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SOURCE AND PROPERTIES OF VARIOUS NATURAL FLAVOR: A REVIEW

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Abstract

Natural flavors are essential in the food and beverage industry, enhancing taste and aroma without artificial additives. This review explores the sources and properties of various natural flavors derived from plants, fruits, spices, and herbs. The paper discusses extraction methods, such as steam distillation, cold pressing, and solvent extraction, highlighting their impact on flavor profiles and quality. It also examines the chemical components responsible for distinct flavors, such as terpenes, esters, and aldehydes, and their interactions in complex flavor systems. Understanding these aspects is crucial for optimizing flavor formulations and ensuring consistency in product development.

Keywords: Natural flavors, extraction methods, terpenes, esters, aldehydes, flavor profiles, food industry.

Introduction

The natural flavor is the sensory impression of a food or other substance and is resulted from the stimulation of the chemical senses of taste and smell. The "trigeminal senses", are detected in regions of the tongue, mouth, and throat, may also occasionally determine flavor.[1,2] Of the three chemical senses, the smell is the main determinant of a food item's flavor. While people have receptors for basic kinds of tastes; sweet, sour, bitter, salty, umami, the smells of a food are potentially limitless. The flavor of the food, as such, can be easily altered by changing its smell while keeping its taste similar.

The human sense of smell is triggered by small, non-polar to medium polar molecules which dock onto receptor proteins of the olfactory epithelium. They signal freshness, quality and authenticity of a food, hence guiding our choice of food. Natural flavor from plant sources occur as complex mixtures with very different, generally low to ultra-trace concentrations, and this is not their only disadvantage. Traditional agriculture suffers from much imponderability. Chemical synthesis seems to be an immediate alternative, but the resulting products must not carry the label 'natural' which, although scientifically unfounded, is preferred by the consumer. According to effective European law (EG 1334/2008) a 'natural flavouring substance' shall mean a compound 'obtained by appropriate physical, enzymatic or microbiological processes from material of vegetable, animal or microbiological origin'. In the US, the Code of Federal Regulation (CFR — Title 21) of the FDA contains a similar definition including the terms 'enzymolysis' and 'fermentation'.

A natural flavor is a combination of naturally derived aroma chemicals and/or essential oils. Natural flavors are very often added to food stuff to enhance the taste of products while avoiding the consistency problems involved with using fruit or other whole flavoring ingredients. Furthermore, adding whole flavoring ingredients like fruit can be extremely costly and is limited by its seasonal availability. All food containing added natural flavors must carry the label declaration "natural flavors/aroma" among the ingredients. To better understand what flavors are and where do they come from, in this section an overview of how flavors are generated will be given, along with some structural and chemical characteristic of the specific flavoring compounds.

Fruit flavorings are mainly generated during ripening process and are produced by secondary metabolism and by the catabolism of small quantities of carbohydrates, lipids and amino acids. Also vegetables flavors are produced essentially by catabolic process but most of these are not due to ripening rather to manipulation.

The natural flavor is the entire range of sensations that people perceive when they eat food or drink a beverage. Flavor encompasses a substance's taste, smell, and any physical traits they perceive While flavor enhancers are compounds that do not have a distinct flavor of their own, added to a wide range of foods to supplement, bring out, or enhance their natural flavor There are hundreds of varieties of flavorings used in a wide variety of foods, from simple food products to complex food applications. They are classified into three major categories used in food under definition agreed in Australia; natural flavoring substances, natural identical flavoring substances, and artificial flavoring substances.[3] Flavor plays an important role in consumer satisfaction and influences further consumption of foods.[4] Flavor, of course, is nearly inseparable from other product attributes such as texture, sweetness, acidity, salt, and appearance so it all gets bundled to most consumers as "taste.[5]

Many factors linked to aroma affect the overall quality of the food. Since processing or cooking conditions, storage, packaging, and ingredients in food often cause modifications in overall flavor by reducing their intensity or producing off-flavor components, the stability of flavors is an important criterion to preserve the properties of foods so the industry devotes a lot of money to research and development for the enhancement and preservation of flavors, as which are delicate and volatile. It is beneficial to encapsulate various food to preserve the flavor's volatile ingredients, where it is limit aroma degradation or loss during processing and storage.[6]

