CHAPTER

Plant extracts as flavoring agents

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8.1 Introduction

Flavor is a very important sensory aspect that acts as one of the driving factors for consumer preferences. The flavor of the food is due to the presence of volatile aroma compounds in the foods. These compounds create a chemesthesic sensation in the oral cavity, which can be perceived by the sensitive nerve endings in the eyes, nose, and buccal cavity (Menis-Henrique, 2020). Also, volatile compounds occur differently in different foods. The specific sensation of flavor from each food is due to the characteristic chemical compounds in that particular food product. Though the flavor is a combination of aroma and taste sensory perceptions, it has been widely established that any substance's aroma and flavor are directly related, independent of the taste. Owing to such importance of the flavor compounds in the food sector, the production and separation of the volatile aromatic compounds have gained widespread importance worldwide. The flavoring compounds can be used to impart or intensify the flavor of food commodities. There has been a rapid growth in the need for processing and preservation of foods to increase shelf-stability. According to the United States- Food and Drug Administration, flavoring agents can be defined as the substances that can be added to food and food substances to impart flavor, while flavor enhancers are the substances that are added to substitute, intensify, or modify an existing flavor or aroma of the food product (Burdock, 2019). Being the most volatile, the flavor compounds tend to be lost to a greater extent during thermal processing and preservation. This can improve the shelf-life of flavor-deficit products that cannot meet consumer standards. One solution for this problem is to add the flavoring compounds separately after the thermal processing of the product in specific quantities based on the required intensity. In a few products like baked goods, flavoring compounds form the basic ingredients required to produce goods (Taylor & Hort, 2007).

The flavoring compounds can be roughly classified into plant-based, artificial, and biotechnologically formed flavors. As suggested by the name, the plant-based flavors are separated from the plant-based sources rich in aromatic compounds, like vanilla, spices, and herbs. The artificial flavors are formulated by treating the chemical compounds to form aromatic substances by certain processes and techniques. The biotechnology flavors are obtained by the bioconversion of any biological material by micro-organisms such as fermentation. Certain foods like coffee, cocoa and fermented meat develop their respective characteristic flavors due

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to a complex process in a combination involving plant material, fermentation and roasting processes (Klinjapo & Krasaekoopt, 2018). The flavor compounds make one of the base ingredients form the final product with the desired functionality and reach in such goods. All these reasons have aided the rapid growth of the flavoring industry and the need for more developments in the production of required flavor compounds. The production of flavor compounds has been traditionally done by separating the volatile aromatic chemicals from direct sources using different solid-liquid extraction (SLE) or distillation techniques. However, such naturally occurring flavor compounds tend to lose the flavor over storage and are less intense. To overcome this problem, synthetic flavoring compounds have been developed artificially in laboratory settings. These synthetic flavor compounds are highly intense, are required in low concentrations and can be stored for a long time without disintegration (Berger, 2015; Grumezescu & Holban, 2017). The term "artificial flavor" or "artificial flavoring" means any substance with flavoring properties, which is not derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf or similar plant material, meat, fish, poultry, eggs, dairy products, or fermentation products. Some of the most commonly used synthetic flavorings are vanilla, chocolate, citrus, butter, coffee etc. Also, the flavors of certain flowers like lavender and rose have been widely used in the food industries for several applications. Table 8.1 summarizes different synthetic flavoring compounds and their commonly used substrates.

Several of these synthetic counterparts of the flavoring exert certain side effects. Allergic reactions, attention deficit hyperactivity disease, and carcinogenicities are the known and suspected health risks of artificial flavors and have been banned by the regulatory agencies against their use in food production and processing (Ramesh & Muthuraman, 2018). The European Union has restricted most of the synthetic flavors for these reasons (Martins, Roriz, Morales, Barros, & Ferreira, 2016; Ramesh & Muthuraman, 2018). The organizations like Flavor and Extract Manufacturers Association (FEMA) and International Organization of Flavor Industry have laid down certain regulations for use of artificfial and synthetic flavors in food produts by exerting permissable limits on each compound based on their biological activity. The artificial compounds such as coumarin, estragole, safrole and isosafrole, p-ppropyl anisole, cinnamyl anthracite etc., have been permanently banned for usage in food products due to their adverse effects. Also, carryover flavors, those present in raw materials and carried over to the final product, are permitted to be used in the limited quantity. The European Food Safety Authority and World Health Organization Joint Expert Committee on Food Additives (WHO-JEFCA) have establisheed a protocol for evaluationg the safety of the additives. All the additives were subsequently categorized into 34 groups based on the consistent chemical, metabolic and biological behavior. In case of the compounds that degrade into fragment, the fragment with highest toxic score is considered and the compound would be placed in the respective chemical category. The chemicals of each category would be assigned with certain permissable limit depending on the toxicity of the group.

