number is second only to the number of genes related to the immune system. Each sensory neuron has only one type of odorant receptor[29], however each receptor can be coupled to various odorants[23].

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[23]Linda B Buck. Unraveling the sense of smell. Nobel Lecture, December 8, 2004. p.267-83. [cited 2013 Dec]. Available from: http://www. nobelprize. org/nobel_prizes/medicine/laureates/2004/buck-lecture. pdf.
[24]Paolo Pelosi. Odorant-binding proteins. Crit Rev Biochem Mol Biol. 1994;29:199-228.
[25]Peter Mombaerts. Seven-transmembrane proteins as odorant and chemosensory receptors.Science. 1999;286:707-11
[26]Linda Buck and Richard Axel. A novel multigene family may encode odorant receptors: a molecular basis for odor recognition. Cell. 1991;65:175-87.
[27]Bettina Malnic et al. The human olfactory receptor gene family.ProcNatlAcadSciU S A. 2004;101:2584-9.
[28]Paul A. Godfrey, Bettina Malnic and Linda B. Buck. The mouse olfactory receptor gene family.ProcNatlAcadSciU S A. 2004;101:2156-61.
[29]Bettina Malnic et al. .Combinatorial receptor codes for odors.Cell. 1999;96:713-23.

2.1. Transduction

Once the coupling of the receptor molecule with the odorant is performed, the transduction process begins. This pathway in mammals is composed of a variable component, the olfactory receptor and four constant elements: Gαolf heterotrimeric G protein; adenylcyclase, which produces the second messenger, the cyclic AMP (cAMP); a channel for cations controlled by cyclic nucleotide, and a chlorine channel. Thus, the response of the sensitive olfactory neurons to different combinations of odorants results, predominantly or solely, from olfactory receptor[30].Different odorants are discriminated by combinatorial codes generated by the stimulation of different receptors yielding different olfactory perceptions[31].

2.2. Communication among olfactory sensory cells.

The sensory neurons cross the cribiform plate of the ethmoid bone, forming the olfactory nerve, and transmit the stimulus directly to a brain structure called the olfactory bulb, where they connect, in structures called glomeruli, with the second neuron in the chain, mitral cells or tufted cells. Each glomerulus contains apical dendrites of approximately 25 mitral cells, which connect with the axons of about 25,000 olfactory receptor neurons. This convergence probably increases the signal and the sensitivity of mitral cells. In the glomeruli, dendrites of about 50 tufted cells and 25 periglomerular cells are also observed. The function of the latter is not well known, yet it is assumed that they exert control functions[32].

The innermost layer of the olfactory bulbs of vertebrates consists of granular cells, which establish synapses with the basal dendrites of mitral cells. These connections are dendrodendritic since these cells have no axons. Its probable role is establishing lateral inhibitory circuits and acting on the plasticity of the olfactory bulb. Granular cells and periglomerular are some of the few neurons that are renewed throughout life[33].

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[30]Peter Mombaerts. Genes and ligands for odorant, vomeronasal and taste receptors.Nat Rev Neurosci. 2004;5:263-78.

[31]Kentaro Kajiya et al. Molecular bases of odor discrimination: reconstitution of olfactory receptors that recognize overlapping sets of odorants. J Neurosci. 2001;21:6018-25.

[32]Denise de Arruda. *The Periglomerular cell of the olfactory bulb and its role in the odor processing*: *a computational model* [Thesis]. Ribeirão Preto, SP: Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto; 2010.

[33]Dale Purves et al. , editors. The chemicals senses.In:_______. *Neuroscience.* 3[nd]ed. Sunderland, MA: Sinauer Associates; 2004. p.337-67.

2.3. Integration in the Central Nervous System

The axons of the mitral cells together form the lateral olfactory tract. Through it, the olfactory bulb sends projections to structures that, as a group, are called primary olfactory cortex. These structures can be divided into three groups: the anterior olfactory nucleus; the rostral olfactory cortex, comprising induseum griseum, the anterior continuation of the hippocampus, the tenia tecta, infralimbic cortex and the lateral olfactory cortex that includes the piriform, periamygdaloid, transitional and entorhinal cortices. The primary olfactory cortex sends projections to cortical and subcortical brain areas that are not considered as part of the olfactory system. Thus, the primary olfactory cortex and anterior olfactory nucleus sends efferent fibers to the thalamus and hypothalamus and some neurons in piriform cortex innervate a region of the orbitofrontal cortex revealing multimodal neurons that respond to olfactory and gustatory stimuli. Along this path, odorants affect cognitive, visceral, emotional and homeostatic behaviors[34,35].

3. Gustation

The words taste and flavor are often used indiscriminately. However, taste is one of our senses, while flavor is a more complex perception, composed of taste, olfactory, and tactile sensations. The sense of taste, or gustation, allows us to perceive and distinguish the presence of sapid substances in food and whatever is brought into the mouth, thus allowing one to ingest nutrients selectively and avoid ingesting poisons and toxins. It is accepted that humans can distinguish five different tastes: sweet, salty, bitter, acid or sour, and umami. The latter, recently recognized, is the sensation caused by monosodium glutamate as well as the amino acid L-aspartate[36]. The existence of a taste sensation associated specifically to fat is debatable[37].

The gustatory pathway begins with the gustatory sensory cells. There are four types of such cells, where type I have the function of support, while type IV probably

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[34]Michael T. Shipley and Matthew Ennis. Functional organization of olfactory system. J Neurobiol. 1996;30:123-76.
[35]Dale Purves et al. , editors. The chemicals senses.In:_______. *Neuroscience.* 3[nd]ed. Sunderland, MA: Sinauer Associates; 2004. p.337-67.
[36]Bernd Lindemann et al. The discovery of umami.ChemSenses. 2002;27:843-4.
[37]Richard D Maates.Is there a fatty acid taste? Annu Rev Nutr. 2009;29:305-27.

generates the other types. Both lack the capacity to generate stimuli decodable as taste sensation. This function is performed by types II and III[38]. Taste sensory cells gather into taste buds. In these structures, 50-100 taste cells are clustered in an oval shape. A small opening, the taste pore, situated at the apex of the bud allows the entry of sapid substances. The taste buds are located in the so-called gustatory papillae, which are visible on the surface of the tongue.

There are four types of papillae. The filiform papillae are the most numerous, however they have no taste sensivity. Its function is tactile sensitivity. The fungiform papillae are mushroom-shaped and cover the anterior 2/3 of the tongue and are innervated by the chorda tympani, one of the branches of the intermediate-facial nerve. There are about 200 of these papillae on the tongue, containing 25% of the taste buds. It is estimated that the tongue has about 1250 taste buds in fungiform papillae. The foliate papillae are located on the sides of the tongue, and are more sensitive to acid taste. These papillae are innervated by the glossopharyngeal nerve. On average, two of those buds occur at the posterolateraltongue with approximately 600 taste buds each, or approximately 25% of taste buds of the tongue. The circumvallate papillae are the largest ones, with a peculiar shape. They are elevations with a central depression surrounded by a "high wall". They are located on the back of the tongue, forming the so-called V lingual. They are sensitive to sour taste, and particularly to bitter taste. Their number varies from 3 to 13 containing 25 taste buds each. Therefore, these buds harbor about 50% of the tongue taste buds. The nerve responsible for the transmission of stimuli received by them is the glossopharyngeal[39].

There are 2500 other taste buds scattered in the oropharynx, proximal esophagus and epiglottis. Its innervation is made by the vagus nerve.

3.1. Transduction

The sapid molecules, which are responsible for these five tastes, are dissolved in saliva and penetrate the taste buds through its pores and come into contact with receptors on microvilli of type II taste cells. Then they bind to receptors termed GPCR (G proteins-coupled receptor for sapid substances). G proteins are a class of proteins, of multigenic origin, present in mammals, which bind to sapid substances or odorants.

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[38]Nirupa Chaudhari and Stephen D. Roper. The cell biology of taste.J Cell Biol. 2010;190:285-96.
[39]Dale Purves et al. , editors. The chemicals senses.In:_______. *Neuroscience.* 3[nd]ed. Sunderland, MA: Sinauer Associates; 2004. p.337-67.

From the activation of these receptors or ionic channels the process of transduction is started, i.e. the cascade of reactions that ultimately promote membrane depolarization of the taste sensory cells, converting chemical stimulus into electrical impulses carried along nerve pathways to the central nervous system, where integration and decoding of these impulses occur. An important family of these receptors is composed of members called T1R1, T1R2[40], andT1R3 which have been more recently discovered[41]. This family of GPCRs mediates the pleasant sweet and umami tastes. These molecules are associated in complex homodimeric or heterodimeric receptors forming molecules that bind to substances with a sweet taste, whether or not saccharides. T1R receptors are critical for the detection of sweet tastes and are expressed in subsets of sapid substances receptor cells TRC. There are three groups of such cells: the co-expressing T1R1 and T1R3 (T1R1+ 3), the co-expressing T1R2 and T1R3 (T1R2+3) and those expressing only T1R3. It has been shown that the T1R2+3 heterodimer is the sweetness receptor that responds to all categories of sweet substances, whether natural sugars, artificial sweeteners and d-amino acids[42].

The umami taste is given by binding monosodium glutamate to receptors such as Taste-mGluR4, Taste-mGluR1 or to the dimer T1R1/T1R3(T1R1+3) resulting from the combination of the two T1 receptors[43,44]. The GPCRs for bitter taste belong to another large family called T2R[45].

After the stimulation of GPCR, transduction of sweet, bitter and umami tastes occurs through two main pathways, mediated by molecules that act as "second messenger" in this cascade. One of them is the cyclic adenosine monophosphate (cAMP). In the case of the gustatory path, a specific G protein, known as Gα-gustducin, has been described and is found primarily in cells expressing T2R[46], whose activation correlates inversely with the concentration of cAMP. The changes in cAMP concentration finally leads to other phosphorylation reactions, which cause inhibition of the potassium channels of the taste sensory cells, which depolarizes the cell and causes

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[40]Mark A. Hoon et al. Putative mammalian taste receptors: a class of taste-specific GPCRs with distinct topographic selectivity. Cell. 1999;96:541-51.
[41]Marianna Max et al. Tas1r3, encoding a new candidate taste receptor, is allelic to the sweet responsiveness locus Sac. Nat Genet. 2001;28:58-63.
[42]Greg Nelson et al. Mammaliansweet taste receptors. Cell. 2001;106:381-90.
[43]Greg Nelson et al. An amino-acid taste receptor.Nature. 2002;416:199-202.
[44]Nirupa Chaudhari. Taste receptors for umami: the case for multiple receptors. Am J ClinNutr.2009;90:738S-742S.
[45]Elliot Adler et al. A novel family of mammalian taste receptors. Cell. 2000;100:693-702.
[46]Susan K. McLaughlin et al. Gustducin is a taste-cell-specific G protein closely related to the transducins. Nature. 1992;357:563-9.

the secretion of neurotransmitters. Another "second messenger" is the release of intracellular calcium mediated by inositol triphosphate (IP3), with activation of the melastatin type transient receptor potential cation channel TRPM5, depolarizing the cell and releasing the ATP neurotransmitter[47]. The activation of TRPM5 may be the common pathway in the transduction of sweet, bitter and umami tastes[48].

Sour tasting substances can stimulate specific channels (PKD2L1) or act through the epithelial sodium channels. Sour taste is perceived in type III sensory cells. The salty taste is transduced by the entry of sodium in the cell through sodium channels called ENaCS, similar to those existing in the kidneys. The rise of the sodium concentration in the cell leads to depolarization and generation of neurotransmitters[49].

3.2. Communication among gustatory sensory cells.

Type II gustatory cells are just receptors because they do not establish bonds with neurons that run to the central nervous system. Type III cells, in turn, communicate directly with nerve fibers by means of synapses and send signals to the central nervous system. Consequently, the continuity of transmission of stimulus requires communication between type II and III cells. When stimulated, the latter release neurotransmitters, probably serotonin to the sensory nerve fiber which depolarizes and transmits the impulse to the brain[50].

3.3. Integration in the Central Nervous System

All stimuli caused by sapid substances trigger reactions of different qualities and intensities in the sensory cells, which are picked up by the facial, glossopharyngeal and vagus nerves and carried to the spinal cord and the nucleus of the solitary tract, which triggers non-conscious reflexes of rejection or acceptance of stimuli. Based on that, new nerve connections transmit stimulation to the so-called primary gustatory cortex, within the operculum-insular area. Neurons in this area, in monkeys, respond to the identity and intensity of flavor. Its response is not attenuated by satiety. New connections lead to

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[47]Robert F. Margolskee. Molecular mechanisms of bitter and sweet taste transduction. J Biol Chem. 2002;277:1-4.
[48]Yifeng Zhang et al. Coding of sweet, bitter, and umami tastes: different receptor cells sharing similar signaling pathways. Cell. 2003;112:293-301.
[49]Jayaram Chandrashekar et al. The receptors and cells for mammalian taste. Nature. 2006;444:288-94.
[50]Yijen A. Huang et al. Presynaptic (Type III) cells in mouse taste buds sense sour (acid) taste. J Physiol. 2008;586:2903-12.

the integrated stimulus into the secondary gustatory or orbitofrontal cortex. This area represents sensory, affective and hedonic food qualities. This is where the integration with the olfactory, visual and tactile sensations occurs. The ingestion control is in this area, which is also integrated into the system of reward and punishment[51].

The perception of taste can be produced from two models of neural representation of stimuli received by sensory cells. The so-called "labeled line" hypothesis states that a particular taste quality activates certain neurons, which otherwise would remain quiescent in the absence of the stimulus. The "across-neuron pattern" hypothesis states that there are no specific neurons for the tastes that are determined by a matrix activation of multiple neurons corresponding to a pattern that correlates with a given taste. Current knowledge seems to confirm the "labeled line" hypothesis[52].

The gustatory neural code also seems to involve a temporal aspect[53].

4. Chemosensory trigeminal system

Such a system consists mostly of multimodal noceptive receptor neurons, whose axons run along the branches of the trigeminal nerve. These nociceptor neurons are typically stimulated by chemicals which are considered irritant, such as: sulphur dioxide, ethanol, acetic acid, ammonia, menthol and carbon dioxide, in addition to capsaicin. Its function is to alert the organism about the potential risk of chemicals that can be ingested, inspired, or have contact with the eyes or other facial structures. This information is carried by the ophthalmic, maxillary and mandibular branches to the spinal component of the trigeminal ganglion, which sends them to the ventral posterior lateral nucleus of the thalamus and then to the somatosensory cortex, which processes the irritation and oral and facial pain. Some of the mouth nociceptive neurons send their axons to the branches of the vague and glossopharyngeal nerves. In addition to the nociceptive neurons, the oral mucosa houses mechanoreceptors whose afferent fibers run by infraorbital nerves, chorda tympani, lingual and glossopharyngeal. These receptors allow the distinction of textures[54,55].

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[51]Edmund T. Rolls and Leslie L. Baylis. Gustatory, olfactory, and visual convergence within the primate orbitofrontal cortex.J Neurosci. 1994;14:5437-52.
[52]Jayaram Chandrashekar et al. The receptors and cells for mammalian taste. Nature. 2006;444:288-94.
[53]Lemon CH and Katz DB. The neural processing of taste.BMCNeurosci. 2007;8(Suppl 3):S5.
[54]Dale Purves et al. , editors. The chemicals senses.In:_______. *Neuroscience*. 3[nd]ed. Sunderland, MA: Sinauer Associates; 2004. p.337-67. [cited 2013 Dec]. http://www. cns. iisc. ernet. in/ns201_13/books/Neuroscience_Purves. pdf.
[55]Martha R. Bajec and Gary J. Pickering. Astringency: mechanisms and perception. Crit Rev Food SciNutr. 2008;48:858-75.

CHEMICAL ORIGIN OF WINE ATTRIBUTES

1.Color

A plain visual inspection allows one to establish the type of wine, and predict, despite not so precisely, some of its features. The origin of the color of the wine is due to pigments, primarily originating from the grapes, but also from their contact with wood. Certain wavelengths of the incident light spectrum on wine are absorbed by the pigments and others are reflected. Thus, the color of red wine results from the absorption of all wavelengths except the red one.