Flavors and fragrances are generally extracted from aromatic plants since times immemorial. The composition of flavor compounds from plant sources range from single to complex substances. Their chemical compounds are elucidated by the modern sophisticated techniques like mass spectroscopy and NMR and followed by production on industrial scale suing chemical synthesis. Flavors are generally used as food additives and they are mostly produced through artificial means i.e. chemical synthesis or by extraction from plant sources. Recently due to consumer's increased interest and health awareness in natural products, there has been more stress towards the use of flavors and fragrances obtained from natural sources. microbes can be used to produce aroma and fragrance compounds which can be labeled "natural". Man is using microbial systems from ages to develop aroma to fermented products like beer, wine, cheese etc. from ages. Vanillin (1874) and coumarin (1868) were the first synthetic flavor and fragrance compounds made available for use in the food industry. The worldwide demand of flavors and fragrances was estimated to be US$ 16 billion in the year 2013. Most of these flavoring and fragrance compounds are prepared by chemical synthesis and only a small fraction of the demand are met from plant or through microbial sources.[7]

These compounds represent a wide variety of chemical classes including hydrocarbons, alcohols, aldehydes, ketones, acids, esters or lactones, all of which are used as food flavoring additives. The methods for obtaining aroma compounds include the direct extraction from aromatic plants, chemical transformations and biotechnological transformations (which include microbial and enzymatic biotransformations, de novo synthesis and the use of genetic engineering tools).[8]

1. Definition of Biotechnology:

Biotechnology is defined as: the use of living systems for the production of useful products. These systems may be plants, animals, microbes or any other parts of their organisms. According to this definition, the biotechnological methods for production of flavor and fragrance compounds include:

1- whole microbial cell,

2- Utilization of microbial pure isolated enzymes

3- Plant cell and tissue culture

4- Genetic engineering of an already existing aromatic plant.

At the moment, the whole cell microbial processes seem to be the most promising for the production of pure aroma and flavor compounds or complex mixtures of them.

In principle there are two kinds of biotechnological aroma production:

a- de novo synthesis and

b- Biotransformation/bioconversion.

De novo synthesis implies the production of aroma compounds using simple cultivation media without any special additions (Fig.1). On the other hand, biotransformation/bioconversion refers to the synthesis of one or several aroma substances by adding precursors of the products to the cultivation media. While de novo synthesis uses the metabolic spectrum of the microorganisms and there fore in general produces a mixture of several aroma compounds, the biotransformation/bioconversion leads to one major product, which is produced by one (biotransformation) or several (bioconversion) biochemical steps.[9]

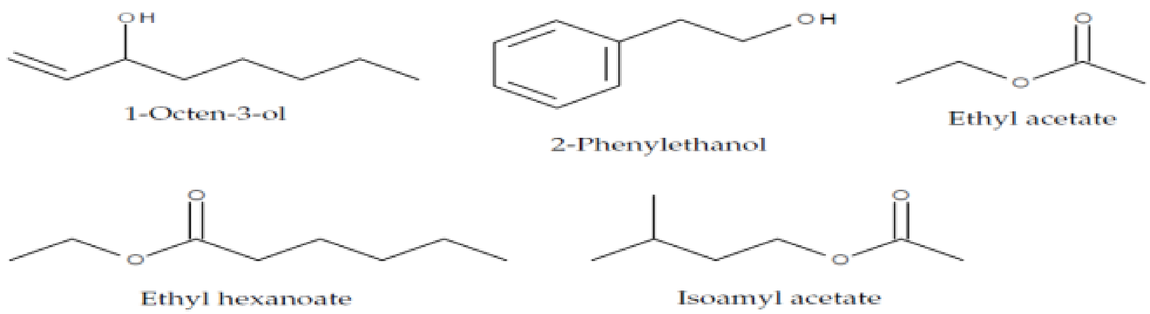

Fig.1. Structure of some bioflavors obtained by de novo synthesis.

2. Reasons for adding flavorings to food products:

Flavorings are added to foods in very small amounts, for various reasons, but mainly to create a character in something bland; for example, chewing gum would taste like rubber without flavor, and hard candy would taste like plain sugar or to create a specific flavor to food products that do not have the desired flavors, such as a soft drink, candies, snacks, and yogurt, or altering or enhancing the flavors lost during food processing of natural food product such as meats and vegetables.[10] For example, pea protein has a tough aftertaste to mask, so flavor ingredients are often needed there.

3. Flavors and fragrances: types and synthesis

Flavors and fragrances are broadly divided into two categories: natural and nature-identical. Natural flavors are prepared by extraction from plants or by enzymatic or microbial processes, and nature-identical flavors and fragrances are synthesized chemically or by conversions of natural substrates. The natural flavors are produced either by de novo synthesis using microbes or plants or through single-step biotransformation of natural substrates by microbes or their enzymes or plant cells (e.g. synthesis of nootkatone using citrus cell cultures). In de novo synthesis, microbes transform carbon or nitrogen compounds into flavor molecules with the help of enzymes such as lipases, proteases, nucleases and some glycosidases. These enzymes are extensively used in industry for the synthesis of flavoring compounds as they catalyze single-step 2 transformations of substrates into natural flavor molecules. Furthermore, microbiological or enzyme based processes have also been developed where complex substrates such as lignin, phenyl-propanoids and phenolic stilbenes are converted to the desired flavors and fragrances.[11]

