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Introductory Chapter: Generation of Aromas and Flavours

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1. The theme

Flavour results in the presence, within the complex matrices, of many volatile and non-volatile components that present different physicochemical properties. While the non-volatile compounds contribute essentially to the taste sensations, the volatile ones influence both taste and aroma in an extraordinary sensation that we call flavour. A vast number of compounds are responsible for the aroma of the food products, such as aldehydes, esters, alcohols, methyl ketones, lactones, phenolic compounds, dicarbonyls, short- and medium-chain free fatty acids and sulphur compounds. So, aromas and flavours play an important role in the quality of food. According to the Regulation (Ec) No. 1334/2008 of the European Parliament and of the Council of 16 December 2008 [1], *“Flavourings are used to improve or modify the odour and/or taste of foods for the benefit of the consumer. Flavourings and food ingredients with flavouring properties should only be used if they fulfill the criteria laid down in this Regulation. They must be safe when used, and certain flavourings should, therefore, undergo a risk assessment before they can be permitted in food. Where possible, attention should be focused on whether or not the use of certain flavourings could have any negative consequences on vulnerable groups. The use of flavourings must not mislead the consumer and their presence in food should, therefore, always be indicated by appropriate labeling. Flavourings should, in particular, not be used in a way as to mislead the consumer about issues related to, amongst other things, the nature, freshness, quality of ingredients used; the naturalness of a product or of the production process, or the nutritional quality of the product. The approval of flavourings should also take into account other factors relevant to the matter under consideration including societal, economic, traditional, ethical and environmental factors, the precautionary principle and the feasibility of controls”*.

Flavours and fragrances are produced through chemical synthesis and microbial biocatalysis or by extraction from plant and animal sources. In recent times, due to consumer's increased interest and health consciousness in natural products, the use of fragrances and flavours

obtained from natural sources has increased; moreover, the chemical synthesis is not desirable as this is not eco-friendly. So, in the food industry, natural ingredients are added to the preparations for efficiency, softness or emotional appeal [2]. For instance, vanillin is a distinctive flavour chemical present in *Vanilla planifolia* beans. Chemically, its name/formula is 4-hydroxy-3-methoxybenzaldehyde. Extracting vanillin flavour from vanilla beans is expensive; however, this flavour compound can also be produced as an intermediate in the microbial degradation of several substrates such as ferulic acid, phenolic stilbenes, lignin, eugenol and isoeugenol. Several microorganisms such as *Pseudomonas putida*, *Corynebacterium* sp., *Arthrobacter globiformis*, *Serratia marcescens* and *Aspergillus niger* are capable of converting eugenol and isoeugenol from essential oils into vanillin [3]. This fragrance can also be extracted, in the form of acetanilide to produce natural vanilla flavour, from the castor sacs of beavers [4] (**Figure 1**).

Microbial biocatalysis [*de novo* microbial processes (fermentation) or bioconversions of natural precursors using microbial cells or enzymes (biocatalysis)] is used in the commercial production of many flavour and fragrance chemicals. This biotechnology can be exploited to obtain both complex flavours—mixtures and individual flavour compounds; many different classes of compounds can be obtained this way including ketones, lactones, esters, aldehydes and acids [5]. Thirty years ago works have been published about the use of microorganisms to achieve desired flavours in foods, for example, cheese [5, 6]. Microbiologists and *flavourists* are exploiting the metabolic action of microorganisms to improve and modify the taste, aroma and flavour of alcoholic beverages, cheese, yogurt, bread, fruit and vegetable products.

Though for a multitude of microorganisms, the metabolic potential for *de novo* flavour biosynthesis is huge, and an extensive variety of products can be detected in microbial culture media; however, in nature, their concentration is too low for commercial applications [7]. Moreover, metabolic diversity can lead to a wide product spectrum of closely related compounds. So, the biocatalytic conversion of a structurally related precursor molecule is the strategy, which permits the accumulation of a desired flavour product to be significantly enriched. A prerequisite for this strategy is that the precursor must be present in nature, and its isolation can be possible in an economically viable way.