The natural flavorings are always safe for consumption and generally do not cause any health complications. The increase in consumer requirement for natural and organic foods has boosted the concept of natural flavorings and additives usage. The sharp rise in market trend has also prompted the increase in natural extracts for flavor purposes in bulk production of food.

Table 8.1 Common synthetic flavors and their use.

S. No	Synthetic flavoring agents	Flavor profile	Application
1.	Diacetyl	Buttery and fermented flavor	Alcoholic beverages, caramel, and pastries
2.	Ethyl decadienate	Fruity flavor	Fruit powders, juices, and beer
3.	Ethyl maltol	Caramelized and smoky flavor	Candy and confectionary
4.	Ethyl propionate	Pineapple and fruity flavor	Juices, candy, fruit powder, beer, and confectionary
5.	Isoamyl acetate	Pear and banana flavors	Juices, candy, fruit powder, beer, and confectionary
6.	Lutidene	Coffee and nutty flavors	Bread, coffee, tea, meat products, and cheese
7.	Methyl anthranilate	Grape flavor	Perfumes, candy, confectionary, fruit powders, juices, wines, non-alcoholic beverages and ready-to-drink beverages
8.	Acetanisole	Tea flavor, tomato fruity flavor	Tea, flavored beverages, and ready-to-drink beverages
9.	Methyl salicylate	Wine and apple flavor	Alcoholic beverages, and non-alcoholic beer like beverages
10.	Furfural mercaptan	Meat and strong flavor	Animal products, meat analogs
11.	2,3,5-Trimethyl thiazole	Nutty flavor	Chocolate and cocoa products, coffee, ready-to-drink beverages, nut based foods, and products with added nuts
12.	Ethyl butyrate	Strawberry, apple, and fruity flavors	Fruit-based foods and beverages
13.	Methyl sulfide	Meat, dairy, and smoky flavor	Processed dairy products and convenience foods, meat products, and meat analogs
14.	Octanal	Grape fruit, citus, and orange flavor	Citrus-based and fruity beverages, fruit powders and ready-to-drink products

8.2 Plant extracts used for flavoring

Humans practised the concept of synthesis of flavor and flavor-based components from the plants from ancient times to improve the aesthetic and organoleptic properties of food and beverages. Most of the plant origin flavors were extracted from spices due to aromatic and volatile/pungent components. Flavoring matters from the plant source were recognized as safe, which has been used as seasoning agents in Indian cuisines. The industrial production and commercialization of fragrances and flavors were started during the 19th century. Europe occupies 36% of the market share in producing essential oils and natural extracts, followed by America (32%) and the Asian Pacific region (26%). The wide array of flavor ingredients was isolated from the spices, for example, cinnamaldehyde from cinnamon oil and benzaldehyde from the bitter almond oil.

The plant-based food flavoring agents are naturally occurring polyphenolic compounds, organic esters, acids, alkaloids, and carotenoids. Many surveys have summarized the consumers' lesser keenness in purchasing products containing artificial additives, in contradiction to natural food additions (Drew, 1994). Also, many research types have proved that a good number of flavoring agents and their precursors exert health-benefiting properties (Ayseli & Ipek Ayseli, 2016; Schwab, Davidovich-Rikanati, & Lewinsohn, 2008). Many flavors have been detected and developed since 1960. Several chemical compounds are ubiquitous and occur as aromatic chemicals in many foods. Not all volatile compounds are aromatic. It is a fascinating challenge to identify the volatile chemical compound that contributes to a specific flavor in a complex food system. Different flavors from various plant sources are summarized in Table 8.2.

8.3 Production of plant-based flavors

Food flavorings have important influence on food evaluation and consumer preferences. As a result, flavor production has been sought after by the food industry for the past decades. Natural flavors like vanilla, banana (ethyl acetate), cocoa, coffee, pineapple, berries, orange, mango, mint, cardamom, etc., have been excessively used in traditional and contemporary foods. However, the natural flavors are mild and are required in large quantities to obtain the required concentration and intensity. This problem has paved the way for the rapid development of synthetic flavors that can be artificially produced using chemical compounds. These synthetic flavors are highly intense and can give the desired flavor in food products even at low concentrations. The production of synthetic flavors can be costing lesser than that of the natural flavors, and it can be done in bulk production, which is not the case for natural aroma chemicals. Due to these above-stated reasons, synthetic flavors have occupied a large market share in the last decade. But the growing inclination of the consumers towards natural foods, free of chemical additives, has been acting as a driving force to the growth of the natural food market. All these reasons added to the rise in consumer acceptance of natural flavors and extracts. This market trend pressurized the flavor production industry to increase the production scale, which was not successful using traditional production practices (Cravotto & Cintas, 2007). This led to the need for further innovations and research in developing the production methods of natural plant-based flavors on a larger scale. The last decade has been a golden era for the research and development in the flavor industry, from production methods to identifying plant flavor sources. Different extraction techniques for plant extracts have been elaborated on in the previous chapters.