4. Natural flavors

United States Code of Federal Regulations (1985) and European Communities (1988) legislations have meant that 'natural' flavor substances can only be prepared either by physical processes (extraction from natural sources) or by enzymatic or microbial processes, which involve precursors isolated from nature (Fig.2). This classification created a dichotomy in the market because compounds labeled 'natural'

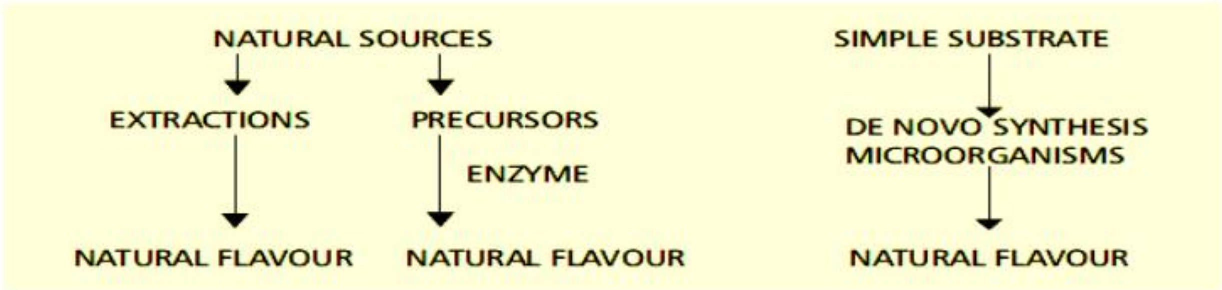

Fig.2: The three pathways for the preparation of 'natural' flavors. The first two involve the extraction of the flavor or precursors from natural sources.The last method is the de novo synthesis of the flavor by microorganisms growing on simple substrates such as glucose and sucrose.

Become profitable products whereas other flavors that occur in nature but are produced by chemical methods must be called 'nature-identical' and are less appreciated by consumers. These differences have stimulated much research aimed at developing new biotechnological processes for these flavoring compounds. The 'natural' routes for flavor production are the bioconversions of natural precursors using biocatalysis, de novo synthesis (fermentation) and isolation from plants and animals. Although from the chemist's point of view there is no difference between a compound synthesized in nature and the identical molecule produced in the laboratory, the price of a flavor sold as natural is often significantly higher than a similar one prepared by chemical synthesis. For example, vanillin (Fig.3, compound 1) is the most important flavor in terms of consumption levels.[12] This compound occurs in the pods of tropical Vanilla orchids (mostly Vanilla planifolia) at levels of 2% by weight, but less than 1% of the global market is covered by the extracted compound. The value of vanillin extracted from pods is variously calculated as being between US$1200/kg and US$4000/kg, whereas the price of synthetic vanillin, that is vanillin prepared mainly from guaiacol, is less than US$15/kg. Therefore, several biotechnological processes for natural vanillin production have recently been developed including the bioconversion of lignin, phenylpropanoids (ferulic acid, eugenol, isoeugenol) and phenolic stilbenes (isorhapontin) in addition to the de novo biosynthesis.