The pigments, which are responsible for the wine color, are the anthocyanins that are present in grapes in the form of glucosides compounds of glucose and a flavonoid component called anthocyanidin. Glucose may also bind to organic acids such as caffeic, coumaric and acetic. The position of the methyl and hydroxyl groups that bind to the B ring of anthocyanidin determine five different types of anthocyanins: cyanin, delphinidin, malvidin, peonin and petunidin. The bluish hues increase with the number of free hydroxyls while the red hue increases with methylation. Malvidin, which is the most abundant anthocyanin in grapes and the most methylated contributes a great deal to the intense color of young red wines[56].Moreover, each of anthocyanins in wine occurs in a five-state molecular dynamic balance. One of them is linked to sulfur dioxide. The remaining ones, within the pH range of the wine, tend to be colorless. A small proportion, which exists in the form of the flavylium cation, is responsible for the red color. This ratio is pH dependent, increasing with its decrease. The rise in pH causes increased quinoidal state of anthocyanins, changing the color of the wine to the blue-violet[57]. The aging of red wine brings, as a consequence, a well-known color change, which shifts the purplish tone gradually to red, and subsequently, to orange and yellow hues. A major cause of this phenomenon is the formation of so-called polymeric pigments, which are less sensitive to pH, and carbon dioxide, allowing the expression of their color. An important compound is the polymer formed by the anthocyanins with

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[56]Ronald S. Jackson. Chemical constituents of grapes and wine.In:_______. *Wine science: principles, practice, perception.* 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.
[57]Yair Margalit and James Crum, editors. Phenolic compounds. In:_______. *Concepts in wine chemistry.* 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.95-129.

procyanidins. Other important pigments are pyranoanthocyanidins which are more intensely orange colored than the anthocyanins, which accounts for 50% of the pigments present in a five-year old wine[58].

The elements responsible for the color in white wine are less known, but it is believed that the light straw-colored, often displayed by these wines is conferred by a limited extraction and oxidation of flavonols such as quercetin and kaempferol. The golden color acquired with age is derived from the oxidation of phenols and galacturonic acid, as well as the caramelization of sugars by Maillard reactions[59].

2. Aroma

Aromas present in wines are traditionally classified as primary, secondary or tertiary. Primary aromas derive from substances contained in grapes, which remain more or less time in the wine. Secondary aromas are created by fermentation processes and wood aging. Tertiary aromas, in turn, are those that develop over the years, for wines with aging potential in the bottle and in the absence of oxygen (reductive aging). This combination of aromas is called "bouquet".

Likewise, defective aromas occur, which must be identified by a taster and may disqualify the wine for consumption.

2.1. Primary aromas

Grapes from the vast majority of cultivars *Vitis vinifera* do not exhibit characteristic aromas. Some exceptions are the floral or citrus scent present in Muscat varieties, vegetable or bell pepper flavors, observable in Cabernet Sauvignon grapes and related cultivars, such as Merlot, Cabernet Franc, Petit Verdot and Carmenère. In the case of Muscat family (Muscat of Alexandria, Muscat Canelli, Muscat Hamburg, Muscat Orange and Muscat Ottonel) and other related varieties (Riesling, Sylvaner, Gewüztraminer, Muller-Thurgau and others), the primary aroma is due to the presence of grape compounds known as monoterpenes, derived from the basic structure isoprene

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[58]Celestino Santos-Buelga and Victor de Freitas. Influence of phenolics on wine organoleptic properties.In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009.
[59]Ronald S. Jackson. Chemical constituents of grapes and wine.In:_______. *Wine science: principles, practice, perception.* 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.

(2-methyl-1,3-butadiene, C5H8). Monoterpenes are usually hydrocarbons (myrcene, limonene), but they also exist as alcohols (geraniol, nerol, linalool) and aldehydes (geranial, neral)[60]. Whenever a Muscat wine exhibits lemon scent, this is because a terpene (responsible for the lemon aroma of the lemon itself) was also present at that grape from where the wine was originated.

In the case of Cabernet Sauvignon and associated grapes, vegetable or bell pepper aroma is due to the presence of pyrazinic compounds in the fruits, especially 2-methoxy-3-isobutyl pyrazine. The concentration of this compound is higher in grapes from cooler regions and especially in those that are not harvested at full maturity[60]. Another cultivar, which is rich in pyrazines, is the Sauvignon Blanc[61].

Wine grapes contain numerous non-volatile compounds and therefore non-odorants, which are precursors of wine aromatic components. They are phenolic acids, cysteine-S conjugates, carotenoids, unsaturated lipids, S-methylmethionine and glycoconjugates.

Phenolic acids are hydroxycinnamic acids, which occur in grapes as esters of tartaric acid. The most common are caftaric acid and coutaric acid, which give rise to the odorants vinyl derivatives 4-vinyl phenol and 4-vinyl guaiacol present in wine. This reaction is mediated by the cinnamate decarboxylase of *Saccharomyces cerevisiae.* Catechins inhibit this conversion and the aromas attributed to these phenols are not too significant in red wines. However, catechins do not inhibit cinnamate decarboxylase of *Brettanomyces* contaminating yeasts and there may be a transformation of vinylphenols into ethylphenol, generating “barnyard”, “stallion”, and “mouse” defective aromas. In white and rosé wines, aromatic vinylphenols can exert some influence. Vinyl guaicol can contribute to the varietal flavor of Gewürztraminer[62].

One of the few phenolic derivatives, presenting as a primary component of grapes, is methyl anthranilate ester. This substance is present in significant amounts in grapes from *Vitis labrusca* cultivar and is responsible for the characteristic aroma of

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[60]Yair Margalit and James Crum, editors. Aroma and flavor.In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.133-92.
[61]Ronald S Jackson. Olfactory system. In:_______. *Wine tasting: a professional handbook*. London: Academic Press; 2002. p.39-78.
[62]Raymond Baumes. Wine aroma precursors. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.251-74.

wines which are made with these varieties ("foxy"). Methyl anthranilate can be detected in small quantities in wine grapes such as Pinot Noir, Riesling and Sylvaner[63].

S-cysteine conjugates are non-volatile precursors and non-odorants of volatile and odoriferous thiols. These compounds are derived from the L-cysteine molecule with a carbon chain linked to the sulfur atom. The activity of an enzyme, the cysteine-S conjugate β lyase, during alcoholic fermentation by *Saccharomyces cerevisiae* breaks the thio-ester bond releasing the aromatic thiol fraction. Thiols are also called mercaptans and the most important one in wine are 4-mercapto-4-methyl-pentan-2-one (4MMP), 3-mercaptohexan-1-ol acetate (A3MH), 3-mercaptohexan-1-ol (3MH), 4-mercapto-4-methyl-pentan-2-ol (4MMPOH) and 3-mercapto-3-methyl-butan-1-ol (3MMB). 4MMP gives Sauvignon Blanc wines a strong odor of boxwood and broom shrub. 3MH is associated with the aroma of grapefruit. This latter compound and its derivative, A3MH, also make up the aromatic profile of the passion fruit. 3MMB, on the other hand, has an aroma of cooked leeks[64,65].

Grape carotenoids, represented primarily by β-carotene, are precursors of C13-norisoprenoids, which are potent odorants. The paths of formation of these compounds, such as α and β-ionone are not well known. The latter gives a scent of violet and raspberry to the wine[66].

Grapes contain unsaturated fatty acids such as linoleic and linolenic acid. These lipids are released after the crushing of the grapes in the pre-fermentation stage, and are degraded by the lipoxygenase enzyme in C-6 compounds such as hexanal and 2-hexenal, which have vegetable, grassy aromas[66].

The S-methylmethionine (SMM) originated from grapes is also present in wine. After bottling and proper storage, under anaerobic conditions, the SMM is converted to dimethyl sulfide. This compound is a powerful odorant and, depending on its concentration, it can bring fine or defective aromas to the wine. In small quantities, the characteristic aroma is corn or asparagus. At higher concentrations, the odor shifts to cooked cabbage or shrimp. At concentrations present in high quality wines, subject to

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[63]Ronald S. Jackson. Chemical constituents of grapes and wine. In:_______. *Wine science: principles, practice, perception.* 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.
[64]Philippe Darriet et al. Un paradoxe: les composés soufrés volatils responsables de defaults et de qualités dans les vins. J Int Sci Vigne Vin. 1999; 33(spec):137-43.
[65]Denis Dubourdieu and TakatoshiTominaga. Poly functional thiol compounds. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry.* New York: Springer; 2009. p.275-93.
[66]Raymond Baumes. Wine aroma precursors. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.251-74.

long storage, this compound is related to the fine truffle aroma that these wines may present[66].

Some volatile substances are present in grapes from *Vitis vinifera* linked to glycosides, forming glycoconjugates. There are different subtypes of these compounds, according to the glycidic fraction: apiose, rhamnose and arabinose. These groups may be bound to monoterpenes, alcohols, phenols, volatilenorisoprenoids, among others. These odorous compounds are progressively hydrolyzed by β-glucosidase[67].

2.2. Secondary aromas

Secondary aromas are generated by fermentation processes and wood aging. Fermentation adds little to the aroma of wine. This reaction is exergonic, releasing energy as heat, which along with plenty of fermentable sugars and oxygen availability provides a huge proliferation of yeasts and the formation of many other substances other than ethanol by its metabolism. Some of these substances are neutral or volatile esters[68].There are about 300 of these molecules in wine and some with aromatic importance; acetates, are formed by a reaction between ethanol and other short chain alcohols (isoamyl alcohol and isobutyl alcohol), which are formed, and acetic acid. Due to their low molecular weight, these esters are volatile and strongly influence the aroma of young wines contributing to its fruity character. They are therefore called "fruity esthers". Isoamyl acetate has a strong odor of bananas, often recognized in Beaujolais Nouveau and other carbonic maceration wines. Benzyl acetate has an aroma similar to apples. In turn, ethyl acetate, which presents an odor of nail polish or model airplane glue, may be present in botrytized wines, since the micro-perforations caused by *Botrytis cinerea* in the grape exocarp allow penetration of acetic bacteria. This organism converts ethanol into ethanoic acid (acetic acid), which generates ethyl acetate[69]. Apparently, acetates bring a greater contribution for aroma in wine than ethyl esters of fatty acids such as ethyl hexanoate, ethyl-octanoate and ethyl decanoate. However, the

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[67]Raymond Baumes. Wine aroma precursors. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.251-74.

[68]Yair Margalit and James Crum, editors. Must and wine composition. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.1-55.

[69]Ronald S. Jackson. Chemical constituents of grapes and wine.In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.

combination of these two ester groups is responsible for a higher aromatic wine quality[70].

Another class of substances responsible for secondary aromas are small molecule organic acids, the so-called short chain fatty acids. Due to its low molecular weight, these compounds volatilize easily from the wine constituting the so-called volatile acidity. The metabolism of yeast is responsible for the synthesis of several of these fatty acids. The most important among them is acetic acid, which, at concentrations below recognition thresholds (about 400 mg/L), increases wine complexity. Above this limit, a vinegar odor becomes recognized, which is considered a defect. Acetic acid accounts for over 90% of volatile acidity. Other acids of this class are formic acid of pungent odor, propionic acid with an odor of fat and butyric acid with an odor of rancid butter. Acids with longer chains, between six and ten carbons have an odor which is described as "goat odor"[71].

Wood staging transfers substances to the wines, which are responsible for other secondary aromas. Among these, β-methyl-γ-octalactona is the source of the scent of coconut, whereas vanillin is responsible for the aroma of vanilla, and benzaldehyde, for aroma of bitter almonds[72,73].

2.3. Tertiary aromas

Tertiary aromas are those that develop over the years on wines with potential bottle aging, in the absence of oxygen (reductive aging). This combination of aromas is called "bouquet". Its development is accompanied by the loss of varietal and fruity aromas. Therefore, long term storage of wines must bring aromatic complexity and softness to compensate for this loss. The genesis of the "bouquet" is not well known. In aromatic white wines, the loss of terpenes and the appearance of their oxides is characteristic. These compounds have a higher threshold of perception and different aromatic characteristics. Thus, linalool oxide has a eucalyptus flavor instead of the floral scent of linalool. Other processes can generate tertiary aromas. One of them, which has been already discussed, is the hydrolysis of glycoconjugates, releasing

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[70]C.A. van der Merwe, C.J. van Wyk. The contribution of some fermentation products to the odor of dry white wines. Am J Enol Vitic. 1981; 32:41-6.

[71]Maurizio Ugliano and Paul A. Henschke. Yeasts and wine flavour. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.313-92.

[72]Ronald S Jackson.Postfermentation treatment and related topics.In:_______. *Wine science: principles, practice, perception.* 2nd ed. Burlington, MA: Academic Press; 2000. p.355-433.

[73]Yair Margalit and James Crum, editors. Oak Products (Cooperage and Cork).In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.217-63.

aromatic substances. With aging, the hydrolysis of these compounds may release aromatic molecules, such as volatile phenols. At the same time, the degradation of wine carbohydrates gives rise to highly aromatic compounds, such as the aldehyde 2-furfural with its caramel odor. As described above, another molecule which apparently has an important role in the "bouquet" is dimethylsulfide which is formed from precursors such as amino acids containing sulfur." The formation of the reduction "bouquet" is also characterized by a decrease in the concentration of acetate and ethyl esters with the exception of increasing concentrations of ethyl esters from diprotic acids[74,75].

2.4. Aromatic defects

2.4.1. Oxidation

The main cause for oxidation is an inadequate storage of wine, when bottles are left standing or under excessive heat. Such conditions affect the characteristics of the cork, allowing air to enter the bottle and the contact of the components of wine with oxygen. The reaction of oxygen with ethanol produces acetaldehyde, a substance of strong aromatic intensity, which resembles the scent of oloroso sherry, toasted walnuts or bruised apples[76].

2.4.2. Reduction

Modern wine making practices often tend to process wines in a reductive environment, systematically isolating it from oxygen. This practice is not innocuous, as it may cause some defects in wine, such as the reduction odors also called odors of “bottle” or of "light" or of "sun" (the photochemical effect of light enhances this problem). The reduction odor is described as a lack of aromatic sharpness, slightly unpleasant garlicky odor, which may resemble sweat.

A reductive medium promotes the formation of sulfur compounds such as hydrogen sulfide, mercaptans, thiols and dimethyl sulfide. Defective aromas associated with these compounds are the smell of rotten eggs, cabbage, burned rubber and cooked corn. Other so-called varietal characteristics, such as the smell of cat urine and passion

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[74]Pérez-Prieto LJ, López-Roca JM and Gómez-Plaza E. Differences in major volatile compounds of red wines according to storage length and storage conditions.J Food Comp Anal.2003; 16:697-705.
[75]Yair Margalit and James Crum, editors. Oxidation and wine aging.In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.193-215.
[76]Ronald S. Jackson. Sensory perception and wine assessment. In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.544-90.

fruit in Sauvignon Blanc wines are knowingly derived from 4-mercapto-4-methyl-pentan-2-one and 3-mercaptohexanol acetate, both volatile sulfur compounds[77]

Two factors contributing to the decrease in redox potential are the concentration of sulfur dioxide (SO_2) and lees, which act as antioxidants by absorbing oxygen.

Another cause of aromatic defects associated with reduction may be the current trend of closing bottles with a screwcap system, which seals the container more effectively than caps made of cork and polymers. Some aromatic defects, particularly the smell of rubber, have been associated with this form of bottle seal[78].

The great art of the oenologist is to balance reductive wine making with small contributions of oxygen, so that the true varietal characteristics and terroir are expressed, in addition to preserving the freshness and fruitiness enabled by oxygen-free wine making.

Enological wisdom, which has developed for centuries, gives us a clear example of this balance. White wine resting on its lees (it has been said that dead yeast act as antioxidants, reducing redox potential) tend to develop reduction aromas. The centuries-old practice of "bâtonnage", in addition to extracting favorable products from the mass of yeast introduced small amounts of oxygen into the wine, restoring the balance between reduction and oxidation.

2.4.3. Corky

The defect known as corky is characterized as a mouldy, cardboard or wet dog odor. Different compounds can cause these defective odors in wine. The most important of these is 2,4,6-trichloroanisole (2,4,6-TCA), which is a product from the activity of fungi present in the cork. This substance together with 2,3,4,6-tetracloroanisole and pentacloroanisole accounts for at least 80% of cases of corky wine. The prevalence of this defectin wines is 2 to 7%. The likely route for the synthesis of 2,4,6-TCA is the O-methylation of highly toxic chlorophenols precursors such as the fungicide pentachlorophenol. Chlorine from cork bleaching with hypochlorite may also be involved in the genesis of anisoles. Although several strains of fungi convert 2,4,6-trichlorophenol to 2,4,6-TCA, the *Trichoderma* and *Fusarium* strains are the most

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[77]Yair Margalit and James Crum, editors. Aroma and flavor.In:_______. *Concepts in wine chemistry.* 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.133-92.

[78]Peter Godden et al. Towards offering wine to the consumer in optimal condition – the wine, the closures and other packaging variables: a review of AWRI research examining the changes that occur in wine after bottling. Wine Ind J. 2005; 2:20-30.

active. Other moldy odors can be attributed to the production of guaiacol (2-methoxyphenol) by fungi of the genera *Penicillium* and *Aspergillus*. Other substances, such as geosmin (trans-1,10-dimethyl-trans-9-decalol) and R(-)-1-octen-3-ol, originating from the fungal metabolism can contribute to the musty odor of wines[79,80,81].