The production of flavor compounds involves the separation of aromatic components from the matrix of the source. The aromatic compounds are generally multicomponent blends of different aromatic and non-aromatic compounds containing traces of raw materials, which can be effectively used as a flavoring agent with the desired final compound outcomes. The flavoring compounds can occur in both solid and liquid physical forms. Different processes can do the manipulation of extracted flavors to modify the state and properties of the compounds. The manipulation method needs to be chosen, considering that the aromatic property of the substances needs to be intact. Most of the extraction processes give the final product in liquid form. The final product concentration is one more important characteristic of the volatile compounds as it determines the amount to be used for achieving a desirable effect in food applications.

Table 8.2 Various plant-based flavoring compounds.

Flavor compound	Plant source (extract)	Flavor perception	References
Vanillin	Vanilla bean	Sweet, floral	Ayala-Zavala, González-Aguilar, and Del-Toro-Sánchez (2009)
Trigonelline	Coffee, fenugreek	Astringent, bitter	(Murlidhar & Goswami, 2012)
Chlorogenic acids	Coffee, papaya, wine, blueberry	Astringent, bitter	Ayseli and Ipek Ayseli (2016)
Pico-crocin	Saffron	Bitter	Akowuah and Htar (2014)
d-Limonene	Citrus oils	Citrus	Rowe (2012)
Linalool	Hops, orange, beer, citrus essential oil, and coffee oil	Citrus, floral	Ayala-Zavala et al. (2009), Boulogne, Petit, Ozier-Lafontaine, Desfontaines, and Loranger-Merciris (2012), Park (2015), Schwab et al. (2008)
Resveratrol	Grapes	Astringent	Singh, Liu, and Ahmad (2015)
Naringin	Oranges, citrus extracts	Bitter	Fan, Li, and Fan (2015)
Gingerol	Ginger roots	Pungent, earthy, and musky	Tzeng, Chang, and Liu (2014)
Cinnamaldehyde	Cinnamon bark	Earthy, bitter	(Unlu, Ergene, Unlu, Zeytinoglu, & Vural, 2010)
Curcumene, α-tumorene	Turmeric roots (*Curcuma longa*)	Earthy, spicy, and musky	(Angel, Menon, Vimala, & Nambisan, 2014)
α-Pinene	Rosemary leaves	Floral, fragrant	(Prakash, Kedia, Mishra, & Dubey, 2015)
Carvone D	Mentha leaves	Cool, minty, fresh, and floral	(de Sousa Barros, De Morais, Ferreira, & Vieira, 2015)
Eugenol	Clove, cinnamon	Spicy, woody, irritant	(Chatterjee & Bhattacharjee, 2015)
Geraniol	Geranium grass	Sweet, floral	(Ahmad & Viljoen, 2015)
2E-Deacanol	Coriander leaves	Grassy, earthy, fresh	(Matasyoh, Maiyo, Ngure, & Chepkorir, 2009)
Isoamyl alcohol	Banana	Banana	Wick et al. (1966)
Eugenol, methyl eugenol	Allspice	Earthy, spicy, woody	(Zabka, Pavela, & Slezakova, 2009)

8.3.1 Flavor extracts in liquid form

The liquid flavors can occur as low viscosity liquids, medium viscous liquids, suspensions, emulsions, or pastes. The viscosity of products can be decreased by adding any carrier substances and increased by slow and mild heating for long timings. The flavor components are generally very intense and need to be added with any carrier material for increasing the stability and scaling up the quantity. The aqueous flavors are commonly added with ethanol or glycerol, whereas lipophilic flavors, vegetable oils or triacetin are prominently used carriers. The process of increasing viscosity by applying mild heat can cause deterioration of the complex's flavor profile and needs to be carefully selected and monitored for suitable flavor complexes. The production of the flavor complexes is a very pristine process in which the aromatic chemical compounds are added slowly in a step-by-step process. Prominently, the low volatile flavors can be added in the initial steps, and high volatiles is added in the final steps to avoid excessive loss. Also, for liquid flavors, food additives like antioxidants and preservatives are added to improve the stability of the complexes.