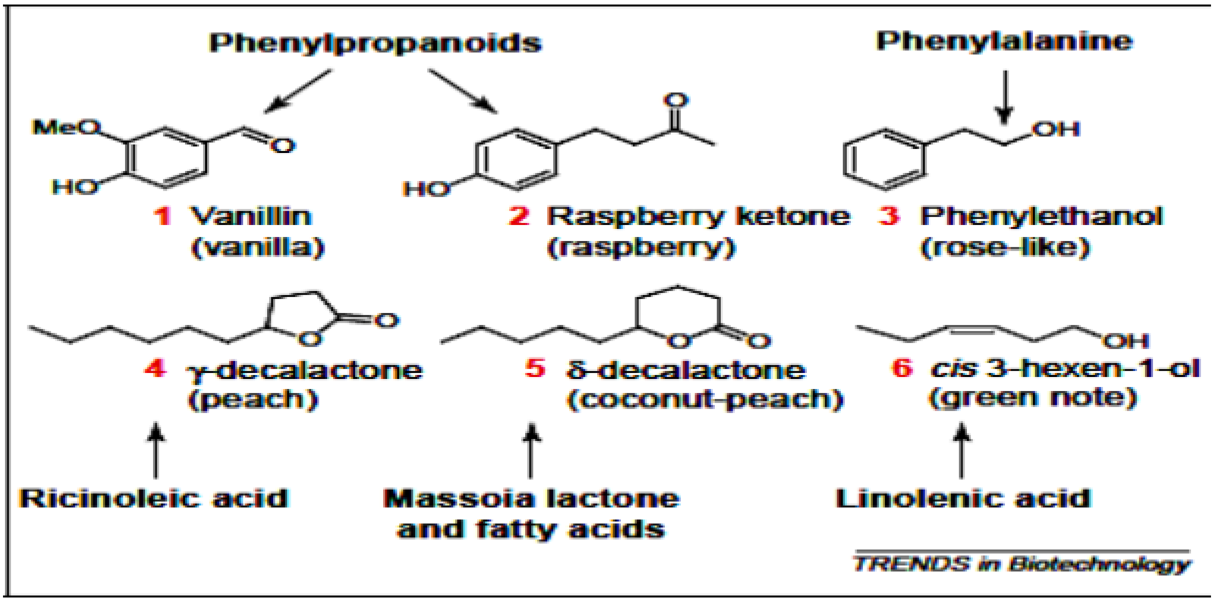

Fig.3: Examples of some relevant natural flavors prepared by biotransformation.

Similarly, raspberry ketone (Fig.3, compound 2) and 2-phenylethanol (Fig.3, compound 3) are phenylpropanoids used in industries as flavors and/or fragrance ingredients. Compound 2 is the key flavor molecule of raspberries in which it occurs in trace amounts (4 mg of ketone from 1 kg of berries). Compound 3 has a rose-like odor and occurs in fermented foodstuffs and in many essential oils. For both compounds extraction is unsuitable and their main mode of production is the bioconversion of some natural precursors.[13] 4-(4-hydroxyphenyl) butan-2-ol (betuligenol), its O-glucoside (betuloside) and 4-hydroxybenzalacetone are possible precursors for biotechnological production of raspberry ketone performed by oxidation of the secondary alcohol of the first two compounds and by double bond saturation of the third, using different microbial systems.[14] In the context of biogeneration of raspberry ketone in the fungus Beauveria bassiana, it emerged that odour inactivation of compound (2) occurs through Baeyer-Villiger oxidation to tyrosol. Moreover, 2-phenylethanol (3) and its acetate are currently produced by yeast degradation of natural L-phenylalanine.[15]

Lactones (Fig. 3, compounds 4, 5) and cis-3-hexenol (Fig. 2, compound 6) are also natural flavors produced at the industrial scale. Compounds (4-5) and analogues with up to twelve carbon atoms are widespread in fermented food, milk products and in a variety of fruits in minute amounts. Some of these materials are manufactured by degradation, via b-oxidation, of natural hydroxy-fatty acids. Specifically, the γ-decalactone (compound 4) is obtained by chain shortening of C-18 ricinoleic acid (from castor oil) by different microorganisms. Improvement of the processes caused the selling price of compound (4) to decrease from US$ 12000/kg in 1986 to US$ 500/kg in 1998.[16] Similarly, some precious γ-lactones containing an odd number of carbon atoms are accessible by degradation of natural hydroxy acids. Interestingly, δdecalactone (5) can be obtained by natural modification either by oxidation of hydroxy-fatty acids or by enzymic reduction of the α-β-unsaturated compound (massoia lactone) the main component of massoi bark oil.[17] Linolenic acid is the natural precursor of cis-3-hexen-1-ol (leaf alcohol) (Fig. 3, compound 6). This compound has an odour of freshly cut grass and is essential for obtaining the 'green' organoleptic note in many formulations. The 'green notes' obtainable by distilling plant oil are expensive and different biotransformations were developed. The lipoxygenase- and hydroperoxide lyase-mediated oxidation of linolenic and linoleic acid produce cis-3-hexen-1-al and hexen-1-al, which can be reduced by yeast to the corresponding alcohols. Additionally, n-hexanol is easily accessible by microbial reduction of the carboxylic group of extractive C-6 caproic acid.[18]

Many biocatalytic processes for other attractive flavors have recently been described. In spite of this the number of industrial applications is limited and the cases illustrated above are the more promising ones. Moreover, an additional problem in this area is the occurrence of adulterations with readily available 'natureidentical' products. The achievement of new analytical methods for discriminating between natural and nature-identical flavors has become essential.[19] Different studies based on stable isotope characterization of aroma have showed promising results and are now applied by specialized laboratories to prove authenticity.[20]