2.4.4. Acetic acid and ethyl acetate

The formation of acetic acid is due to the bacteria *Acetobacter* and *Gluconobacter,* which can proliferate in wine in the presence of oxygen. These microorganisms oxidize ethanol to acetaldehyde, which, in turn, is oxidized to acetic acid. As seen above, acetic acid accounts for over 90% of the volatile acidity of the wine, usually between 0.2 and 0.4 g/L. The concentration of acetic acid in wine must not exceed 0.7 g/L. Above this concentration, a vinegary or even pungent odor is perceived. The ethyl acetate is always synthesized by acetic bacteria as a side product from the formation of acetic acid. The detection threshold is between 150 and 200 mg/L. An odor of nail polish is perceived with concentrations above the detection threshold[82].

2.4.5. Other aromatic defects

Numerous other defective aromas can occur in wines[81]. Excess sulfur dioxide, a substance used in several stages of wine making, gives wines a smell of burnt matches. Another substance used as a preservative, sorbate, can promote the development of defective aromas described as "geranium".

Diacetyl, a metabolic product from fungi and bacteria, are usually present in wine in small concentrations. Its butter aroma, if subtle, may be pleasant, and appears frequently in Chardonnay wines. Its concentration above the threshold for recognition brings unpleasant odors to the wine.

Ethylphenols produced by fungi of the genus Brettanomyces/Dekkera, as quoted above, are responsible for defective aromas described as stable-like, stallion and mouse.

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[79]María Luisa Álvarez-Rodríguez et al. Cork taint of wines: role of the filamentous fungi isolated from cork in the formation of 2,4,6-trichloroanisole by o methylation of 2,4,6-trichlorophenol. Appl EnvironMicrobiol.2002;68:5860-9.

[80]Yair Margalit and James Crum, editors. Oak Products (Cooperage and Cork).In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.217-63.

[81]Ronald S Jackson.Olfactory system. In:_______. *Wine tasting: a professional handbook*. London: Academic Press; 2002. p.39-78.

[82]Yair Margalit and James Crum, editors. Wine faults. In: ______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.331-48.

Reduced sulfur compounds may be responsible for defective aromas of wine. Mercaptans bring odors of manure or rotten onions, while disulfide presents an odor that resembles cooked cabbage or shrimp. Compounds related with 2-mercaptoethanol and 4-(methylthio)butanolgenerate, respectively, intense odors of stable and chives/garlic.

3. Taste and oral sensations

3.1. Sweetness

The perceived sweetness in wine has its origin in different substances. The main ones are sugars or saccharides, a class of carbohydrates. One of its features is the sweet taste. Among the most simple, there are small molecules with five or six carbons called monosaccharides. Five-carbon molecules are called pentose while six-carbon ones are known as hexoses. Monosaccharides can react with each other in a polymerization process, forming larger molecules known as disaccharides, oligosaccharides or polysaccharides, according to the number of monosaccharides composing the new molecule (two, few or many).

Ripe grapes are extremely rich in carbohydrates. The most abundant are the hexoses such as glucose and fructose, both with concentrations of 80 to 130 g/L and a small amount of rhamnose (0.15 a 0.4 g/L). Xylose and arabinose pentoses are also found in low concentrations. Glucose and fructose are polymerized, producing sucrose, a disaccharide that is found in concentrations of up to 10 g/L. *Vitis vinifera* grapes tend to exhibit lower concentrations of sucrose than non-*vinifera* grapes. Pectin, a polysaccharide, is present with a concentration of 0.2 a 4 g/L. Roughly, glucose and fructose represent 95% of the carbohydrates from the juice of ripe grapes. Hyper mature grapes have a higher percentage of fructose. The evaluation of sweetness of these sugars is made by comparison with a 10% sucrose solution used as a standard, arbitrarily set at 100. The sweetest one, fructose exhibits a relative sweetness index of 115, while glucose, 70. Wine, however, is rich in other sugars, which may not have a sweet taste.

Dry wine has less than 2 g/L of residual sugar. The hexoses (glucose and fructose) present in must are fermented by yeast completely, turning into alcohol. These monosaccharides are therefore called fermentable sugars. Residual sugar consists of small amounts of non-fermented pentose and hexose, and polysaccharides known as non-fermentable sugars. Sucrose, which is present in small quantities in must, or added to it in the chaptalization process is dissociated into fructose and glucose, which are fermented, whereby sucrose should completely disperse. Therefore, the degree of sweetness of a wine depends on the amount of residual sugar after fermentation. Sweet wines are produced with musts that are extremely rich in grape sugars, which do not fully ferment or their fermentation is interrupted by the addition of a grape spirit, which kills the yeast, or by addition of concentrated grape must, as it occurs in certain German wines. Botrytized wines have a greater concentration of other monosaccharides such as galactose and arabinose. These wines also have another sugar, hexodiulose, formed by the oxidation of fructose. The metabolism of *Botrytis cinerea* also produces a, polyalcohol related to sugars, 2,3-butanediol.

Other carbohydrates and derivatives may be present in wine as polysaccharides (rhamnogalacturanos, mannoproteins, glucans), polyalcohols (xylitol, arabitol, mannitol, inositol), and sugar acids such as gluconic and galacturonic acid. These compounds contribute little to the sweetness of the wine, however increase the feeling of wine smoothness and body[83,84,85].

Thus, highly concentrated carbohydrates in ripe grapes are fermented and converted to ethanol. Unfermented residual sugar is primarily responsible for the sweetness of the wine.

3.2. Acidity

Every wine is acidic. Acidity is constitutional part of this beverage, and there are no alkaline types. Acids are essential in wine. They ensure microbiological and color stability and contribute for longevity. And they also determine wine freshness and liveliness. When one says: this wine is acidic, a more proper way to say it would be: "The sensation of acidity of this wine is excessive for its structure."

Thus, for better understanding wine balance, the knowledge of the origins of acidity and sensations generated by it, is required.

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[83]Yair Margalit and James Crum, editors. Must and wine composition. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.1-55.
[84]Ronald S. Jackson. Chemical constituents of grapes and wine. In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.
[85]M. Luz Sanz and Isabel Martínez-Castro. Carbohydrates. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.231-48.

Wine organic acids can come from the grapes or can be formed during the fermentation process. The first are natural organic acids, which develop during the vegetative cycle of the vine. The major ones are tartaric, malic and citric acids. Acids obtained from fermentation are: succinic acid, acetic acid and lactic acid.

3.2.1. Acids derived from grapes

Tartaric acid (2,3-dihydroxybutanedioic or 2,3-dihydroxysuccinic) with molecular formula $C_4H_6O_6$, rarely found in other fruits, is predominant in grapes. It is present in concentrations of 5 to 10 g/L, in *Vitis vinifera* musts, accounting for 1/3 of the acids present in wine. Its concentration in wine is barely affected by the action of yeast.

Hydroxybutanedioic or hydroxysuccinic acid, also called malic acid ($C_4H_6O_5$) is present at concentrations of 2 to 4 g/L in wine grapes, depending on the cultivar. Alcoholic fermentation reduces its concentration in 20 to 30% and during malolactic fermentation, this acid is consumed. The name "malic" originates from the Latin word "mala", which means apples, in which this acid is abundant. The sensation produced by this compound is an extreme and aggressive acidity, as seen in some green apples.

2-hydroxypropane-1,2,3-tricarboxylic acid citric acid, of molecular formula $C_6H_8O_7$ is abundant in the fruit group which is named after it: citrus fruits. Kiwifruit, strawberries and raspberries are also rich in citric acid, and in grapes, it is present at lower concentrations. In wine making, it can be used to correct acidity.

3.2.2. Fermentation derived acids

Succinic or butanedioic acid ($C_4H_6O_4$) is produced during fermentation and is present in wine at a concentration of 0.4 to 1 g/L. It exhibits a complex, mixed flavor of acidity, bitterness and saltiness. The "vinous" character of wine is provided by this acid.

2-hydroxypropanoic acid ($C_3H_6O_3$), also called lactic acid is generated by malolactic fermentation made by lactobacilli from malic acid which is more aggressive and harsh to taste. By replacing malic acid by lactic acid, the wine becomes softer and less "green".

The set of natural and derived acids referred to herein, constitutes the fixed acidity of a wine. However, during the fermentation process, low molecular weight acids are produced. Because of this characteristic, these components are volatile and represent another portion of the total wine acidity: volatile acidity, whose main component is acetic acid. Although present in all wines, it must be below the normal threshold of perception (0.5 g/L). High levels of volatile acidity, which allow detection, are identified as defects.

Ethanoic acid or acetic acid ($C_2H_4O_2$) is produced in small amounts during fermentation. Bacteria of genus *Acetobacter* convert ethanol to acetaldehyde and then to acetic acid (vinegar). Under specific conditions, these bacteria can also synthesize ethyl acetate from ethanol. Thus, the defect that occurs when there is wine spoilage by *Acetobacter* is a mixture of smells of vinegar and nail polish.

Other acids that make up volatile acids are formic, propionic and butyric.

3.2.3. Measurements of acidity.

The total acidity of a wine (TA) is the total concentration of its organic acids plus the concentrations of sodium and potassium. The titratable acidity is the sum of the concentrations of titratable protons, measured by titration with a strong base. The titratable acidity is therefore lower than the total acidity. TA is measured in grams per liter (g/L) and usually lies between 4.5 g and 7 g/L. Because it is the most abundant acid, wine total acidity is usually expressed in tartaric acid equivalents. However, this measure does not provide an accurate correlation with the sensation of acidity of the wine. To better understand this phenomenon, one must understand the concept of pH. One of the characteristic of acids is its degree of ionization in an aqueous solution. In this situation, some of the acid molecules dissociate into two parts with electric charges: a hydrogen atom with a positive charge, and the remainder of the molecule with a negative charge. Free hydrogen ions determine the characteristic of an acidic solution. Each acid has a dissociation constant (Kd) and a number of ionized molecules which defines if an acid is strong or weak. Strong acids are those in which virtually all its molecules dissociate in water, whereas in weak acids, dissociation is small. The organic acids present in wine are all weak. However, there are differences among them: Kd for tartaric acid is 9.10×10^{-4} while for malic acid, it is 3.50×10^{-4}. Therefore, tartaric acid is approximately three times stronger, since it produces approximately 3 times more hydrogen ions than the same amount of malic acid. Thus, it also follows that smaller amounts of a strong acid may release the same amount of hydrogen ions than higher amounts of a weak acid. Consequently, the phenomenon that best correlates with our sense of acidity in wine is the concentration of ionized hydrogen, i.e. pH.

pH is a measurement defined as the inverse logarithm of the concentration of hydrogen ions. Its scale is usually 0 - 14, with 7 being the point of neutrality. From the definition, it follows that: the lower pH values are, the greater the acidity. Because the scale is logarithmic and not linear, the variation of a point on the scale corresponds to an increase or decrease of 10 times the concentration of hydrogen ions and, possibly, our taste of acidity[86,87].

Other factors may affect the perception of acidity as the salivary flow rate and the concentration of sodium bicarbonate in the saliva (which neutralizes the acid), the extract of wine and temperature.

The important thing for the taster to remember is that wine is a chemically acidic beverage and what should be assessed is if the feeling of acidity resulting from the balance between the acids present and other components of wine is appropriate, conveys freshness and above all, is pleasant.

3.3. Bitterness and astringency

Bitterness, as previously discussed, is a taste sensation which is awakened by coupling the sapid substance to a GPCR of the T2R family. Astringency, in turn, is the feeling of dryness, shrinkage, wrinkling and roughness of the oral mucosa caused by substances that are capable of precipitating salivary proteins, notably the so-called proline-rich proteins. It is generally accepted that astringency is a tactile sensation detected by the mechanoreceptors of the oral mucosa, although there is some evidence of a specific component of astringent taste. The sensation of astringency is complex, as multiple factors can modify it. Thus, a lower pH tends to exacerbate the astringent sensation. Some tastes, sweet in particular, can reduce the astringent sensation. This feeling is also influenced by the intensity of individual salivary flow. The role of sensitivity to 6-n-propylthiouracil, which is genetically determined, in the perception of astringency is controversal[88,89].

A description of perceived astringency is difficult and imprecise. In an attempt to understand the sensations caused by astringent compounds and standardize their

[86]Michael J. Leonardelli. Acidity in wine: the importance of management through measurement. [cited 2014 Jan]. Available from: http://gwi. missouri. edu/publications/2013spring. pdf.
[87]Yair Margalit and James Crum, editors. Must and wine composition. In:_______. *Concepts in wine chemistry*. 2[nd] ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.1-55.
[88]Martha R. Bajec and Gary J. Pickering. Astringency: mechanisms and perception. Crit Rev Food Sci Nutr. 2008;48:858-75.
[89]Isabelle Lesschaeve and Ann C Noble. Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. Am J Clin Nutr. 2005;81(1 Suppl):330S-5.

description, a hierarchical classification of oral sensations aroused by red wine has been developed[90].

Astringency and possible bitterness of wines, especially red wines, are mainly conferred by the so-called "tannins", which have great importance in its assessment. However, the sensations caused by the tannins are among the least understood in the organoleptic evaluation of wines. For better understanding, it is necessary to know the phenolic composition of the wine. The word "tannin" is known and used by all wine tasters. However, this term does not correspond to a defined chemical compound. Its etymology lays on the Gallic word "tanno" which means oak. The general definition of tannin is a group of plant extracts, which form complexes with proteins, causing their clotting. These compounds, particularly tannic acid, have been used for centuries for tanning leather. A common chemical feature of these extracts is that they are phenolic compounds. These phenols are extremely important in assessing the wines, especially red wines. Tannins are polymers of simpler phenols[91]. They are responsible for astringency, color and possible bitterness. Such substances are also important for the conservation and ripening capacity of wines. The antioxidant and cardio-protective action provided by wines is exerted by polyphenolic compounds.

These compounds are derived from phenol, the simplest of the aromatic alcohols (which have a cyclic carbon ring). The phenolic derivatives present in wine may be simpler or exhibit multiple phenol rings constituting the so-called polyphenolic compounds. The polyphenols present in wine derive from grapes, its stems, seeds, yeast metabolism and the wood of the barrels or vats. These are usually divided into two broad classes: non-flavonoids and flavonoid.

3.3.1. Non-flavonoids polyphenols

Non-flavonoids polyphenols are simple phenolic compounds from different sources. For wines, which do not age in wood containers, its origins are substances derived from hydroxycinnamic acid, which are the predominant phenolic compounds in grape juice and white wine. Hydroxycinnamic acid derivatives are rarely found as free acids in wine. Its usual presentation is conjugated with tartaric acid to form esters. Nevertheless, these derivatives continue to be called "acid" on the oenological jargon.

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[90] Richard Gawel et al. A mouth-feel wheel: terminology for communicating the mouth-feel properties of red wine. Aust J Grape Wine Res. 2000; 6:203-7.

[91] Thomas Collins. Tannins: types and amounts in grapes and wines. In: New York Wine Industry Workshop Proceedings, Geneva, NY, 2-4 April 2003.

Its main products are coutaric, caftaric and fertaric acids. These "acids" are found in the grape pulp, and therefore are present in wine. Although they do not affect taste, they play an essential role in wine color. They are the first to be oxidized, and responsible for the development of brown color in white wines. In small quantities, oxidative acids and its derivatives: coutaric and caftaric acids produce a golden straw color, which is so appreciated in some white wines.

Considering wines aged in wood, the most abundant phenolic compounds are derivatives of hydroxybenzoic acid, such as gallic and ellagic acid. These components originated from the hydrolysis of its polymeric forms, ellagitannins and galitanins, commonly called hydrolysable tannins, which are extracted from oak wood. White wines, which are matured for six months in oak barrels, have a level of approximately 100 mg/L. Red wines which are aged for two or more years in wood containers, the level reaches about 250 mg/L[92].

Although present in small amounts, another class of phenolic non-flavonoid substances, stilbenes, especially resveratrol, is of great importance for its antioxidant and cardio-protective action. Stilbenes originate exclusively from grape skins, which are produced in response to fungal attacks to vines. For this reason, red wines have higher concentrations of resveratol, about 7 mg/L. Pink wines usually have concentrations of 2 mg/L and white wines, 0.5 mg/L[92].

3.3.2. Flavonoid polyphenols

Flavonoids are more complex polyphenolic compounds with multiple aromatic rings. They constitute the majority of red wine polyphenols. The main flavonoids are flavanols, flavonols and anthocyanins. Flavan-3,4-diol (leucoanthocyanidins) are present in lesser quantities.