8.3.2 Flavor extracts in solid form

The dry form of food flavors is an important method of flavor incorporation in certain food products like tea, coffee, spice blends, etc. In such cases, the food flavors can only be used in powder or solid form. The powdered flavor matrices also are more stable and can be used for delayed flavor delivery. The dry flavors can also be an effective way to avoid deterioration of flavor compounds in foods during further processing. The production of dry flavors can be done using spray drying or spray chilling, encapsulation, compaction, coacervation and melt extrusion.

8.3.2.1 Spray drying

Spray drying is one of the most common methods used to convert liquid foods into a solid form. The spray drying of flavoring matrices involves converting liquid flavor and carrier material into the slurry, atomization of slurry, and drying and encapsulation. The carrier materials used for flavoring compounds are maltodextrins and plant starches. The carrier substances are made into a slurry using any continuous phase like water, alcohol, etc., into which the aromatic compounds are added. The flavor-slurry is atomized into the drying tower along with hot air to evaporate the continuous phase. During this process, the carrier molecules form a membrane around the flavoring substances to form a solid, powder-like form. In the spray chilling process used for heat-sensitive materials, cold air is used to atomize the slurry instead of the heated gas. The chilled air will freeze the carrier material forming granule like particles with flavoring compounds (Okuro, Eustáquio de Matos, & Favaro-Trindade, 2013). In both spray drying and freezing methods, the particles are separated from the air stream suing cyclone separator, after which they are carefully packed so that they do not get into contact with air. The optimal flavor particle is generally hollow on the inside and is small and round. The spray-dried flavor particles are generally used to produce the tea and coffee blends as they tend to hold the flavor for longer shelf periods. The details about spray drying for the encapsulation of flavoring substances have been elaborated on in further sections of this chapter.

8.3.2.2 Plated or extended flavors

The plating or extension of flavors is one of the traditional and old methods to produce dry flavors. The method of plating involves the flavors to be adsorbed on to any dry or powdery carrier material. The most commonly used carrier materials are salt, maltodextrins, starches, or lactose. The flavor substances in liquid form are fed onto a bed of carrier material under continuous stirring, using nozzles or sprayers. The continuous movement in the bed is achieved by paddles or stirrers, which helps distribute the flavor substances throughout the carrier material. It is a very economical process with minimal equipment usage. However, this procedure does not yield a product of high shelf-stability.

8.3.2.3 Compaction

The compacted flavors are granulated particles of dry components of a diameter ranging from 0.5 to 5 mm. The most important food application of the granulated flavors is in the beverage industry (tea, coffee and instant cocoa drink mixes). This process uses the spray-dried powder, compacted firmly using rollers, after which it is broken into small granules of flavoring agents. It is advantageous to be used in granulated food matrices and instant mixes. It is also much easier to fortify the material with certain high-value substances like vitamins in granules rather than powder. It is widely used in the tea industry as powdered tea tends to lose flavor soon in tea bags and is not suitable for de-mixing and blending steps in tea processing.

8.4 Advanced technologies to assess the quality of plant-based flavorings

8.4.1 Isotopic ratio mass spectrometry

Every chemical reaction chain differs in one form or the other by the isotopes of the same element. The fact of zero-point energy in any chemical reaction directly reflects on the mass fractions of the atoms. These mass variations, especially in lighter elements like hydrogen or carbon, are useful in detecting specific material origin. In the case of the aroma chemicals, these variations can be successfully used to differentiate between plants, animal, biotechnological and synthetic origins of the volatiles. One of the easiest routes is identifying the type of plant-based photosynthesis method adapted, that is, C3, C4, or CAM pathways. These three pathways do not let carbon accumulation as ^{13}C, but at different levels. This can be used to identify the type of plant from which the volatile compound has originated. The difference in the levels of accumulation can be denoted by delta ^{13}C ($d^{13}C$), which is the ratio of ^{13}C: ^{12}C stable isotopic forms compared with the ratio of PeeDee belemnite mineral. The typical $d^{13}C$ ratio for C4 plants is −10 to −16, −23 to −32 for C3 plants and −12 to −30 for CAM plants. The $d^{13}C$ ratio for chemically synthesized flavors from fossil fuels ranges from −15 to −33 (Asche, Michaud, & Brenna, 2003). Vanilla is one of the most successfully distinguished flavor using this method. The original vanillin is produced from a tropical plant called the CAM pathway, containing an isotope ratio of −12. The vanillin from the petrochemical origin (synthetic flavor) shows an isotope ratio of −24, and the one derived from ferulic acid from the C3 rice plant shows a −31. Similar the carbon elemental isotopes, other isotopes like hydrogen and deuterium ratios can also be used similarly. However, these ratios can be affected by nonbiological reactions like proton transfer at active sites (Rowe, 2012).