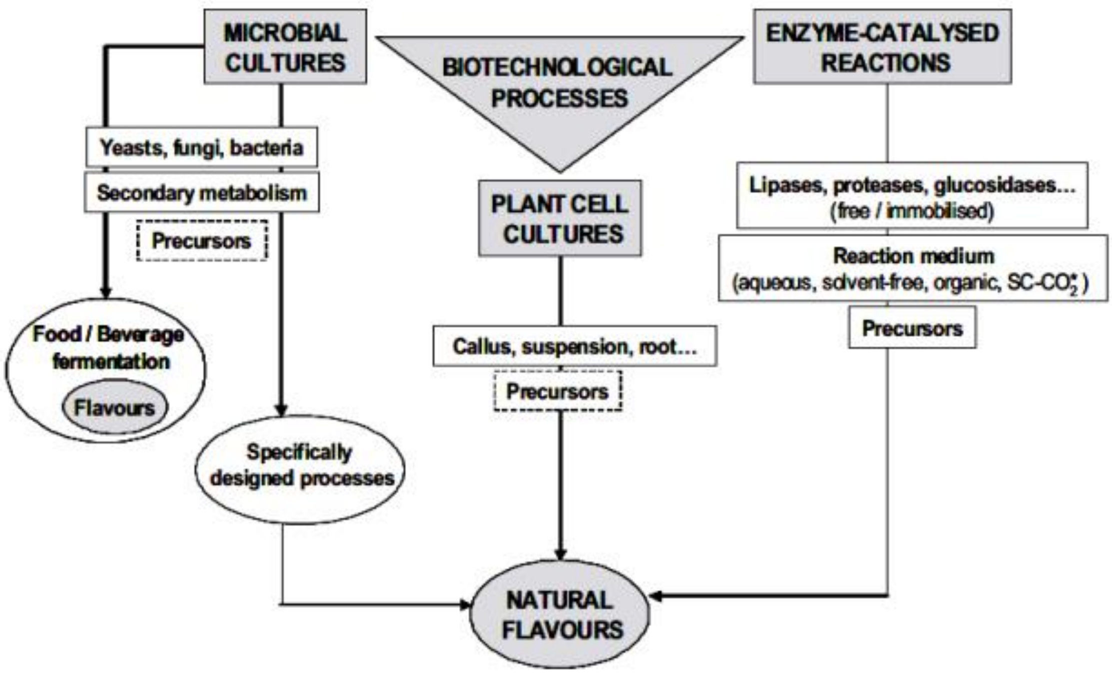

Fig.4: Biotechnological processes for the production of flavor compounds *SC-CO2: supercritical carbon dioxide

5. How do I know if my food contains flavorings:

When flavorings are added to food, they will appear in the list of ingredients as a flavoring or a more specific description. Flavorings are generally added at between 0.1-2% of the food and are most commonly found in beverages, dairy products, confectionery, savory snacks, and health and wellness products. Flavorings are not assigned E numbers.[21]

6. Classification of food flavors:

There are three major classifications of food flavorings which are based on their origin: Natural flavoring substances Nature produces countless flavoring substances which provide a broad array of tastes and aromas in food. Natural flavorings are obtained from animals, fruits, spices, herbs, as well as those derived from vegetables and wine, by physical, or enzymatic processes or microbial fermentation (CIAA, 2008).

CIAA GUIDELINES on Regulation (EC) No. 1334/2008 on flavorings and certain food ingredients with flavoring properties for use in and on foods.

To prepare a natural flavor, the aroma chemicals must be extracted from the source substance; e.g., a natural strawberry must come from a strawberry plant – berry, leaf, or stem. Some flavorings are produced from essential oils, such as almonds and lemon. The methods of extraction can involve extrusion, solvent extraction, or distillation; e.g., menthol obtained by fractionated distillation from mint oil. Limonene is obtained by steam distillation from oranges. Vanilla; from fresh fruits by expression; flavor from ginger by extraction.[22] The extracts are then usually further purified and subsequently added to food products to flavor them. Table (1) shows some plant produce flavors while Table (2) shows principal flavoring agents in some foodstuff.

Table 1: Some plants produce flavors

Plant type	**Examples**
Herbs	Basil, Mint, Parsley, Celery, Thyme, etc.
Spices	Cardamon, Clove, Turmeric, Peppercorns, etc.
Aromatic Seeds	Aniseed, Cumin, Fennel, Dill, Caraway, etc.
Fruits	Orange, Lemon, Apple, Banana, Strawberry, Pineapple, etc.
Vegetables	Onions, Garlic, Mushrooms, Corn, Peas, Cabbage, Turnips, etc.

Table 2: Principal flavoring agent in some foodstuff

Foodstuff	Principal flavoring agent
Mint	Menthol
Thyme	Thymol

Cloves	Eugenol
Pepper	Piperidine
Lemon	Citral
Garlic	Diallyl disulfide
Turmeric	Curcumin

7. Natural identical flavoring substances:

Due to the high cost or unavailability of natural flavor extracts, most commercial flavorants are nature-identical, which means that they are chemically and organoleptically identical to natural flavors, but they are obtained by chemical processes or by chemical modification of other natural substances (not extracted from the source materials). An example is vanillin, which is identical to vanilla but not obtained from vanilla pods. It is an organic compound contained in vanilla beans. It is one of the most flavorful and aromatic substances used in the food industry. flavor-guide.html). Table (3) illustrates the list of known nature-identical flavoring agents.