Flavanols are the most abundant class of flavonoids in grapes and wine. They are originated from skins and seeds, and are usually called flavan-3-ols. Two of the common forms of this class are catechins and epicatechins. Oligomers of these two substances form procyanidins. These are present in grapes as monomers, but they tend to polymerize in wine, forming the so-called condensed tannins, or proanthocyanidins[93].

[92]Andrew L. Waterhouse. Wine phenolics. Ann N Y Acad Sci. 2002;957:21-36.
[93]Baoshan Sun and M. Isabel Spranger. Review: Quantitative extraction and analysis of grape and wine proanthocyanidins and stilbenes. CiêncTécVitiv. 20:59-89. 2005

Flavonols are present in grape skins and apparently play a protective role against UV-B rays. The major ones are quercetin, kaempferol and the mirecitin.

Another important group of flavonoids are anthocyanins, which are important in determining the color of the wines described above.

Thus, the polyphenols present in wine serve multiple functions:

- With regard to non-flavonoids, cinnamic acid derivatives, they are vital for the phenomena of browning white grapes must, and white wine. Concentrations found in wines do not contribute to astringency or bitterness. Hydrolysable tannins also rarely affect these characteristics[94].
- Antioxidant activity: some simple phenolic groups, such as catechol and 1,4dihidroxiquinona, which form polyphenolic compounds present in wine, have the characteristic of being easily oxidized. This property gives them a potent antioxidant action because when oxidized, they protect other wine components from oxygen free radicals which are quite reactive. Preserving the color of musts is one of the consequences of this protection. The use of sulphites (SO_2) during vinification enhances antioxidant activity, since these compounds degrade oxidized hydroquinone, making it available again to capture new reactive oxygen anions[95].
- Among flavonoids, flavanols are largely responsible for bitterness and astringency. Polymer catechins and their derivatives, such as procyanidins and condensed tannins, are some of the main sapid substances in red wine. The chemical structure of flavanols also influences the perception of bitterness and astringency. Epicatechin is bitterer and more astringent than catechin. The polymerization of these compounds increases the sensation of astringency and decreases bitterness. Condensed tannins of low molecular weight are both bitter and astringent. Those with high molecular weight have little influence on the appreciation of wines. With age, polymers tend to grow, become insoluble and precipitate. Thus, phenol concentration decreases with wine aging[95,96].

[94]Michael Rentzsch et al. Non-flavonoid phenolic compounds.In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.509-27.
[95]Andrew L. Waterhouse. Wine phenolics. Ann *N Y Acad Sci.* 2002;957:21-36.
[96]Isabelle Lesschaeve and Ann C Noble. Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. Am J ClinNutr.2005;81(1 Suppl):330S-5.

WINE ASSESSMENT

The attributes of the wine described above are some of the qualities valued when assessing wines. There are different approaches when evaluating wines. The most trivial of these activities, the hedonistic wine tasting by savvy consumers, is individual. In this case, the consumer does not seek to quench his thirst with wine nor to reach the feeling of relaxation and fluctuation from light inebriation. Rather, he seeks pleasurable sensations and wine characteristics that meet his personal taste. For this kind of assessment, there is no concept of right or wrong, or even errors of judgment, since assessment is personal. Another type of wine assessment is the evaluation of the differences between samples and their ranking. Oenophilic societies and expert panels in contests and awards usually do this type of tasting. In producing countries with regulation of production of wines and award of certifications such as "Controlled Designation of Origin (DOC, AOC)" or " Quality Wine Produced in a Specific Region (VQPRD)", tasting becomes the wine discriminatory and classificatory instrument. It allows for verification whether the organoleptic characteristics of a given wine meet the specifications required for the grant of a certificate and placing of the wine in one of the legal categories in the growing region. There are still evaluation tastings performed by oenologists, producers, middlemen, dealers and traders. The particular tasting performed by a sommelier seeks wine characteristics that provide gastronomic matching with the restaurant dishes. Wine tasting by a wine critic tends to carry the strong bias of subjectivity, on his or her personal taste, not always coincident with that of the consumer.

The common feature in all these sorts of wine assessments is that they are evaluations conducted through tasting, with greater or lesser degree of technical organization, and usually, with no scientific strictness. Their result is expressed by a description, assigning a score, or a rating.

Unlike these methods of assessment, there is also wine sensory evaluation, which employs sensory analysis techniques. This discipline is based on a branch of psychology: psycho-physics, which investigates the relationship between physical stimuli and the perceptions aroused by them. Sensory analysis is structured and uses knowledge from different fields such as sociology, physiology and psychology itself.

The results are subjected to statistical tests to verify its significance. Sensory analysis aims to bring objective responses in relation to food, beverages and other products as to how they are perceived by the people, through their sense organs[97,98].

Sensory analysis assumes the existence of a proper environment, rigorous experimental design, use of methods of effective and descriptive sensory discrimination. The difficulties arising from complex experimental design and the need for prior training of the participants hinder its customary use in the wine industry[99]. However, sensory evaluation is an important tool in the development, evaluation and establishment of food and beverage marketing strategies. Sensory analysis reduces the bias inherent to regular tastings, but does not fully eliminate it.

1. Causes of bias and misconceptions in tasting

Errors in wine assessment have various origins. Physiological and psychological factors are important causes for differences in performance among tasters and consequently in their understanding of the wine tasted. The level of knowledge about wines and the degree of training on tasting lead to a wide individual variation in wine assessment. One of the main obstacles preventing the activity of wine tasting to be objective is the language used, so that the sensory perceptions obtained when tasting a particular wine can be communicated to others.

1.1 Physiological factors

1.1.1. Sensory adaptation

The phenomenon of sensory adaptation has been known for a long time. It constitutes in the specific decreased sensitivity to a stimulus by repeated or prolonged exposure to it. Sensitivity returns with time in the absence of exposure to such

[97]Adriano G. Cruz et al. Sensory analysis: relevance for prebiotic, probiotic, and synbiotic product development. Compr Rev Food Sci Food Saf.2010; 9(4):358-73.
[98]Jorge Herman Behrens. Minicourses 2010: fundamentals and techniques of sensory analysis. Regional Council of Chemistry - Region IV (SP).[cited 2014 Jan]. Available from: http://www. crq4. org. br/sms/files/file/analise_sensorial_2010. pdf.
[99]Lucie Perrin et al. Comparison of three sensory methods for use with the Napping® procedure: Case of ten wines from Loire valley. Food Qual Prefer. 2008; 19(1):1-11.

stimulus[100,101]. In the practice of wine tasting, it is important that a time interval between each inhalation of the aroma and between sips of the same wine is respected. Rinsing one's mouth with water or chewing neutral foods such as bread is also intended to avoid adaptation.

1.1.2. Sensory thresholds and individual variation

Detection threshold is the concentration of a stimulant required for 50% of the components of a human panel to identify the presence of the stimulus, without characterizing it. Threshold of perception or recognition, on the other hand, is the minimum concentration of a substance that allows identification of the stimulus. The recognition threshold is typically greater than the detection threshold. It is important to be aware of the statistical nature of these definitions[102].

Individual sensory variations affect wine tasting from the moment of visual evaluation. If different individuals are requested to point out, under the wavelength spectrum, a pure color, such as pure yellow, it will be seen that different wavelengths (575 nm or 586 nm) will be depicted as "pure yellow"[103].

There is also an interpersonal physiological variation at perception thresholds to different odorants and tastants

The sensitivity to stimulus intensity for the four basic tastes exhibits, likewise, interpersonal variation[104].

These factors produce different descriptions of the same wine within a group of tasters. Some qualities and defects can be notable for a taster and go completely unnoticed by others. A clear example of this phenomenon is the wide variation in the detection of 2,4,6 trichloroanisole and in rejection of wines with high concentrations of this compound[105].

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[100]Georg Von Békésy. The effect of adaptation of the taste threshold observed with a semiautomatic gustometer. J Gen Physiol. 1965;48:481-8.
[101]Pamela Dalton. Psychophysical and behavioral characteristics of olfactory adaptation.ChemSenses. 2000;25(4):487-92.
[102]José Aparecido da Silva and Reinier Johannes Antonius Rozestraten. Manual prático de psicofísica. [cited 2014 Jan]. Available from: page 3. wikispaces. com/file/view/manual+de+psicofisica. pdf.
[103]Phillipe Lanthony. La Perception des couleurs. J Int Sci Vigne Vin. 1999; 33(speciss):59-62.
[104]Juyun Lim et al. Measures of individual differences in taste and creaminess perception. Chem Senses. 2008;33(6):493-501.
[105]John Prescott. Estimating a ‘‘consumer rejection threshold’’ for cork taint in white wine. Food Qual Prefer. 2005;16(4):345-9.

1.1.3. Genetic variation

1.1.3.1. Vision

The first characteristic of the wine perceived by a taster is its appearance, and particularly its color. As previously mentioned, dyschromatopsia has a prevalence, which is not negligible, especially in the male population. About 8% of men and 0.5% of women have congenital abnormalities of color vision[106]. Thus, the likelihood of a male taster not to be capable of distinguishing shade variations between a young purple red wine and another more evolved red-orange colored wine is not negligible.

1.1.3.2. Gustation

The perceptual capacity for basic tastes, particularly sweet and bitter, has a significant population variation, whose genetic mechanisms are beginning to be unraveled[107,108]. The genetic regulation of taste perception of some related chemicals such as phenylthiocarbamide (PTC) and 6-n-propylthiouracil (PROP) is well known, and in the general population, there are people with and without the ability to feel its bitter taste[109]. With respect to PROP, a division between individuals able to taste the bitterness aroused by this substance (tasters) was detected: some of them (supertasters) have high sensitivity to this substance, describing the taste of PROP as extremely bitter[110]. Apparently, the number of lingual fungiform papillae varies for each of these phenotypes, whereby in supertasters its density is higher[110,111].

The most likely gene related to the greater or lesser capacity to feel the bitterness of PROP is the TAS2R38, which features single nucleotide polymorphism, with three amino acid substitutions determining the proline-alanine-valine haplotype (PAV), which are tasters, and alanine-valine-isoleucine (AVI) which are non-tasters. PAV appear in the population as homozygous or heterozygous, while the observed AVI are homozygotes. Other haplotypes and genotypes are rare[112].

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[106]Michael Kalloniatis and Charles Luu. Color perception. In: Kolb H, Fernandez E, Nelson R, editors. *Webvision: the organization of the retina and visual system*. [Copyright 2014].Available from: http://webvision. med. utah. edu/book/part-viii-gabac-receptors/color-perception/.
[107]Kim Unkyung et al. Genetics of human taste perception. J Dent Res. 2004;83(6):448-53.
[108]Danielle R. Reed et al. Heritable variation in food preferences and their contribution to obesity. Behav Genet. 1997;27(4):373-87.
[109]Sun-Wei Guo and Danielle R. Reed) Guo SW, Reed DR.The genetics of phenylthiocarbamide perception.Ann Hum Biol. 2001;28(2):111-42.
[110]Linda M. Bartoshuk et al. PTC/PROP tasting: anatomy, psychophysics, and sex effects. PhysiolBehav. 1994;56(6):1165-71.
[111]Inglis J. Miller Jr, Reedy FE Jr. Variations in human taste bud density and taste intensity perception. Physiol Behav. 1990;47(6):1213-9.
[112]John E. Hayes et al. Supertasting and PROP bitterness depends on more than the TAS2R38 gene. ChemSenses. 2008;33(3):255-65.

There is controversy regarding the relationship of these genetic characteristics and the perception of other flavors and mouth sensations. There is evidence that supertasters perceive the taste of concentrated solutions of sucrose, citric acid, sodium chloride and quinine more intensely[113]. The perception of sweetness can vary depending on the sensitivity to PROP[114], however most studies point towards an increase in the perception of sweetness in supertasters[115].

Individuals who perceive PROP as bitter or extremely bitter tend to consider the oral sensation of alcohol as annoying and unpleasant and tend to consume alcoholic beverages less frequently[116,117].

Wine evaluation may be influenced according to the taster status with respect to the perception of PTC/PROP. Thus, tasters and supertasters perceive acidity, bitterness and astringency of red wines more intensely than non-tasters[118].

1.1.3.3. Olfaction

The genetic determination of individual variation in olfactory capacity related to specific odorants is less known. Some types of specific anosmia are known, whose incidence in families seems to follow a recessive Mendelian inheritance pattern[119]. One of the most often studied compounds is androstenone, a steroid, whose odor is associated with sweat and is not detected by approximately 6% of the population, in addition to being described as pleasant or offensive in different populations[120,121].

Regarding wines, the olfactory sensitivity of a volatile compound, alcohol cis-3-hexen-1-ol, appears to be genetically determined. This alcohol is present in fruits and vegetables such as raspberry and broccoli, and also, in white wine. Its aroma is described as recently mown grass and the ability to perceive it is linked to a gene that encodes the OR2J3 odorant receptor located in chromosome 6q. There are five

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[113] John E. Hayes et al. Supertasting and PROP bitterness depends on more than the TAS2R38 gene. Chem Senses. 2008;33(3):255-65.

[114] Adam Drewnowski et al. Genetic sensitivity to 6-n-propylthiouracil (PROP) and hedonic responses to bitter and sweet tastes.Chem Senses. 1997;22(1):27-37.

[115] Linda M. Bartoshuk. Comparing sensory experiences across individuals: recent psychophysical advances illuminate genetic variation in taste perception. Chem Senses. 2000;25(4):447-60.

[116] Valerie B. Duffy et al. Associations between taste genetics, oral sensation and alcohol intake. PhysiolBehav. 2004;82(2-3):435-45.

[117] Alexander A. Bachmanov et al. Chemosensory factors influencing alcohol perception, preferences, and consumption. Alcohol Clin Exp Res. 2003;27(2):220-31.

[118] Gary J Pickering et al. Intensity of taste and astringency sensations elicited by red wines is associated with sensitivity to PROP (6-n-propylthiouracil. Food Qual Prefer. 2004;15(2):147-54.

[119] John E Amoore.Specific anosmia and the concept of primary odors.ChemSenses Flavor.1977;2(3):267-81.

[120] Elizabeth A. Bremner et al. The prevalence of androstenone anosmia.Chem Senses. 2003;28(5):423-32.

[121] Johan N. Lundström et al. Olfactory event-related potentials reflect individual differences in odor valence perception. Chem Senses. 2006;31(8):705-11.

haplotypes, in which some amino acid substitutions, referred to as T113A and R226Q diminish the sensitive capacity for cis-3-hexen-1-ol. The concurrent presence of two substitutions abolishes the olfactory sensitivity to this compound[122]Cis-3-Hexen-1-ol was described as aromatic wine component of Riesling, Sauvignon Blanc and Pinot Noir varieties[123,124].

1.1.4. Age

Visual acuity, auditory and tactile sensitivity decline with age[125]. The decrease in olfactory sensitivity with age has been intensively studied. Neuronal changes in the epithelium and in the olfactory bulb have been demonstrated as well as differences between the young and the elderly in the activation of areas of the central nervous system. Psychophysical and potential related to chemosensory events studies also show loss of olfactory ability in the elderly[126].

The loss of taste sensitivity has also been studied. The discrimination and perception of intensity for salty, sweet, bitter and umami tastes in the elderly have been tested with aqueous solutions of NaCl, KCl, sucrose, aspartame, acetic acid, citric acid, caffeine, quinine hydrochloride, monosodium glutamate and inosine 5´- monophosphate and with these same compounds in processed food products. Investigation has also been made to check if the odor of these tastants interferes with their taste perception. The elderly discriminate differences of concentration both in aqueous solution and food, with or without the use of a nose clip used to prevent identification of odors by retronasal olfaction. The perception of the absolute intensity of the compounds in aqueous solution or in food products without the nose clip is diminished in the elderly[127].

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[122]Jeremy F. McRae et al. Genetic variation in the odorant receptor OR2J3 is associated with the ability to detect the "grassy" smelling odor, cis-3-hexen-1-ol. Chem Senses. 2012;37(7):585-93.

[123]Pavla Polášková et al. Wine flavor: chemistry in a glass. ChemSocRev. 2008;37(11):2478-89.

[124]Michael Qian, Yu Fang, Kennedy J, Watson B. Development of aroma compounds in Pinot noir grapes and their relative importance in wine (Year 1). [cited 2014 Jan]. Available from: http://owri. oregonstate. edu/sites/owri. org/files/documents/Wine_Progress_Reports/2002-03/Development%20of%20aroma%20compounds%20in%20Pinot%20noir%20Grapes%20and%20their%20Relative%20Importance%20in%20Wine%20(Year%201). pdf

[125]Larry E. Humes et al. The effects of age on sensory thresholds and temporal gap detection in hearing, vision, and touch. Atten Percept Psychophys.2009;71(4):860-71.