Another huge problem during bioprocess development is the cytotoxicity of the flavour compounds and of their precursors. According to Dubal et al. [7], *in situ* product recovery or sequential feeding of small amounts of the precursor is essential to improve the overall performance of a bioprocess. Flavour compounds are mainly hydrophobic and bound preferentially to lipid structures, like cellular membranes, which make them the main target for product accumulation during microbial processes. Still, microbial processes offer possibilities for biocatalysis that cannot always be possible by using isolated enzymes. The cellular environment, namely the cell wall, and intracellular pH protect the protein that may lead to improved catalyst stability [8].

Plant and animal sources are also an important source of bioflavours. One major disadvantage is that these bioactive compounds are present in a very small quantity, making their isolation and formulation very expensive. Moreover, aroma and flavour, like for many quality attributes of fresh and processed fruits and vegetables, are affected by the culture, cultivar selection of the plant material prior to consumption-production and postharvest processes that affect the physiology of the plant [9]. Additionally, thermally generated flavours are also

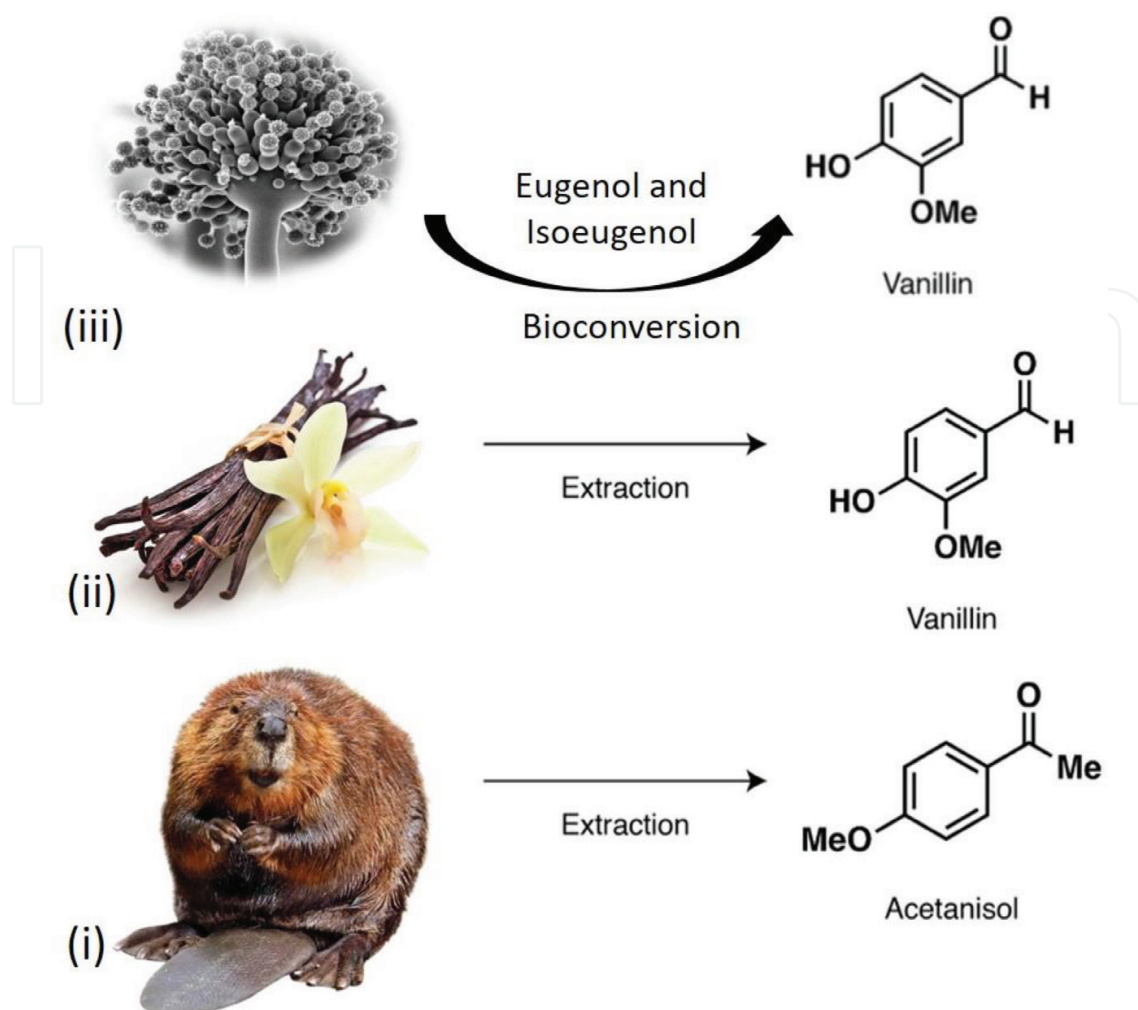


Figure 1. Schematic representation of several ways to obtain vanillin or vanillin-like flavour: (i) acetanisole from the castor sacs of beavers, to produce natural vanilla flavour, (ii) vanilla beans and (iii) bioconversion through microbial degradation of eugenol and isoeugenol by the fungus *Aspergillus niger*.

a relevant horticultural topic once the flavours of most horticultural food products are generated during cooking or thermal processing [10].