Table 3: The list of known nature-identical flavoring agents

Chemical	**Odor**
Diacetyl	Buttery
Isoamyl acetate	Banana
Cinnamic aldehyde	Cinnamon
Ethyl propionate	Fruity
Limonene	Orange
Ethyl-(E, Z)-2,4-decadienoate	Pear
Allyl hexanoate	Pineapple
Ethyl maltol	Sugar, Cotton candy
Methyl salicylate	Wintergreen
Benzaldehyde	Bitter almond
Methyl anthranilate	Grape
Ethylvanillin	Vanilla
Manzanate	Apple
2,4-Dithiapentane	Truffle

8. Natural Flavors in Food:

Natural and artificial flavors provide a very fascinating function in the food we consume. They add flavor, and most significantly, they ensure that food is more appealing for consumers to eat. Flavors have the ability to replace specific qualities of taste that have been absent during food processing, pasteurization and food storage. In the manufacturing industry, the addition of false flavor to juices is to ensure uniformity after being packaged. Flavors are used in food products as signature dishes to ensure that the food tastes the same when it is consumed globally. The main distinction between natural and artificial taste, is that natural flavors derive from natural sources.[23] This does not imply that a granola bar with blueberry is comprised of smashed blueberries, however, the granola bar consists of a chemical originally found in blueberries and is added to the food product in the laboratories. Purely human, on the other hand, makes artificial flavors. The distinction stems from the origin of molecules of taste, whether it is from a natural source, or refined in the laboratory or processed synthetically. All natural and artificial flavorings in food products can compromise between 60 to 100 ingredients, which does not indicate that all other ingredients are in the clear. A mixture often has a preservative or solvent that formulates up to 80-90% of the flavoring of the meat. The distinction between natural and artificial flavors eventually originates from microscopic differentiation. The quantity of preservatives and diluents in natural flavors is very restricted, to such a degree that it can be associated to any health effects, and that creates immense confusion and misleads consumers.[24] A study conducted at the Nutrition and Dietetics Academy is confident that natural or artificial flavors may induce food cravings.

It is crucial for consumers to have knowledge of ingredients in food products, in order to understand that any type of excess food will affect weight loss. Figure 5 clarifies the ingredients of natural and artificial compounds. Any material, natural or artificial, when consumed in excess, can be harmful to the body. Consumers need to understand that chemical flavors are controlled and food scientists use the allowed dosages in flavor creations.

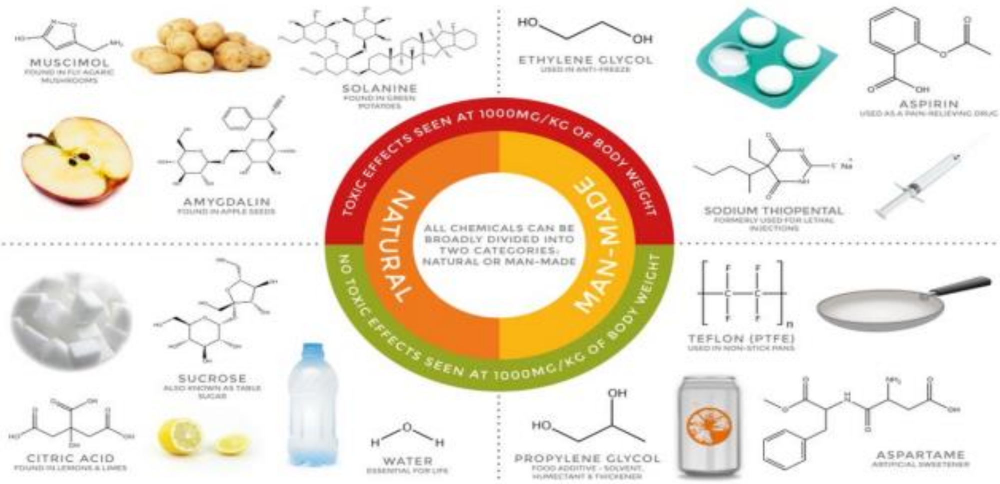

Figure 5: Natural versus artificial compounds.[25]

9. Quality Control in Flavor Analysis:

Product quality is defined as the structure of all features that distinguish separate units of a food product and have a value in regulating the degree of acceptability of that unit to the consumer.[26] Flavor industries seek to provide a reliable product of high quality for the consumer. Quality control plays a vital role in ensuring that this task has been fulfilled. Quality control in the flavor industries is distributed between two functions, the sensory analysis of the organoleptic evaluation and the analysis of the chemical and physical properties of a flavor. This is included in all the raw materials that are utilized in the flavor of the end product.