[126]Hummel T et al. Age-related changes in chemosensory functions. In: Rouby C, Schaal B, Dubois D, Gervais R, Holley A, editors. *Olfaction, taste, and cognition*. Cambridge: Cambridge University Press; 2002.

[127]Jos Mojet et al. Taste perception with age: generic or specific losses in supra-threshold intensities of five taste qualities? Chem Senses. 2003;28(5):397-413.

1.1.5. Cross-modal perception

One of the characteristics of the mammalian brain is the integration of concurrent sensory stimuli, such that the perception of each one of them is altered by one another. The perception of the flavors of foods and beverages results from the integration of different sensory afferents. Different modal sensory interactions have been studied, yet the important ones in evaluating wines involve vision, olfaction, gustation and oral chemestesic sensation. In primates, sensory modalities such as vision, olfaction and gustation are integrated in the orbitofrontal cortex. There is a secondary gustatory area in the caudolateral orbitofrontal cortex. In addition to that, neurons with olfactory responses are present in a more medial region, and neurons from an intermediate area receive afferent visual stimuli. Some neurons in the orbitofrontal cortex exhibit bimodal responses both to gustatory and olfactory stimuli and gustatory and visual stimuli. Very close to these neurons there are interconnected unimodal sensory neurons, which suggests that the orbitofrontal cortex is the first cortical area of convergence of these three modalities[128].

In the evaluation of wine characteristics, different sensory interactions modulate assessment. The most important are those that occur between gustation and olfaction and between vision and olfaction. Relations between taste and olfaction are varied and complex. In a series of four experiments, Frank and Byram found that the strawberry odor added to whipped cream with sucrose increased the perception of sweetness, whereas the odor of peanut butter added to the same kind of whipped cream did not cause the same effect. Also, the scent of strawberry caused no increase in perception of salinity and lost 85% of its capacity to increase the perception of sweetness of the cream with sucrose if tasted with occluded nostrils. It was concluded that an odor´s influence on taste is both odorant and tastant dependent[129].

Neuroimaging studies show the activation of brain areas such as the frontal operculum, ventral insula/caudal orbitofrontal cortex, the amygdala and the anterior cingulate cortex with unimodal stimuli of odor and taste and bimodal stimuli with

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[128]Edmund T. Rolls and Leslie L. Baylis. Gustatory, olfactory, and visual convergence within the primate orbitofrontal cortex.J Neurosci. 1994;14(9):5437-52.
[129]Robert A. Frank and Jennifer Byram. Taste–smell interactions are tastant and odorant dependent. Chem Senses. 1988; 13(3):445-55.

mixtures of the same odorants and tastants[130]. The response in these areas can be supra-additive, in which greater activity was observed when subjects received mixtures of odors and tastes than when they received the corresponding stimuli in an isolated form[131]. In this case, such increase is dependent on experience. Although the multisensory integration of tastes and odors is independent of experience, perceptual congruence may be a phenomenon of multisensory integration resulting from repeated pairing of odors and tastes. The tasting qualities of odors, i.e. the "taste" of the odor, arise from associative learning with the development of taste/odor bimodal neurons from unimodal neurons, which originally only respond to olfactory stimuli. Associative learning leads to effects such as assigning greater sweetness or acidity to unknown and relatively neutral odors when the exposure to them is accompanied by sweet or acidic solutions. These effects have a strong perceptual reality since they are independent of whether or not one likes the smell, or have the knowledge of which smells and tastes are matched. Perception of flavor is a cerebral construct from the combination of actual tastes and the "taste properties of odor", which are encoded in memory. The caramel aroma, for instance, activates memory representations of caramel flavor, which includes a sweet component. The result is the perception of the sweet "taste property" of this odor[132].

Temporal and spatial characteristics of stimulus presentation also influence odor/taste integration. Thus, odor perception locus varies if the gustatory and olfactory stimuli are presented simultaneously, when the tastant/odorant blend is perceived as a unit and the odor is perceived in the posterior oral cavity. If the odor is presented beforehand, the olfactory sensation is perceived as originating in the nose. If the taste stimulus precedes the odorant, the sensation is perceived at the tip of the tongue[133].

Flavor assessment of wines is indeed strongly influenced by sensory integration among its odorants and tastants, since it is a beverage with remarkable aromas and tastes, whose assessment involves an analysis of these characteristics, which are presented sequentially. These standardized procedures for wine tasting reinforce associative learning and the assignment of taste properties to wine aromas.

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[130]Ivan E. T. De Araujo et al. Taste-olfactory convergence, and the representation of the pleasantness of flavour, in the human brain. Eur J Neurosci.2003;18(7):2059-68.
[131]Dana M. Small et al. Experience-dependent neural integration of taste and smell in the human brain.J Neurophysiol. 2004;92(3):1892-903.
[132]Dana M. Small and John Prescott. Odor/taste integration and the perception of flavor. Exp Brain Res. 2005;166(3-4):345-57.
[133]Georg von Békésy. Olfactory analogue to directional. J Appl Physiol. 1964;19:369-73.

The interactions between vision and olfaction are likewise able to alter wine assessment. The intensity of a flavor can be enhanced by a color commonly associated with it. This effect may be due to the addition of a small olfactory percept induced by color to the actual olfactory percept. Interestingly, even colors, which are not “appropriate” to solutions of certain odorants, may increase their olfactory perception[134]. "Appropriate" colors for solutions with fruity aromas decrease latency in identifying their odors and increase acuity. The assessment of odor is also influenced by the color of a solution. Thus, we tend to prefer an odor that comes from a solution with "appropriate" color. This is probably because color helps to identify an odor, and the ability to identify it modifies the affective response to that odor[135].

In olfactory analysis of wines, odors tend to be represented by objects having the same color of the wine. This phenomenon can induce a perceptual illusion. Morrot et al. have demonstrated this effect in an experiment using two samples of wine, one white and one red, whose aromatic descriptions made by a panel of tasters were analyzed lexically. A group of descriptors which were most frequently used to characterize the white wine was obtained, as well as another group for the red wine. In a subsequent tasting, two samples of the same white wine were served, one of which received an odorless dye, to make it look like a red wine. The white sample aroma was described with its typical descriptors of white wines such as white fruits and flowers. Nevertheless, the white wine which had been "dyed" in order to resemble a red wine, received typical aromatic descriptors of a red wine, characterizing a color-induced olfactory bias[136].

Another experiment, by Parr et al. extended this research by subjecting four samples of wine to a jury of experts and to another one formed by social wine drinkers. The four samples consisted of a Chardonnay white wine, the same white wine with color additives, so as to make it look like an aged Chardonnay or a young red wine, and a Pinot Noir red wine. They were served alternatively on transparent or opaque wine glasses. The jury of experts was shown to be affected by olfactory bias induced by color because when the wine was tasted in transparent glasses, more red wine descriptors were attributed to the dyed Chardonnay. Apparently, the cognitive model used by

[134]Debra A Zellner and Mary A Kautz. Color affects perceived odor intensity. J Exp Psychol Hum Percept Perform.1990;16(2):391-7.
[135]Debra A Zellner et al. Influence of color on odor identification and liking ratings. Am J Psychol. 1991;104(4):547-61.
[136]Gil Morrot et al. The color of odors. Brain Lang. 2001;79(2):309-20.

experts is the color identification and subsequent description from prototypes stored in their memories. This process can lead to the identification of false positives, i.e., description of aromatic characteristics that are not actually present in that wine sample. The handling of the wine, so as to make it look like an aged Chardonnay had no effect, and did not modify aromatic descriptors. When opaque glasses were used for tasting, white wine descriptors were maintained. The performance of social wine drinkers, with opaque glasses, was worse than that of experts[137].

The neurophysiological basis of these phenomena is the activation of cortical association areas in the presence of visual and olfactory stimuli. Brain scanning using functional magnetic resonance imaging of individuals exposed to odors and colors alone or combined has shown that the activity in the caudal region of the orbitofrontal cortex, the insular cortex and the anterior hippocampus increases gradually with the perception of semantic congruence of the odor-color pairs presented[138,139].

1.2. Psychological factors

If a taster has access to information about qualitative characteristics which are not intrinsic of the wine, such as their reputation, rating or price, these can influence evaluation which can be based on prototypes of the taster's repertoire.

By using lexical analysis, Brochet and Morrot compared comments from a panel of tasters, who were offered, twice and one week apart, the same average quality Bordeaux. On both occasions the wine was labeled differently, as Vin de Table or as Grand Cru. The set of descriptors varied with the terms associated with the description of great wines being used for the wine labeled as Grand Cru, while for the wine labeled as Vin de Table, other terms were employed such as simple and unbalanced. This phenomenon was called perceptive expectation[140].

The information about wine price and the moment at which this information is provided to the taster are factors that influence the assessment of wine quality. Regarding this fact,an experiment was conducted, by Almenberg and Dreberin which a wine considered expensive was offered to be evaluated in a panel of 135 individuals

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[137]Wendy V. Parr et al. The nose knows: Influence of colour on perception of wine aroma. J Wine Res. 2003;14(2-3):79-101.
[138]Robert A. Österbauer et al. Color of scents: chromatic stimuli modulate odor responses in the human brain. J Neurophysiol. 2005;93(6):3434-41.
[139]Jay A Gottfried and Raymond J Dolan.The nose smells what the eye sees: crossmodal visual facilitation of human olfactory perception. Neuron. 2003;39(2):375-86.
[140]Frédéric Brochet and Gil Morrot. Influence du contexte sur la perception du vin implications cognitives et méthodologiques. J Int Sci Vigne Vin. 1999;33(4):187-92.

(40% women), and another wine considered inexpensive was served for evaluation by another panel of 131 individuals (33% women). In this study, subjects were randomly designated to evaluate the expensive or inexpensive wine. For each group there were three possibilities: receive instructions, taste wine, receive and fill out an evaluation questionnaire; receive instructions including the price of wine, taste wine, receive and fill out an evaluation questionnaire; receive instructions, taste wine, receive an evaluation questionnaire including the price of wine and fill it out. The conclusion was that by revealing wine price before tasting made their assessment change to a better evaluation in the case of expensive wine, among women. Among male tasters, no difference was observed. Price revelation after tasting, yet before the registration of the tasting notes, did not lead to significant differences in the assessment of the wine[141].

1.3. Knowledge and training

An issue often raised is whether the ability of wine experts is due to their greater perceptual capacity or greater cognitive ability. The comparison of performance between novices and experts in wine suggests, in experiments to test memory in intentional and incidental conditions, that knowledge, particularly of the varietal characteristics of the wine and the vocabulary associated with these characteristics is an important component in the performance of a wine specialist[142].

As previously mentioned, Parr et al. have demonstrated that wine experts perform better in aromatic identification than beginners[143]. Furthermore, contrary to the view that the best performance of experts in the aromatic recognition would be due to their higher semantic capacity, another study by the same group has concluded that, at least with regard to olfaction, perceptual capacity is critical for knowledge wine expertise[144].

A comparison made through functional MRI on brain activation areas in sommeliers and lay persons (controls), after stimulation with glucose or wine, has shown that the pattern of activity differs between them. The activation of the prefrontal

[141] Johan Almenberg and Anna Dreber. When does the price affect the taste? Results from a wine experiment. SSE/EFI Working Paper Series in Economics and Finance, no 717, 2009.[cited 2014 Feb]. Available from: http://hdl. handle. net/10419/56240.

[142] Angus L. Hughson and Robert A. Boakes. The knowing nose: The role of knowledge in wine expertise. Food Qual Prefer. 2002; 13(7-8):463-72.

[143] Wendy V. Parr et al. The nose knows: Influence of colour on perception of wine aroma. J Wine Res. 2003;14(2-3):79-101.

[144] Wendy V. Parr et al. Demystifying wine expertise: olfactory threshold, perceptual skill and semantic memory in expert and novice wine judges. Chem Senses. 2002;27(8):747-55.

dorsolateral cortex is significant in sommeliers, but not in controls. This region, linked to high-level cognitive processes such as working memory and the selection of behavioral strategies may be important in optimizing or modifying behavioral strategies linked to taste. This difference may be responsible for more refined sensitivity of the combination of olfactory and gustatory perceptions by sommeliers[145].

1.4. Language

The faithful representation of our experience depends heavily upon language, which allows us to communicate it to others. Language is also a tool to remind us of experiences, thus serving as an aid for memory fixation. In the case of perceptual memory, language is often poor. This lack of a language to describe perceptions is not always recognized, as for other memories, language is usually precise. In this way, conditions are created for the emergence of memory illusions denominated verbal overshadowing, in which the generated verbal representation can be superimposed to the perceptual memory itself. Wine tasting involves individual variation regarding perceptual expertise (wine drinkers vs. non-drinkers) and with regard to verbal expertise (trained individuals vs. untrained). Moreover, memories of taste and olfaction enhance verbal overshadowing. Melcher and Schooler compared the performance of individuals to identify wines previously tasted and described, among other samples. Tasters were divided in three categories: Those who drink red wine less than once per month (little or no perceptual experience), people who drink red wine at least once a month (moderate perceptual expertise high) and with little or no training (low verbal expertise), and experts. The results showed that verbal overshadowing occurs when there is a large discrepancy between verbal and perceptual expertise. The performance of beginners was at most slightly improved by verbalization. The performance of experts was not modified by verbalization. The performance of the intermediary group with moderate to high perceptual expertise and low verbal expertise was impaired by verbalization[146].

In an investigation of the terms used to describe the attributes of the wine, Lesschaeve found that the language varies according to the category and the training of tasters. A comparison of wine descriptors used by ordinary consumers, connoisseurs or

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[145] Alessandro Castriota-Scanderbeg et al. The appreciation of wine by sommeliers: a functional magnetic resonance study of sensory integration. Neuroimage. 2005;25(2):570-8.

[146] Joseph M. Melcher and Jonathan W. Schooler. The misremembrance of wines past: Verbal and perceptual expertise differentially mediate verbal overshadowing of taste memory. J Mem Lang. 1996; 35(2):231-45.

members of a trained panel for descriptive analysis of wine showed that the descriptions from connoisseurs do not explain the expressions of likes and dislikes of consumers. The language used by experts in the description of wine, which is often used for advising lay consumers on what to buy does not always correspond to their perception. Multivariate analysis of sensory descriptors and the lexicon used to describe wine showed that similar words may refer to different perceptions to connoisseurs and consumers. The same word used by one or other of these groups can refer to a different sensory perception and, adversely, different words used by these two groups can refer to a single perception. Sensory descriptive analysis, which accurately describes and quantifies the sensory attributes of wines, can be a valuable tool in the translation of the consumers´ descriptors in well-defined sensory attributes[147].

Tasting made by experts is supposedly analytical. Thus, the expression of such tasting should be organized around the different senses involved in it: vision, olfaction, taste and somesthesia. In order to verify this, Brochet and Morrot used a specific software to analyze the co-occurrence of words in a text and to group them into lexical fields. This software was applied to four important wine tasting corpuses and the results suggested that the tasting notes contained therein do not strictly follow a sensory analytical model. Lexical fields, which were established by analysis, contain a visual, an olfactory, and a gustatory descriptor, forming groups associated to a type of wine, thus establishing wine prototypes. The study concluded that the description of the experts is based on prototypes, which are related to the color aspects of the wine. Furthermore, tasting notes combine sensory properties with other non-sensory properties, use hedonistic and idealistic values and are individual, therefore making sense especially to the taster himself. Each expert has his own strategies in the construction of tasting notes, which are not shared with other experts and probably with consumers, making the understanding among them difficult[148].

People associated with the wine market, such as wholesalers, retailers and importers are characterized by having great experience but little formal training in evaluating wines. Often, their purchasing decisions are influenced by analyses of tasters with higher levels of formal training. Therefore, the effectiveness of communication

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[147]Isabelle Lesschaeve. The use of sensory descriptive analysis to gain a better understanding of consumer wine language.In: 3rd International Wine Business & Marketing Research Conference Ecole Nationale Supérieure Agronomique, Montpellier, France, July 6-7-8, 2006. [cited 2014 Feb]. Available from: http://academyofwinebusiness. com/wp-content/uploads/2010/05/Lesschaeve. rtf. pdf.
[148]Frédéric Brochet and Denis Dubourdieu. Wine descriptive language supports cognitive specificity of chemical senses. Brain Lang. 2001;77(2):187-96.

between groups of experienced tasters, with different levels of formal training in wine competition is of great importance to the wine business. The identification of wines from their descriptions can be a measure of their accuracy and communicative value. The performance of two groups of tasters for recognizing three Australian Chardonnay wines, from their descriptions produced beforehand, was studied. One group consisted of individuals who worked in wine-related activities, however without any formal training. The other group was composed of oenology students with 109 hours of structured training in evaluating wines. This group was divided into two others, with the same number of members, one of which tasted and described the wines, which were then supplied to the second half of the trained students and to the untrained group. Along with the wines, the descriptions produced by half the trained students were provided. The main object of the investigation was the correct matching between the descriptions provided and the matched wines. It has been concluded that the matching success was higher in both groups than if it were simply left by chance. However, the performance of the trained group was significantly better.