Coming from plants, spices play a major role in the global flavours and food industry. The global spice industry amounts to over 1.1 million tons and accounts for US\$ 3.475 billion in value [11]. According to Sarma et al. [11], Brazil, China, India, Indonesia, Madagascar, Malaysia, Spain, Sri Lanka and Vietnam are the major producers, and the USA, the European Union, Japan, Singapore and Saudi Arabia are the major consumers of spices around the world. Black pepper, cardamom, ginger, turmeric, cinnamon, clove, nutmeg, tamarind and vanilla constitute the major spices; in addition, spices originated from seeds such as coriander, cumin, fennel, and fenugreek, and those originated from herbs such as saffron, lavender, thyme, oregano, celery and basil.

Among the huge number of volatiles found in nature, medium-sized 4- and 5-alkanolides and some carboxylic acid esters confer pleasant sensory impact attributes, such as fruity, floral,

spicy, creamy and nutty to foods, drinks and perfumed/flavoured articles such as toothpaste, fragrances and perfumes [12]. The first synthesized-microbial compound to be introduced in the European market, at a market price of around EUR 10,000 per kg, was 4-decanolide. Nowadays, the driver of research for new and pleasant fragrances is a mixture of scientific and economic considerations. In addition, some flavour chemicals have shown to possess not only sensory properties but also other desirable properties such as anti-inflammatory properties (1,8-cineole) and others that put some flavours close to pharmaceuticals—antimicrobial and antioxidant (vanillin, essential oil constituents), antifungal and antiviral (some alkanolides), somatic fat reducing (nootkatone) and blood pressure regulating (2-[E]-hexenal) [12].

2. Flavour perception in humans

The most multisensory of our everyday experiences is the perception of flavour. According to Spence [13], complex multisensory interactions give rise to the flavour experiences that we all know and appreciate, indicating that we rely on the integration of cues from all of the human senses. Academic advances are now contributing for chefs and gastronomic professionals, of the food industry, increasingly taking the latest scientific findings and applying them in their food designs.