10. Sensory Analysis:

Sensory analysis in the flavor field is separated into two sections, affective and analytical measurements. Analytical tests are utilized in the descriptive analysis of a substance, conducted by a professional sensory expert, and the affective analysis is utilized to assess that specimens are preferable to others. Sensory analysis include the distinction in flavor, color and aroma of a flavor material, when an analyst is evaluating the flavor, flavor strength and attributes are most important. [26]

Over time, taste and color changes and this is known as a flavor agent. Non-enzymatic browning affects fruit flavors. A newly produced color of strawberry flavor is bright red and tastes very fresh while an older flavor of strawberry becomes a brownish-red color with a prune smell. A flavor's refusal conditions are primarily the variations in taste. The rejection criteria of a flavor is mainly the inconsistencies in taste and color when compared to a standard, which is the old batch of the same flavor.

The olfactory nerve is used during sensory evaluation, (Figure 6), as it is the shortest human nerve.[27] It is situated in the olfactory mucosa, also called mucus membrane, which sits along the roof of the nasal cavity or nostril. This nerve is composed of several small nerve fibers, which are called fascicles, which are joined together by connective tissues. The primary function of olfactory nerve is to enable one to smell. When one inhales air particles, the air particles travels through the nasal cavity and interacts with olfactory nerve receptors. The receptors will send the information to the central nervous system and the information will be received as a scent.

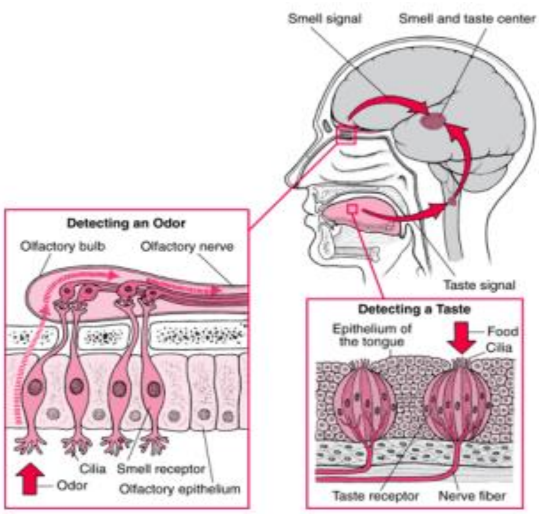

Figure 6: Taste and smell perceptions.[28]

11. Flavoring agent of nature

Flavors that are naturally occurring using physiological, microbiological, or biochemical techniques to flavor products generated from unprocessed plant or animal components. They may be used in their unprocessed state or processed for usage by humans, however artificial flavoring agents are not permitted. The word "natural" flavoring compounds are either one sort of flavoring substance or a combination of flavoring materials that are obtained from plant or animal components through mechanical methods like roasting or heating or through chemical methods like the extraction process, the process of distilling enzymatic, or microbial activities. Complex volatile oil (anise oil), aldehyde (vanillin), ginger oil, peppermint oil, and lemongrass oil are a few examples of natural flavouring ingredients.[29]

12. Natural Identical Flavoring:

Nature identical flavors, such as esters, aldehydes, ketone, acids, and lactones, are generated chemically or by conversion of natural substrates (Figure 7), and they can be made either by microbial fermentation or by using enzymes (6).