In a second experiment, a group of oenologists produced consensual descriptions of the wines that were presented to the group with no training, in another session of tasting and matching. The matching performance of the untrained group was significantly greater with consensual descriptions, produced by oenologists, than with the descriptions produced by their peers. The results also seem to indicate that the descriptions are interpreted by both the group with no training and by the trained group, synthetically instead of analytically[149].

1.5. Information

The information about what is being tasted can change sensory perception by introducing an important bias in the assessment. The identification and subsequent naming of odors is seldom a consensus task. It has been found that the identification of aromas repeatedly presented at sequential tasting sessions is more consistent when lists of names of the odorants are not provided in advance and when the choice of names for

[149]Richard Gawel. The use of language by trained and untrained experienced wine tasters. J Sens Stud. 1997; 12(4):267-84.

odors was free and up to each taster. Therefore, providing verbal cues decreases the performance in identifying reintroduced odors[150].

Identity information of a food product can, in itself, influence the perception of basic tastes. In one experiment ten solutions with varying concentrations of sucrose (sweet), NaCl (salty), tartaric acid (sour), quinine (bitter) and monosodium glutamate (umami) were labeled with names of familiar foods for the tasters (lemon, consommé soup, coffee jelly and candy caramel) or random numbers. The group of tasters who tasted the samples labeled with food names provided more familiarity and liking ratings when compared with the rates assigned by the group who tasted the samples labeled with numbers. This effect increased with the perception of congruence between label name and taste of the sample[151].

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[150]Claire Sulmont-Rossé et al. Odor naming methodology: correct identification with multiple-choice versus repeatable identification in a free task. Chem Senses. 2005;30(1):23-7.
[151]Masako Okamoto et al. Influences of food-name labels on perceived tastes. Chem Senses. 2009;34(3):187-94.

DISCUSSION

The section about the anatomy and physiology of the sense organs, in the beginning of this paper, shows significant progress made in recent years in the understanding of sensory mechanisms. The great development of molecular biology and genomics have led to unraveling many processes involved in the generation of sensations by effective stimuli on the sensory receptors and their transmission to neural centers, which will identify and evaluate them. A reflection of this intense research activity is the granting of two Nobel prizes to researchers who studied molecular sensory mechanisms in the last decade. The 2012 Nobel Prize in Chemistry was awarded to Robert J Lefkowitz and Brian K Kobilka for their studies on receptors coupled to G proteins. Richard Axel and Linda Buck won the Nobel Prize in Physiology or Medicine 2004 for their discovery of odorants receptors and the organization of the olfactory system[152].

With regard to wine, a considerable amount of scientific research has been made to investigate its chemical composition and the relationship among its components and its organoleptic characteristics[153,154,155].

A greater knowledge about the chemical composition of wine and a better understanding of how it generates its organoleptic characteristics are not sufficient to address the enormous difficulties involved in wine tasting. An accurate chemical description of a wine does not bring a mental representation of it. The taste of a wine is in our minds and not in the bottle[156]. The elucidation of the molecular mechanisms involved in sensory reception, in addition to the discovery of afferent sensory pathways and their central projection are also not sufficient to answer a central question in

[152]Nobel Foundation. Nobel Prize. [cited 2014 Mar]. Available from: http://www. nobelprize. org/nobel_prizes/medicine/laureates/

[153]Pavla Polášková, Herszage J, Ebeler SE. Wine flavor: chemistry in a glass. ChemSoc Rev. 2008;37(11):2478-89.

[154]Michael Qian et al. Development of aroma compounds in Pinot noir grapes and their relative importance in wine (Year 1). [cited 2014 Jan]. Available from: http://owri. oregonstate. edu/sites/owri. org/files/documents/Wine_Progress_Reports/2002-03/Development%20of%20aroma%20compounds%20in%20Pinot%20noir%20Grapes%20and%20their%20Relative%20Importance%20in%20Wine%20(Year%201). pdf.

[155]Remedios R. Villamor. The impact of wine components on the chemical and sensory properties of wines [dissertation].Washington, DC: Washington State University; 2012. [cited Mar 2013]. Available from: http://research. wsulibs. wsu. edu/xmlui/bitstream/handle/2376/4103/Villamor_wsu_0251E_10425. pdf?sequence=1.

[156]Frédéric Brochet. Le goût du vin en conscience. J Int Sci Vigne Vin. 1999; 33(speciss):19-23.

cognitive neuroscience: in what way is stimulus information represented in the central nervous system. Some progress in this area has been achieved with studies using methods such as functional magnetic resonance imaging and positron emission tomography[157,158,159].

In addition to purely sensory aspects, other influences such as idealist, hedonic and life experiences exert influence over the taster. The phenomenal character of sensory experiences has intrinsic, consciously accessible, non-representational features, their "qualia". Thus, sensory experience is strictly personal, and particularly, regarding chemical senses, it provides difficult communication[160,161162]. The communication of critical judgment, as discussed above is prototypical and it follows personal strategies[163].

These difficulties inevitably incite questions about the accuracy and reproducibility of the evaluations made by experts and wine critics. The opinions of the critics are far from being uniform. One study compared the assessment from three reputable critics (Robert Parker, Jancis Robinson and James Suckling) for 2004 vintage Bordeaux wines. It was concluded that the agreement between Parker and Suckling was reasonable, whereas there was considerable disagreement between Parker and Robinson[164].

Another study was designed to verify whether consumers recognized wines from their description by specialized critics. Initially, the discerning taste of the participants was tested by means of a triangular test. Among subjects who were able to distinguish

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[157]Frédéric Brochet. La dégustation: Etude des représentations des objets chimiques dans le champ de la conscience. Paris: AcadémieAmorim; 2001. [cited 2014 Mar]. Available from: http://www. academie-amorim. com/documents/brochet. pdf.

[158]John O'Doherty et al. Representation of pleasant and aversive taste in the human brain.J Neurophysiol. 200;85(3):1315-21.

[159]Robert J. Zatorre. Processing of olfactory affective information: contribution of functional imaging studies. In: Rouby C, Schaal B, Dubois D, Gervais R, Holley A, editors. *Olfaction, taste, and cognition*.Cambridge, UK: Cambridge University Press; 2002. p.324-34.

[160]Sophie David. Linguistics Expressions for Odors in French.In: Rouby C, Schaal B, Dubois D, Gervais R, Holley A, editors. *Olfaction, taste, and cognition*.Cambridge, UK: Cambridge University Press; 2002. p.82-99.

[161]Claire Sulmont-Rossé et al. Odor naming methodology: correct identification with multiple-choice versus repeatable identification in a free task. Chem Senses. 2005;30(1):23-7.

[162]Claire Sulmont-Rossé et al. You'll never drink alone: wine tasting and aesthetic practice. In: Alloff F, editor. *Wine and philosophy: a symposium on thinking and drinking*. Malden, MA: Blackwell Publishing; 2008. p.157-71.

[163]Frédéric Brochet and Denis Dubourdieu. Wine descriptive language supports cognitive specificity of chemical senses. Brain Lang. 2001;77(2):187-96.

[164]Dom Cicchetti. Documented disagreement among wine experts: a rational response for consumers. In: AAWE 4th Annual Conference UC Davis, Davis, California June 25-28, 2010. [cited 2014 Mar]. Available from: http://aic. ucdavis. edu/aaweconf/abstracts/Cicchetti. pdf.

the different wine in the triangular test, therefore exhibiting a good tasting judgment, only 51% were able to match the wines with their respective descriptions contained in The Wine Advocate magazine[165].

The consistency among judges at wine contests in assigning scores or awards has great importance when these experts participate in series of tasting sessions in major contests or in consecutive contests, in which the same wines may be present for judgment. To investigate the quality of judges and their overall performance, a study by Hodgson was conducted over four consecutive years in a large Californian wine fair (California State Fair from 2005 to 2008). In this yearly contest, during the evaluation period, about 3,000 wines in 4-6 flights per day are tasted. The flights usually consisted of 30 wines. Four triplicate samples (same wine from the same bottle) were served to 16 panels of jurors, inserted in one of the flights. The ability of a juror to evaluate consistently replicated samples of an identical wine was investigated. The findings showed that the judges were utterly consistent in only 18% of cases, mainly for the low-scored wines. Another conclusion was that the best performance in relation to the consistency observed in a year did not necessarily correlate with the best performance in the following year. An analysis of variance (ANOVA) was performed for each panel to check if the source of variation was the quality of the wine, the jury's bias and inconsistency, or both. The compilation of these analyses, from 2005 to 2008, showed that in only 50% of the time, the wine was the significant factor of the score assigned. For the other half, other factors played a significant role in the assigned score[166].

By evaluating prizes awarded to wines participating in contests, strong inconsistency has been found. A study of 13 California wine contests identified, from a database of 4167 wines (California grapevine), 375 that participated in the same five contests. Out of these, no wine received a gold medal in five contests, or even in four of them. Six wines won three gold medals, 20 won two and 106 won one. A total of 75% of the wines that received a gold medal received no awards in other contests while 23% received a bronze medal. Thus, the possibility of winning at least one gold medal, for these wines that participated in the five contests is high (35%). On the other hand, 98% of the wines that won gold medals did not win any medals or won just a bronze medal in at least one of the four other contests.

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[165] Roman L. Weil. Debunking critics' wine words: can one distinguish the smell of asphalt from the taste of cherries? (No Accounting for Taste). J Wine Econ.2007; 2(2):136-44.
[166] Robert T. Hodgson. An examination of judge reliability at a major U. S. wine competition.J Wine Econ.2008; 3(2):105-13.

When the medals granted were converted to numerical scores, using a scale of 18 points starting at 80, it was found that the correlations between the scores awarded to wines in 13 contests were very weak, where the best correlation was 0.33 and the median only 0.10. Therefore, there is no correlation between the performance of a wine in a contest and its performance in another contest.

It was concluded that there was practically no consensus on the quality of wines in 13 contests. It is quite possible that the wines, which were awarded a gold medal in a particular contest, will not receive the same award, or receive another different medal in other contests. Moreover, the odds of receiving a gold medal may be statistically explained by chance only[167]. Perhaps these differences can be explained by the inconsistency of the jury.

Despite these limitations, a considerable part of the quality wine market is influenced by personal opinions of critics or groups of critics representing specialized publications.

Critics act in two ways: like judges, applying their training, knowledge and experience to decide if a wine meets certain conventional standards approved for a type of wine, or when there are no established standards, they act in determining these patterns, based on their idiosyncratic preferences. This critical activity influences consumers who rely on this information (tasting notes, scores) to define their options. Furthermore, producers in their production and pricing strategies use the quality parameters, which are employed by critics to assess wines[168]. An alarming consequence of these findings is that producers, driven by market pressures generated by reviews from influential critics, may begin to develop stereotypes of wines designed to meet this specific demand. The result could be the homogenization of wines, produced to meet the personal taste of a certain critic, who, in turn, assigns higher scores to the wine that, consequently, will achieve greater commercial success. This process would lead to a decrease of diversity and a threat to the typicity of "terroir" wines.

The influence of the score from experts over wine price is a matter of great debate. To evaluate this interference in the market, Lecocq and Visserb conducted a large study. Data were obtained from structured databases generated by three

[167]Robert T. Hodgson. An Analysis of the concordance among 13 U. S. wine competitions.J Wine Econ.2009;4(1):1-9.

[168]Greta Hsu, Peter W. Roberts and Anand Swaminathan. Standards for quality and the coordinating role of critics.2007. [cited 2014 Mar]. Available from: http://citeseerx. ist. psu. edu/viewdoc/download?doi=10. 1. 1. 151. 5007&rep=rep1&type=pdf.

experimental studies conducted by the National Institute of Consumption in France in 1992, 1993 and 2001. The first sample consisted of 519 wines from Bordeaux, the second 613 wines from Burgundy and the third, 255 wines from Bordeaux. A technique called 'hedonic price functions' was used, which constitutes a regression analysis of price versus other characteristics to determine which of them are effectively significant. In this study, the objective characteristics investigated for each of the three sets of wines were: name, color, ranking, designation of origin and vintage. The sensory characteristics were established by blind tasting by experts and their olfactory and gustatory impressions were recorded. Tasters assigned scores 0-20 to the wines as a measure of quality. The conclusion was that most of the price differences between the wines from these sets were due to objective data, available on the label for the consumer, such as ranking, vintage and designation of origin. Scores by experts have a significant and positive impact on the price of wine, although less than any objective variable[169].

A U.S. study investigated the price/quality relation of California wines using the model of quality indices. The indices used were the medals received in nine tasting events in 1995. A medal received in a particular tasting session produced a quality index for a specific wine, in which the value assigned was 1. Wines with no medals were assigned the value 0. For example, the variable SFMEDAL (medal received at San Francisco fair) took the value of 1 when the wine received a medal, and 0 if it did not. The sample consisted of 1884 different wines that won at least one medal in one of these tasting events in 1995. The objective of this investigation was to determine which indices would be the best measures for wine quality and the relationship to its final consumer price. Enrollment in these tasting events required the information of the suggested retail price.

It has been demonstrated that some tastings events (San Francisco, Orange County, Sacramento and Riverside) had a greater positive impact on the composition of prices, while others (New World International and San Diego) appear to have had a significantly negative impact. Varietal wines from Cabernet Sauvignon, Chardonnay, Pinot Noir and Merlot showed above-average prices.

A medal won at a tasting event in San Francisco added US$ 3.65 to the price of a bottle. At the tasting event in Orange County, a medal added US$ 2.33, in Sacramento

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[169]Sébastien Lecocq and Michael Visserb. What Determines wine prices: objective vs. sensory characteristics. J Wine Econ.2006; 1(1): 42–56.

there was an increase of US$ 1.89, and in Riverside, the increase was US$ 2.02. In New World International and San Diego, US$ 1.14 and US$ 1.02 were subtracted, respectively, from the price of a bottle.

Four-year Chardonnays were priced at US$ 3.36 higher than expected. For Cabernet Sauvignon, winning a medal at the tasting in San Francisco had the price raised in approximately US$ 6.07. Medals received at San Francisco or Sacramento tastings raised the price of a bottle of Merlot in approximately US$ 3.50. For medals conferred at the Orange County tasting event, the increase was US$ 2.86. Having won a medal at San Francisco tasting event, Pinot Noir wines had an increase of approximately US$ 5.32. The conclusion was that winning a medal in the tastings events of San Francisco, Orange County and/or Sacramento was associated with higher price and quality for the award-winning wine[170].

The impact from the scores assigned by influential critic Robert Parker U.S. in setting prices was well demonstrated for Bordeaux wines belonging to the 2002 vintage. From 1994 to 2002, Parker visited Bordeaux in the spring which followed the harvest to taste the wines en primeur. The scores he assigned were usually published in the April issue of his magazine, *Wine Advocate*, and producers set prices for sale, en primeur, after a few weeks. In 2003, Parker visited the region and evaluated the wines in the beginning of September when prices had already been set. The average of the scores awarded to wines and the average prices of the two vintages were then compared. The scores for the 2001 vintage were slightly higher than those of 2002 and their apparent quality was similar. However, the prices of the two vintages differed markedly. For the 2001 vintage, wines bottles cost on average 3 Euros more than in 2002. The price variance was also much higher for the 2001 vintage. Similarly, the correlation between score and prices was stronger for this vintage than for that of 2002. The impact on prices is much more noticeable in wines that received high scores, reaching 10 euros per bottle[171].

Within a classic economic concept which dictates that in a stable market, with perfectly informed consumers, prices should remain in balance, it would be expected that the role of wine critics, providing more information to consumers would contribute to price convergence to a quality adjusted equilibrium. However, a study to investigate

[170]Tony Lima. Price and quality in the California wine industry: an empirical investigation. J Wine Econ.2006; 1(2):176-90.
[171]Héla Hadj Aliy, Sébastien Lecocqz and Michael Visser. The impact of gurus: Parker grades and en primeur wine prices. 2007. [cited 2013 Dec]. Available from: http://ermes. u-paris2. fr/doctrav/0718. pdf.

the influence of critics on price deviation from the predicted equilibrium, adjusted for quality and, with full information, concluded that the very opposite occurs. American wines evaluated by the Wine Spectator magazine between 1984 and 2008, were studied. The dispersion of the price/quality ratio has increased with the level of exposure of wine to criticism in the past. The dispersion also increased with the level of maximum scores obtained by the wine. This is enhanced when the difference between the highest score and the average score is large. These two effects are more intense for lower-quality wines, imposing an overpricing to mid-quality wines[172].