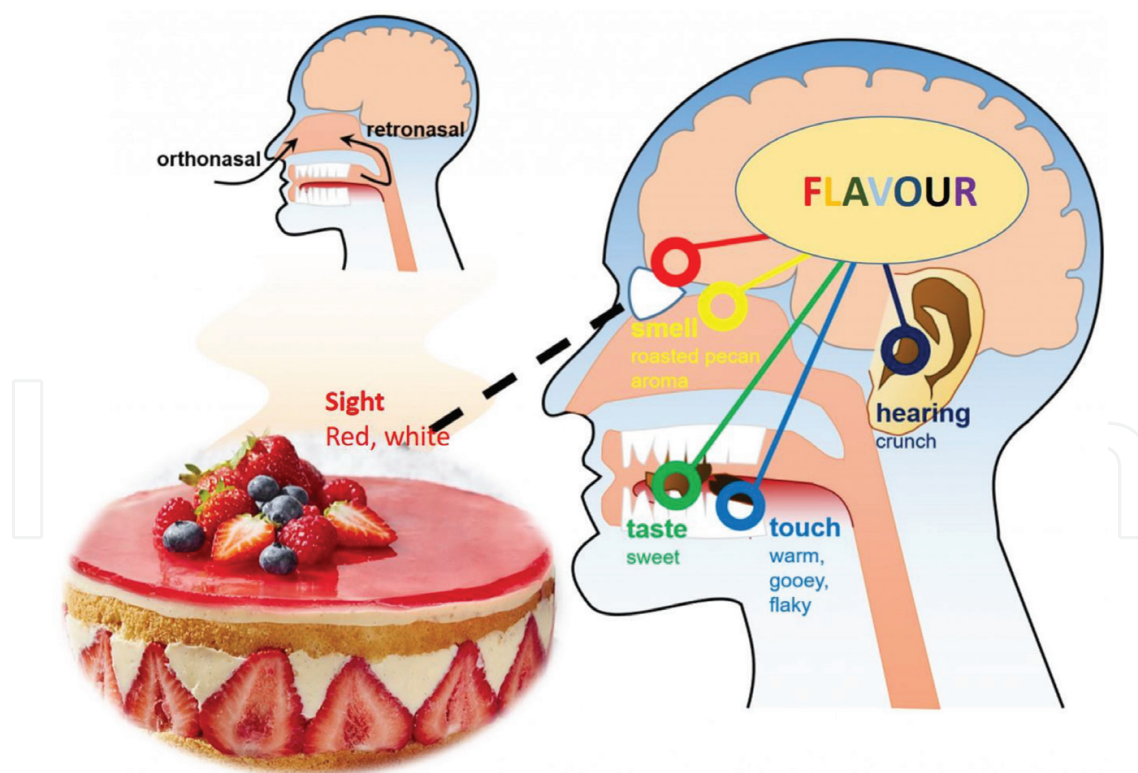


Figure 2. Man perception of flavour depends on the combined information from all five senses. The aroma of a strawberry cheesecake stimulates the odour-sensing cells through both orthonasal and retronasal ways. In addition, the red-white colour, sweet taste, gooey and chunky texture, and crunching sound of the cookies and the blueberries we hear as we bite into are all integrated into the brain to give the delicious flavour of the strawberry cheesecake. Image adapted from Kanwal and Wierbowski [19].

Flavour is the combination of taste, olfactory and oral texture inputs can be highly influenced by the sight of food and by cognitive descriptions and attention. This contribution shows how flavour is built by the appropriate combinations of these different sensory inputs and modulatory processes in the human brain [14]. Recent studies show that the primary taste cortex in the anterior insula provides separate and combined representations of the taste, temperature and texture of food in the mouth, independently of hunger, and thus of reward value and pleasantness [15].

Man is born with some flavour preferences, and most of them are acquired through experience. Pavlovian conditioning is an example of how man is able to acquire several preferences in terms of flavour, which becomes better liked through its association with an already enjoyed taste, nutritive content and positive post-ingestive effect [16]. Pavlovian conditioning is also the cause of “food craving”, which is elicited by signs predicting the intake of an appetising food [17]. For instance, in order to perceive the food by the taste or olfactory receptors, aroma and taste components must be released in the saliva, which depends on the food matrix composition and structure and on the masticatory behaviour. Aroma compounds have then to be transported from the oral to the nasal cavity [18]. So, it is the retronasal aromas that are combined with gustatory cues to give rise to flavours. On top of these two senses, trigeminal inputs also contribute to flavour perception [13] (**Figure 2**).

3. Final remarks

Human capability to select and consume safe and nutritious foods is vital. This ability is carried out by the sensory systems of the mouth and nose, which together give rise to the flavour of foods. So, flavour corresponds to the combined effect of taste, aromatics and chemical feelings suggested by food in the mouth. Flavour is a crucial determinant of food intake and consumption, conditioning the act of “buying food”.

Currently, the majority of the aromatic compounds used in the industry (beverages, food, feed, pharmaceutical, etc.) are extracted from synthetic or natural source of plants. However, recent advances, namely in metabolic engineering, have created a huge interest for natural products, particularly in the aroma and flavour industries, seeking new methods to obtain fragrance and flavour compounds naturally, allowing to obtain safe, nutritious and flavourish foods and drinks.

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