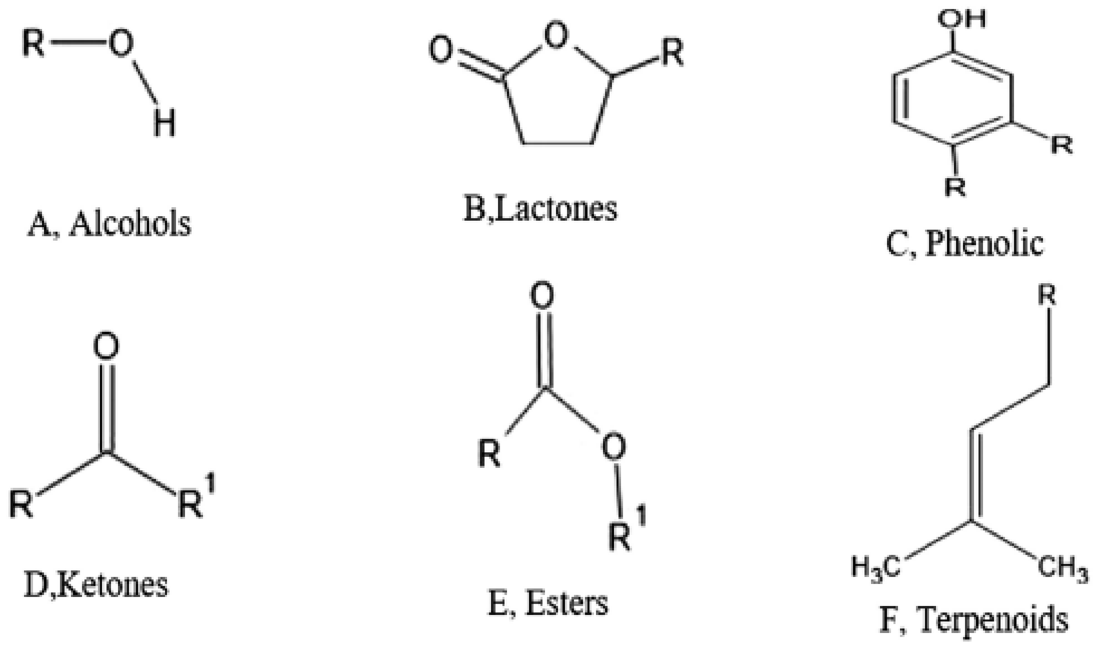

Figure 7: Chemical structures of some of the most relevant flavor and fragrance compounds

13. Flavors of the Terpene Family:

Terpenes are responsible for a great numbers of flavors and are among the main components of essential oils extracted from many different sources. Table 4 reports a selection of flavoring substances, mainly terpenes, isolated from essential oils.

Table 4: Flavoring substances isolated from essential oils

Flavoring substance	Odor	Possible Source
Anethol	Herbaceous-warm, anisic	Anise (Pimpinella anisum) Fennel (Foeniculum vulgare) Star anise

		(Illicium verum)
Allyl isothiocyanate	Pungent, stinging	Black mustard (Brassica nigra)
Benzaldehyde	Bitter almond	Bitter almond (Prunus amygdalus var.amara)
S (+)-Carvone	Warm-herbaceous, bread like, spicy, floral, caraway, dill	Caraway (Carum carvi)
R (-)-Carvone	Warm-herbaceous, bread like, spicy, spearmint	Spermint (Mentha spicata)
1,8-Cineole	Fresh, camphoraceous-cool	Eucalyptus (Eucalyptus globules)
Cinnamic aldehyde	Warm, spicy, balsamic	Cassia (Cinnamomum cassia) Cinnamon (Cinnamomum zeylanicum)
Citral	Lemon	Lemongrass (Cymbopogon citratus, C. flexuosus) Litsea cubeba
Citronellal	Fresh, green, citrus	Eucalyptus citriodora
Decanal	Orange peel	Orange (Citrus sinensis)
Dimethyl sulfide	Sharp, green radish, cabbage	Commini (Mentha arvensis)
Eugenol	Warm-spicy	Clove (Syzygium aromaticum)
Geraniol	Floral, rose	Palmarosa (Cymbopogon martini) Citronella (Cymbopogon nardus)
Geranyl acetate	Sweet, fruity-floral, rose, green	Lemongrass (Cymbopogon citratus)
(Z)-3-Hexenol	Green, grassy	Corn mint (Mentha arvensis)
D-Limonene	Fresh, Orange peel	Citrus (Citrus species)
Linalool	Refreshing, floral-woody	Basil (Ocimum basilicum) Bois de Rose (Aniba rosaeodora) Camphor tree (Cinnamomum camphora)
Linalyl acetate	Sweet, floral-fruity	Bergamot mint (Mentha citrata)
Massoia lactone	Coconut	Massoia tree (Cryptocaria massoia)
Methyl chavicol	Sweet-herbaceous, anise, fennel	Basil (Ocimum basilicum)
Methyl cinnamate	Fruity-balsamic	Eucalyptus campanulata
Methyl N-methyl anthranilate	Musty-floral, sweet	Mandarin (Citrus reticulata)
Nootkatone	Fruity, sweet, citrus, grapefruit peel	Grapefruit (Citrus paradisi)
Terpinenol-4	Warm-peppery, earthy-musty	Tea tree (Melaleuca alternifolia)
Thymol	Sweet-medicinal, herbaceous, warm	Thyme (Thymus vulgaris) Origanum (Origanum vulgare)

Conclusion

Natural flavors, sourced from a variety of plants, fruits, spices, and herbs, play a crucial role in enhancing the sensory qualities of food and beverages. The methods of extraction, including steam distillation and cold pressing, significantly impact the quality and profile of these flavors. The key chemical components, such as terpenes and esters, contribute to the distinct taste and aroma characteristics. Understanding the sources and properties of natural flavors is essential for the development of consistent and high-quality flavor formulations. As the demand for natural ingredients grows, ongoing research and innovation will continue to improve extraction techniques and flavor applications, ensuring that natural flavors remain a valuable component of the food industry.

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