Another interesting survey studied the relationship between the scores awarded to blindly-tasted wines and their prices. A total of 523 wines were tasted by 506 volunteers, in 17 double-blind tasting sessions (neither the people in charge for the service, nor the tasters had any information about the wines, except their color). About 12% of participants had some training in assessing wines and they were called experts. The results indicate that the correlation between score and price is small and negative. On average, except for experts, tasters tend to enjoy expensive wines a bit less. Another consideration from these results is that the average consumer cannot benefit from assessments made by experts simply because they do not enjoy the same type of wine experts do[173].

Given all these difficulties and uncertainties in the information that is provided to the wine market, and particularly to the lay final consumer, by experts and specialized critics, how should one go about choosing the right wine? How can one be sure that the description of the characteristics of the wine produced by critics matches the feelings that will be experienced when consuming that wine?

The descriptive quantitative analysis could be a reliable tool in determining the sensory profile of wines. Its advantages would be: confidence in the judgment of a team of 10 to 12 trained tasters, the development of an objective descriptive language closer to the consumer's language, the consensual development of descriptive terminology to be used and the repetitions of blind tests performed by all the judges, with statistical

[172]Karl Storchmann, Alexander Mitterling and Aaron Lee. The detrimental effect of expert opinion on price-quality dispersion evidence from the wine market.AAWE Working Paper. Economics. 2012; 118.[cited 2013 Dec]. Available from: http://www. wine-economics. org/aawe/wp-content/uploads/2012/10/AAWE_WP118. pdf.

[173]Robin Goldstein et al. Do More expensive wines taste better? Evidence from a large sample of blind tastings. J Wine Econ. 2008; 3(1):1-9.

analysis[174]. As previously discussed, the application of quantitative descriptive sensory analysis is complex and difficult, and its adoption as an information generator tool for communication of the wine industry with consumers is still very restricted. Alternative methods have been proposed such as Napping®, by which a series of samples are evaluated by their geometric distribution on a two-dimensional space, according to similarities or differences between them detected by the evaluators, complemented by descriptive methods such as ultra-flash profile and free profile[175,176]. Specific characteristics of the wine, as its astringency can be described and evaluated by both the conventional descriptive analysis[177] with simpler methods such as the descriptive method based on frequency of citation for odor profiling[178]and free choice profiling to evaluate color and appearance[179].

Still, these more accurate forms of sensory description are underused and fail to guide the consumer. An alternative would be the one proposed by Jancis Robinson, according to which the consumer would benefit from reading the comments from a single wine critic and building a correlation of such critic's comments with his own opinion, in order to understand the critic’s taste and preferences. This correlation would form the basis for interpreting future reviews, facilitating the selection of wines when purchasing[180]. Nevertheless, the construction of this correlation demands many years and presupposes the maintenance of the critic’s criteria all along this period.

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[174]Jorge Herman Behrensand, Maria Aparecida Azevedo P. da Silva. Perfil sensorial de vinhos brancos varietais brasileiros através de análise descritiva quantitativa. CiêncTecnol Aliment. 2000; 20(1):60-7.
[175]Jérôme Pagès. Collection and analysis of perceived product interdistances using multiple factor analysis: Application to the study of 10 white wines from the Loire Valley. Food Qual Prefer. 2005;16(7):642-9.
[176]Lucie Perrin et al. Comparison of three sensory methods for use with the Napping® procedure: Case of ten wines from Loire valley. Food Qual Prefer. 2008; 19(1):1-11.
[177]Margaret A. Cliff, Marjoire C. King and Jimmy Schlosser. Anthocyanin, phenolic composition, color measurement and sensory analysis of BC commercial red wines. Food Res Int. 2007; 40(1):92-100.
[178]Eva Campo et al. Comparison of conventional descriptive analysis and a citation frequency-based descriptive method for odor profiling: An application to Burgundy Pinot noir wines. Food Qual Prefer. 2010; 21(1):44-55.
[179]Eduarda Cristovam, Alistair Paterson and John R. Piggott. Differentiation of port wines by appearance using a sensory panel: comparing free choice and conventional profiling. EurFood Res Technol. 2000;211(1): 65-71.
[180]Jancis Robinson. *Confissões de uma amante de vinhos.* São Paulo: DBA Artes Gráficas; 2008. p.259.

CONCLUSIONS

We have seen that the information generated by critics is often inconsistent and difficult to interpret. The terms used in their reviews are often inaccurate and bear little relation to the sensations usually perceived by consumers. Routine sensory analysis with scientific methodology is difficult to implement, and its results would need to be transcribed into ordinary language for ordinary consumers. We conclude that amateur wine consumers are somewhat helpless when seeking guidance for buying wine bottles that best suit their preferences.

I firmly believe that the best alternative for the true wine lover is to belong to an association of wine oenophiles and participate in its tasting sessions. This way, amateurs will have the opportunity to taste numerous wines and discuss about them with their peers without having to buy them and, after having established their own opinion, they could safely purchase the wines of their predilection.

REFERENCES

Adler E, Hoon MA, Mueller KL, Chandrashekar J, Ryba NJ, Zuker CS. A novel family of mammalian taste receptors. Cell. 2000;100:693-702.

Aliy HH, Lecocqz S, Visserx M. The impact of gurus: Parker grades and en primeur wine prices. 2007. [cited 2013 Dec]. Available from: http://ermes.u-paris2.fr/doctrav/0718.pdf.

Almenberg J, Dreber A. When does the price affect the taste? Results from a wine experiment. SSE/EFI Working Paper Series in Economics and Finance, nº 717, 2009. [cited 2014 Feb]. Available from: http://hdl.handle.net/10419/56240.

Alvarez-Rodríguez ML, López-Ocaña L, López-Coronado JM, Rodríguez E, Martínez MJ, Larriba G, et al. Cork taint of wines: role of the filamentous fungi isolated from cork in the formation of 2,4,6-trichloroanisole by o methylation of 2,4,6-trichlorophenol. Appl Environ Microbiol. 2002;68:5860-9.

Amoore JE. Specific anosmia and the concept of primary odors.Chem Senses Flavor. 1977;2(3):267-81.

Arruda D. *The Periglomeural Cell of the Olfactory Bulb and its Role in the odor processing: a computational model* [Thesis]. Ribeirão Preto, SP: Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto; 2010. 75f. [citeddez 2013]. Available from: http://www.teses.usp.br/teses/disponiveis/59/59135/tde-23092010-171519/pt-br.php).

Aumatell MR. Sensory analysis in quality control: the gin as an example. [cited 2013 Dec]. Available from: http://www.intechopen.com/download/get/type/pdfs/id/23744.

Bachmanov AA, Kiefer SW, Molina JC, Tordoff MG, Duffy VB, Bartoshuk LM, Mennella JA. Chemosensory factors influencing alcohol perception, preferences, and consumption. Alcohol ClinExp Res. 2003;27(2):220-31.

Bajec MR, Pickering GJ. Astringency: mechanisms and perception. Crit Rev Food SciNutr. 2008;48:858-75.

Baoshan S, Spranger I. Review: Quantitative extraction and analysis of grape and wine proanthocyanidins and stilbenes. CiêncTécVitiv. 20:59-89. 2005. Available from: http://www.scielo.oces.mctes.pt/pdf/ctv/v20n2/v20n2a01.pdf.

Bartoshuk LM, Duffy VB, Miller IJ. PTC/PROP tasting: anatomy, psychophysics, and sex effects. PhysiolBehav. 1994;56(6):1165-71.

Bartoshuk LM. Comparing sensory experiences across individuals: recent psychophysical advances illuminate genetic variation in taste perception. Chem Senses. 2000;25(4):447-60.

Baumes R. Wine aroma precursors. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p:251-74.

Behrens JH, Silva MAA. Perfil sensorial de vinhos brancos varietais brasileiros através de análise descritiva quantitativa. CiêncTecnol Aliment. 2000; 20(1):60-7.

Behrens JH. Minicourses 2010: fundamentals and techniques of sensory analysis. Regional Council of Chemistry - Region IV (SP). [cited 2014 Jan]. Available from: http://www.crq4.org.br/sms/files/file/analise_sensorial_2010.pdf.

Bowmaker JK, Dartnall HJ. Visual pigments of rods and cones in a human retina.J Physiol. 1980;298:501-11.

Bremner EA, Mainland JD, Khan RM, Sobel N. The prevalence of androstenone anosmia. Chem Senses. 2003;28(5):423-32.

Brochet F. *La dégustation: étude des representations des objets chimiques dans le champ de la conscience*. Paris: AcadémieAmorim; 2001. [cited 2014 Mar]. Available from: http://www.academie-amorim.com/documents/brochet.pdf.

Brochet F. Le goût du vin en conscience. J IntSciVigneVin. 1999; 33(spec iss):19-23.

Brochet F, Dubourdieu D. Wine descriptive language supports cognitive specificity of chemical senses. Brain Lang. 2001;77(2):187-96.

Brochet F, Morrot, G. Influence du context sur la perception du vin implications cognitives et méthodologiques. J IntSciVigneVin. 1999;33(4):187-92.

Buck L, Axel R. A novel multigene family may encode odorant receptors: a molecular basis for odor recognition. Cell. 1991;65:175-87.

Buck LB. Unraveling the sense of smell. Nobel Lecture, December 8, 2004. p.267-83. [cited 2013 Dec]. Available from: http://www.nobelprize.org/nobel_prizes/medicine/laureates/2004/buck-lecture.pdf.

Campo E, Ballester J, Langlois J, Dacremont C, Valentin D. Comparison of conventional descriptive analysis and a citation frequency-based descriptive method for odor profiling: An application to Burgundy Pinot noir wines. Food Qual Prefer. 2010; 21(1):44-55.

Castriota-Scanderbeg A, Hagberg GE, Cerasa A, Committeri G, Galati G, Patria F, et al. The appreciation of wine by sommeliers: a functional magnetic resonance study of sensory integration. Neuroimage. 2005;25(2):570-8.

Chandrashekar J, Hoon MA, Ryba NJ, Zuker CS. The receptors and cells for mammalian taste. Nature. 2006;444:288-94.

Chaudhari N, Pereira E, Roper SD. Taste receptors for umami: the case for multiple receptors. Am J ClinNutr. 2009;90:738S-742S.

Chaudhari N, Roper SD. The cell biology of taste. J Cell Biol. 2010;190:285-96.

Cicchetti D. Documented disagreement among wine experts: a rational response for consumers. In: AAWE 4th Annual Conference UC Davis, Davis, California June 25-28, 2010. [cited 2014 Mar]. Available from: http://aic.ucdavis.edu/aaweconf/abstracts/Cicchetti.pdf.

Cliff MA, King MC, Schlosser J. Anthocyanin, phenolic composition, color measurement and sensory analysis of BC commercial red wines. Food Res Int. 2007; 40(1):92-100.

Collins T. Tannins: Types and Amounts in Grapes and Wines. In: New York Wine Industry Workshop Proceedings, Geneva, NY, 2-4 April 2003. [cited 2014 Jan]. Available from: http://locale.mannlib.cornell.edu/gsdl/cgi-bin/library.cgi?a=q&r=1&hs=1&e=q-01000-00---off-0wiwp--00-1----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about-tannis--00-3-1-00-0--4--0--0-0-11-10-0utfZz-8-00&t=1&q=tannins.

Cristovam E, Paterson A, Piggott JR. Differentiation of port wines by appearance using a sensory panel: comparing free choice and conventional profiling. EurFood Res Technol. 2000;211(1): 65-71.

Cruz AG, Cadena RS, Walter EH, Mortazavian AM, Granato D, Faria JA, Bolini HM. Sensory analysis: relevance for prebiotic, probiotic, and synbiotic product development. Compr Rev Food Sci Food Saf. 2010; 9(4):358-73.

Dalton P. Psychophysical and behavioral characteristics of olfactory adaptation. Chem Senses. 2000;25(4):487-92.

Darriet P, Lavigne-Cruege V, Tominaga T. Un paradoxe: les composés soufrés volatils responsables de defaults et de qualités dans les vins. J Int Sci Vigne Vin. 1999; 33(spec):137-43.

David S. Linguistics Expressions for Odors in French. In: Rouby C, Schaal B, Dubois D, Gervais R, Holley A, editors. *Olfaction, taste, and cognition*. Cambridge, UK: Cambridge University Press; 2002. p.82-99.

de Araujo IE, Rolls ET, Kringelbach ML, McGlone F, Phillips N. Taste-olfactory convergence, and the representation of the pleasantness of flavour, in the human brain. Eur J Neurosci. 2003;18(7):2059-68.

Weil RL. Debunking critics' wine words: Can one distinguish the smell of asphalt from the taste of cherries? (No Accounting for Taste). J Wine Econ. 2007; 2(2):136-44.

Derbyshire D. Wine-tasting: it's junk science. The Guardian,The Observer. 2013 Jun 23. [cited 2013 Dec]. Available from: http://www.theguardian.com/lifeandstyle/2013/jun/23/wine-tasting-junk-science-analysis.

Drewnowski A, Henderson SA, Shore AB. Genetic sensitivity to 6-n-propylthiouracil (PROP) and hedonic responses to bitter and sweet tastes. Chem Senses. 1997;22(1):27-37.

Dubordieu D, Tominaga T. Poly functional thiol compouns. In: Moreno-Arribas MV, Polo MC, editors. Wine Chemistry and Biochemistry. New York: Springer; 2009. p.275-93.

Duffy VB, Peterson JM, Bartoshuk LM. Associations between taste genetics, oral sensation and alcohol intake. Physiol Behav. 2004;82(2-3):435-45.

Frank RA, Byram J. Taste–smell interactions are tastant and odorant dependent. Chem Senses. 1988; 13(3):445-55.

Gawel R, Oberholster A, Francis IL. A mouth-feel wheel: terminology for communicating the mouth-feel properties of red wine. Aust J Grape Wine Res. 2000; 6:203-7.

Gawel, R. The use of language by trained and untrained experienced wine tasters J Sens Stud. 1997; 12(4):267-84.

Gibbs M, Tapia M, Warzynski F. Globalization, superstars, and reputation: theory and evidence from the wine industry. J Wine Econom. 2009; 4(1):49-64. Available from: http://www.wine-economics.org/journal/details-content/volume-4-2009-no-1/

Godden P, Lattey K, Francis L, Gishen M, Cowey G, Holdstock et al. Towards offering wine to the consumer in optimal condition – the wine, the closures and other packaging variables: a review of AWRI research examining the changes that occur in wine after bottling. Wine Ind J. 2005; 2:20-30. [cited 2014 Jan]. Available from: http://ww
Leonardelli w.screwcapinitiative.com/upload/20_4%20AWRI%20Report.pdf.

Godfrey PA, Malnic B, Buck LB. The mouse olfactory receptor gene family. Proc Natl Acad Sci U S A. 2004;101:2156-61.

Goldstein R, Almenberg J, Dreber A, Emerson JW, Herschkowitsch A, Katz J. Do more expensive wines taste better? Evidence from a large sample of blind tastings. J Wine Econ. 2008; 3(1):1-9.

Gottfried JA, Dolan RJ. The nose smells what the eye sees: crossmodal visual facilitation of human olfactory perception. Neuron. 2003;39(2):375-86.

Guo SW, Reed DR. The genetics of phenylthiocarbamide perception. Ann Hum Biol. 2001;28(2):111-42.

Hayes JE, Bartoshuk LM, Kidd JR, Duffy VB. Supertasting and PROP bitterness depends on more than the TAS2R38 gene. Chem Senses. 2008;33(3):255-65.

Hodgson RT. An analysis of the concordance among 13 U.S. wine competitions. J Wine Econ. 2009;4(1):1-9.

Hodgson RT. An examination of judge reliability at a major U.S. wine competition. J Wine Econ. 2008; 3(2):105-13.

Hoon MA, Adler E, Lindemeier J, Battey JF, Ryba NJ, Zuker CS. Putative mammalian taste receptors: a class of taste-specific GPCRs with distinct topographic selectivity. Cell. 1999;96(4):541-51.

Hsu G, Roberts PW, Swaminathan A. Standards for Quality and the Coordinating Role of Critics. 2007. [cited 2014 Mar]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.151.5007&rep=rep1&type=pdf.

Huang YA, Maruyama Y, Stimac R, Roper SD. Presynaptic (Type III) cells in mouse taste buds sense sour (acid) taste. J Physiol. 2008;586:2903-12.

Hughson AL, Boakes RA. The knowing nose: The role of knowledge in wine expertise. Food Qual Prefer. 2002; 13(7-8):463-72.

Humes LE, Busey TA, Craig JC, Kewley-Port D. The effects of age on sensory thresholds and temporal gap detection in hearing, vision, and touch. Atten Percept Psychophys. 2009;71(4):860-71.

Hummel T, Heilman S, Murphy C. Age-related changes in chemosensory functions. In: Rouby C, Schaal B, Dubois D, Gervais R and Holley A, editors. *Olfaction, taste, and cognition*. Cambridge: Cambridge University Press; 2002.

Iannario M, Manisera M, Piccolo D, Zuccolotto P. Sensory analysis in the food industry as a tool for marketing decisions. Adv Data Anal Classif. 2012; 6(4):303-21.

International Organization of Vine and Wine. Statistical report on world vitiviniculture 2012. [cited 2013 Dec]. Available from: http://www.oiv.int/oiv/info/enizmiroivreport.

International Organization of Vine and Wine. World vitiviniculture situation in 2012. In: XXXVIth World Congress of Vine and Wine Bucarest, 3rd June 2013. [cited 2013

Dec]. Available from: http://ebookbrowsee.net/oiv-world-vitiviniculture-situation-in-2012-pdf-d502699851.

Jackson RS. Chemical constituents of grapes and wine. In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.

Jackson RS. Olfactory system. In:_______. *Wine tasting: a professional handbook*. London: Academic Press; 2002. p.39-78.

Jackson RS. Post fermentation treatment and related topics. In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.355-433.

Jackson RS. Sensory perception and wine assessment. In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.544-90.

Kajiya K, Inaki K, Tanaka M, Haga T, Kataoka H, Touhara K. Molecular bases of odor discrimination: Reconstitution of olfactory receptors that recognize overlapping sets of odorants. J Neurosci. 2001;21:6018-25.

Kalloniatis M, Luu C. Color perception. In: Kolb H, Fernandez E, Nelson R, editors. *Webvision: the organization of the retina and visual system*. [Copyright 2014]. Available from: http://webvision.med.utah.edu/book/part-viii-gabac-receptors/color-perception/.

Kim UK, Breslin PA, Reed D, Drayna D. Genetics of human taste perception. J Dent Res. 2004;83(6):448-53.

Kolb H. Gross anatomy of the eye. In: Kolb H, Fernandez E, Nelson R, editors. *Webvision: the organization of the retina and visual system*. [Last Updated January 25, 2012]. Available from: http://webvision.med.utah.edu/book/part-i-foundations/gross-anatomy-of-the-ey/

Kolb H. How the retina works. Am Sci. 2003;91:28–35. [cited 2013 Dec]. Available from: http://www.americanscientist.org/libraries/documents/20058313632_306.pdf.

Kolb H. Photoreceptors. In: Kolb H, Fernandez E, Nelson R, editors. *Webvision: the organization of the retina and visual system*. [Last Updated January 25, 2012]. Available from: http://webvision.med.utah.edu/book/part-ii-anatomy-and-physiology-of-the-retina/photoreceptors/.

Kringelbach ML. The human orbitofrontal cortex: linking reward to hedonic experience. Nat Rev Neurosci. 2005;6:691-702.

Lanthony P. La Perception des couleurs. J Int Sci Vigne Vin. 1999; 33(spec iss):59-62.

Lecocq S, Visserb M. What Determines wine prices: objective vs. sensory characteristics. J Wine Econ. 2006; 1(1):42-56.

Lemon CH, Katz DB. The neural processing of taste. BMC Neurosci. 2007;8(Suppl 3):S5.

Leonardelli MJ. Acidity in wine: the importance of management through measurement. [cited 2014 Jan]. Available from: http://gwi.missouri.edu/publications/2013spring.pdf.

Lesschaeve I, Noble AC. Polyphenols: factors influencing their sensory properties and their effects on food and beverage preferences. Am J Clin Nutr. 2005;81(1 Suppl):330S-5.

Lesschaeve I. The use of sensory descriptive analysis to gain a better understanding of consumer wine language. In: 3rd International Wine Business & Marketing Research Conference Ecole Nationale Supérieure Agronomique, Montpellier, France, July 6-7-8, 2006. [cited 2014 Feb]. Available from: http://academyofwinebusiness.com/wp-content/uploads/2010/05/Lesschaeve.rtf.pdf.

Lim J, Urban L, Green BG. Measures of individual differences in taste and creaminess perception. Chem Senses. 2008;33(6):493-501.

Lima T. Price and quality in the California wine industry: an empirical investigation. J Wine Econ. 2006; 1(2):176-90.

Lindemann B, Ogiwara Y, Ninomiya Y. The discovery of umami. Chem Senses. 2002;27(9):843-4.

Lundström JN, Seven S, Olsson MJ, Schaal B, Hummel T. Olfactory event-related potentials reflect individual differences in odor valence perception. Chem Senses. 2006;31(8):705-11.

Malnic B, Godfrey PA, Buck LB. The human olfactory receptor gene family. Proc Natl Acad Sci U S A. 2004;101:2584-9.

Malnic B, Hirono J, Sato T, Buck LB. Combinatorial receptor codes for odors. Cell. 1999;96:713-23.

Margalit Y, Crum J, editors. Aroma and flavor. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.133-92.

Margalit Y, Crum J, editors. Must and wine composition. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.1-55.

Margalit Y, Crum J, editors. Oak Products (Cooperage and Cork). In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.217-63.

Margalit Y, Crum J, editors. Oxidation and wine Aging.. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.193-215.

Margalit Y, Crum J, editors. Phenolic compounds. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.95-129.

Margalit Y, Crum J, editors. Wine faults. In:_______. *Concepts in wine chemistry*. 2nd ed. South San Francisco, CA: The Wine Appreciation Guild; 2004. p.331-48.

Margolskee RF. Molecular mechanisms of bitter and sweet taste transduction. J Biol Chem. 2002;277:1-4.

Mattes RD. Is there a fatty acid taste? Annu Rev Nutr. 2009;29:305-27.

Max M, Shanker YG, Huang L, Rong M, Liu Z, Campagne F, Weinstein H, Damak S, Margolskee RF. Tas1r3, encoding a new candidate taste receptor, is allelic to the sweet responsiveness locus Sac. Nat Genet. 2001;28:58-63.

McLaughlin SK, McKinnon PJ, Margolskee RF. Gustducin is a taste-cell-specific G protein closely related to the transducins. Nature. 1992;357:563-9.

McRae JF, Mainland JD, Jaeger SR, Adipietro KA, Matsunami H, Newcomb RD. Genetic variation in the odorant receptor OR2J3 is associated with the ability to detect the "grassy" smelling odor, cis-3-hexen-1-ol. Chem Senses. 2012;37(7):585-93.

Melcher JM, Schooler, J.W. The misremembrance of wines past: Verbal and perceptual expertise differentially mediate verbal overshadowing of taste memory. J Mem Lang. 1996; 35(2):231-45.

Miller IJ Jr, Reedy FE Jr. Variations in human taste bud density and taste intensity perception. Physiol Behav. 1990;47(6):1213-9.

Mojet J, Heidema J, Christ-Hazelhof E. Taste perception with age: generic or specific losses in supra-threshold intensities of five taste qualities? Chem Senses. 2003;28(5):397-413.

Mombaerts P. Genes and ligands for odorant, vomeronasal and taste receptors. Nat Rev Neurosci. 2004;5:263-78.

Mombaerts P. Seven-transmembrane proteins as odorant and chemosensory receptors. Science. 1999;286:707-11.

Morrot G, Brochet F, Dubourdieu D. The color of odors. Brain Lang. 2001;79(2):309-20.

Nathans J, Piantanida TP, Eddy RL, Shows TB, Hogness DS. Molecular genetics of inherited variation in human color vision. Science. 1986;232:203-10.

Nelson G, Chandrashekar J, Hoon MA, Feng L, Zhao G, Ryba NJ, et al. An amino-acid taste receptor.Nature. 2002;416:199-202.

Nelson G, Hoon MA, Chandrashekar J, Zhang Y, Ryba NJ, Zuker CS. Mammalian sweet taste receptors. Cell. 2001;106:381-90.

Nobel Foundation. Nobel Prize. [cited 2014 Mar]. Available from: http://www.nobelprize.org/nobel_prizes/medicine/laureates/

O'Doherty J, Rolls ET, Francis S, Bowtell R, McGlone F. Representation of pleasant and aversive taste in the human brain. J Neurophysiol. 200;85(3):1315-21.

Okamoto M, Wada Y, Yamaguchi Y, Kimura A, Dan H, Masuda T, Singh AK, Clowney L, Dan I. Influences of food-name labels on perceived tastes. Chem Senses. 2009;34(3):187-94.

Österbauer RA, Matthews PM, Jenkinson M, Beckmann CF, Hansen PC, Calvert GA. Color of scents: chromatic stimuli modulate odor responses in the human brain. J Neurophysiol. 2005;93(6):3434-41.

Pagès J. Collection and analysis of perceived product interdistances using multiple factor analysis: application to the study of 10 white wines from the Loire Valley. Food Qual Prefer. 2005;16(7):642-9.

Parr WV, Heatherbell D, White KG. Demystifying wine expertise: olfactory threshold, perceptual skill and semantic memory in expert and novice wine judges. Chem Senses. 2002;27(8):747-55.

Parr WV, White KG, Heatherbell DA. The nose knows: Influence of colour on perception of wine aroma. J Wine Res. 2003;14(2-3):79-101.

Pelosi P. Odorant-binding proteins.Crit Rev Biochem Mol Biol. 1994;29:199-228.

Pérez-Prieto LJ, López-Roca JM, Gómez-Plaza E. Differences in major volatile compounds of red wines according to storage length and storage conditions. J Food Comp Anal.2003; 16:697-705.

Perrin L, Symoneaux R, Maître I, Asselin C, Jourjon F, Pagès J. Comparison of three sensory methods for use with the Napping® procedure: Case of ten wines from Loire valley. Food Qual Prefer. 2008; 19(1):1-11.

Peynaud E, Blouin J. *O gosto do vinho*. São Paulo: Martins Fontes; 2010.

Pickering GJ, Simunkova K, DiBattista D. Intensity of taste and astringency sensations elicited by red wines is associated with sensitivity to PROP (6-n-propylthiouracil. Food Qual Prefer. 2004;15(2):147-54.

Polásková P, Herszage J, Ebeler SE. Wine flavor: chemistry in a glass. Chem Soc Rev. 2008;37(11):2478-89.

Prescott J, Norris L, Kunst M, Kim S. Estimating a ''consumer rejection threshold'' for cork taint in white wine. Food Qual Prefer. 2005;16(4):345-9.

Purves D, Augustine GJ, Fitzpatrick D, Hall WC, Lamantia AS, Mcnamara JO, editors. Vision: the eye. In:_______. *Neuroscience*. 3nd ed. Sunderland, MA: Sinauer Associates; 2004. p.229-58. Available from: http://www.cns.iisc.ernet.in/ns201_13/books/Neuroscience_Purves.pdf.

Purves D, Augustine GJ, Fitzpatrick D, Hall WC, Lamantia AS, Mcnamara JO, editors. Central visual pathways. In:_______. *Neuroscience*. 3nd ed. Sunderland, MA: Sinauer Associates; 2004. p.259-82. Available from: http://www.cns.iisc.ernet.in/ns201_13/books/Neuroscience_Purves.pdf.

Purves D, Augustine GJ, Fitzpatrick D, Hall WC, Lamantia AS, Mcnamara JO, editors. The chemicals senses. In:_______. *Neuroscience*. 3nd ed. Sunderland, MA: Sinauer Associates; 2004. p.337-67. [cited 2013 Dec]. http://www.cns.iisc.ernet.in/ns201_13/books/Neuroscience_Purves.pdf.

Qian M, Fang Y. Development of aroma compounds in Pinot noir grapes and their relative importance in wine (Year 1). [cited 2014 Jan]. Available from: http://owri.oregonstate.edu/sites/owri.org/files/documents/Wine_Progress_Reports/2002-03/Development%20of%20aroma%20compounds%20in%20Pinot%20noir%20Grapes%20and%20their%20Relative%20Importance%20in%20Wine%20(Year%201).pdf.

Quandt RE. On wine bullshit: some new software? J Wine Econom. 2007. 2(2): 129-35. Available from: http://www.wine-economics.org/journal/details-content/volume-2-2007-no-2/

Reed DR, Bachmanov AA, Beauchamp GK, Tordoff MG, Price RA. Heritable variation in food preferences and their contribution to obesity. Behav Genet. 1997;27(4):373-87.

Rentzsch M, Wilkens A and Winterhalter P. Non-flavonoid phenolic compounds. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p:509-27.

Jackson RS. Chemical constituents of grapes and wine. In:_______. *Wine science: principles, practice, perception*. 2nd ed. Burlington, MA: Academic Press; 2000. p.232-75.

Robinson J. *Confissões de uma amante de vinhos*. São Paulo: DBA Artes Gráficas; 2008. p.259.

Rolls ET, Baylis LL. Gustatory, olfactory, and visual convergence within the primate orbitofrontal cortex. J Neurosci. 1994;14:5437-52.

Santos-Buelga C, de Freitas V. Influence of phenolics on wine organoleptic properties. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p:529-70

Sanz ML, Martínez-Castro I. Carbohydrates. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p:231-48.

Shipley MT1, Ennis M. Functional organization of olfactory system. J Neurobiol. 1996;30:123-76.

Silva JA, Rozestraten RJA. Manual prático de psicofísica. [cited 2014 Jan]. Available from: pge3.wikispaces.com/file/view/manual+de+psicofisica.pdf.

Small DM, Prescott J. Odor/taste integration and the perception of flavor.Exp Brain Res. 2005;166(3-4):345-57.

Small DM, Voss J, Mak YE, Simmons KB, Parrish T, Gitelman D. Experience-dependent neural integration of taste and smell in the human brain. J Neurophysiol. 2004;92(3):1892-903.

Storchmann K, Mitterling A, Lee A. The detrimental effect of expert opinion on price-quality dispersion evidence from the wine market.AAWE Working Paper. Economics. 2012; 118. [cited 2013 Dec]. Available from: http://www.wine-economics.org/aawe/wp-content/uploads/2012/10/AAWE_WP118.pdf.

Sulmont-Rossé C, Issanchou S, Köster EP, Burnham D, Skilleås OM. You'll never drink alone: wine tasting and aesthetic practice. In: Alloff F, editor. *Wine and philosophy: a symposium on thinking and drinking*. Malden, MA: Blackwell Publishing; 2008. p.157-71.

Sulmont-Rossé C, Issanchou S, Köster EP. Odor naming methodology: correct identification with multiple-choice versus repeatable identification in a free task. Chem Senses. 2005;30(1):23-7.

Ugliano M, Henschke PA. Yeasts and wine flavour. In: Moreno-Arribas MV, Polo MC, editors. *Wine chemistry and biochemistry*. New York: Springer; 2009. p.313-92.

van der Merwe CA, van Wyk CJ. The contribution of some fermentation products to the odor of dry white wines. Am J Enol Vitic. 1981; 32:41-6.

Vilis T. The Physiology of the Senses Lecture 1: The eye. In:_______. *The Physiology of the Senses: transformations for perception and action* [Online Course; Revised 16/08/2012]. Available from: http://www.tutis.ca/Senses/L1Eye/L1Eye.pdf.

Villamor RR. The impact of wine components on the chemical and sensory properties of wines [dissertation]. Washington, DC: Washington State University; 2012. [cited Mar 2013]. Available from: http://research.wsulibs.wsu.edu/xmlui/bitstream/handle/2376/4103/Villamor_wsu_0251E_10425.pdf?sequence=1.

von Békésy G. Olfactory analogue to directional J Appl Physiol. 1964;19:369-73.

von Békésy G. The effect of adaptation of the taste threshold observed with a semiautomatic gustometer. J Gen Physiol. 1965;48:481-8.

Waterhouse AL. Wine phenolics. Ann N Y Acad Sci. 2002;957:21-36.

Wittwer G, Rothfield J. Projecting the world wine market from 2003 to 2010. Australas Agribus Rev. 2005; 13:paper 21. [cited 2013 Dec]. Available from: http://www.agrifood.info/review/2005/Wittwer_Rothfield.html.

Zatorre RJ. Processing of olfactory affective information: contribution of functional imaging studies. In: Rouby C, Schaal B, Dubois D, Gervais R, Holley A, editors. *Olfaction, taste, and cognition*. Cambridge, UK: Cambridge University Press; 2002. p.324-34.

Zellner DA, Bartoli AM, Eckard R. Influence of color on odor identification and liking ratings. Am J Psychol. 1991;104(4):547-61.

Zellner DA, Kautz MA. Color affects perceived odor intensity. J Exp Psychol Hum Percept Perform. 1990;16(2):391-7.

Zhang Y, Hoon MA, Chandrashekar J, Mueller KL, Cook B, Wu D, Zuker CS, Ryba NJ. Coding of sweet, bitter, and umami tastes: different receptor cells sharing similar signaling pathways. Cell. 2003;112:293-301.