8.4.2 Radiocarbon dating

Radiocarbon dating is a method of estimating the age of any biological matter by measuring the ^{14}C isotope present in it. The measured isotope is compared against a standard, which is ^{14}N isotope generally. The ^{14}N isotope has an estimated half-life of 5700 years, which can be used to estimate the half-life period of ^{14}C isotope. The measurement is usually done using a scintillation counting protocol, which indicated the carbon isotope age. It indicates if the material is of recent biological origin or if it is a fossil fuel product. It can be a good test for aroma chemicals that are generally isolated from essential oils, like cinnamaldehyde (from cassia oil). Naturally occurring cinnamaldehyde can be differentiated from the chemically modified compound from benzaldehyde.

8.5 Encapsulation of plant extract flavorings

Generally, the flavoring agents are highly volatile substances and tend to degrade due to heat, light, oxygen, chemical reacting ability, and microbial infestation. The natural flavoring agents are more volatile and less stable than their synthetic counterparts. These are mostly added at the end of the processing line to avoid denaturation and other losses. Encapsulation can be defined as a process to entrap on substance (generally target components) into another substance (Nedovic, Kalusevic, Manojlovic, Levic, & Bugarski, 2011). The process of encapsulation is prominently carried out in biological processes to improve the bioavailability of high-value compounds. It helps in delivering the unstable components without undergoing any degradation or denaturation during the processing. Encapsulation of plant-based flavors is a beneficial method to avoid degradation and losses during usage. This process helps in several ways, like (1) improved handling convenience, (2) reduced environmental reactivity and (3) improved concentration and dispersion characteristics of active compound (Lesmes & McClements, 2009). Microencapsulation and nanoencapsulation are the most efficient encapsulation techniques that encompass and protect the flavors during food processing, and also promote the controlled release, easier handling of flavors, reduce flavor interaction with external environmental factors and transfer rate from the core to impart even flavor to the components (Gharsallaoui, Roudaut, Chambin, Voilley, & Saurel, 2007). The encapsulation technique, both micro or nanoscale, can protect the enclosed material against environmental degradation and also help in the controlled release of the material. The encapsulation technique converts the liquid flavor extracts into powder form, easy to store and handle. The encapsulated powder flavors can be used in several industries like chewing gum, powdered drinks, instant beverages, and bakery and confectionery products (Klinjapo & Krasaekoopt, 2018). The encapsulated material can be called core material, active substance, or internal phase, whereas the encapsulating material can be a shell, coat, membrane, or carrier phase (Gharsallaoui et al., 2007). The core material selection is based on the properties like solubility, glass transition, molecular weight, permeability, stability, film-forming, emulsifying and crystaization properties, and desired functionality like strength, flexibility, type of release and concentration of the encapsulates (Nedovic et al., 2011). The coating materials are the protective barriers between the core and environment, need to be food-grade, biodegradable, and non-reactant and had to be recognized as safe (GRAS). The major coating materials used in the food industry are:

- Carbohydrates: Starch, maltodextrins, amylose, cyclodextrins, and modified starches
- Plant extracts: Gum arabica, gum tragacanth, pectin, and galactomannans
- Proteins: Albumin, zein, gluten, gelatin, casein, whey protein isolate, soy protein isolate, and pea protein
- Lipids: Phospholipids, fatty acids, and glycerides

- Animal and microbial origin: Chitosan, xanthan, and dextran

Microencapsulation is a method of enclosing small quantities of any compound in a shell-like casing to protect from the external environment (Saifullah, Shishir, Ferdowsi, Tanver Rahman, & Van Vuong, 2019; Yousuf, Gul, Wani, & Singh, 2016). The encapsulation technique involves converting the core material into tiny droplets initially, which the wall material can encompass through different processes. The most important encapsulating processes are spray drying, freeze-drying, fluidized bed drying and solvent evaporation. Coacervation and extrusion are also recently sought techniques for microencapsulation of flavor compounds (Shishir, Xie, Sun, Zheng, & Chen, 2018). Nanoencapsulation is a technique similar to microencapsulation, except that it delivers the encapsulated powder of nanoscale (typically $>\mu$m). The nanoencapsulation is beneficial than the microlevel for reasons like enhanced bioavailability, targeted drug transport and release (Saifullah et al., 2019; (Shishir, Xie, Sun, Zheng, & Chen, 2018). Tables 8.3 and 8.4 elaborate on different types of micro and nanoencapsulation trends of various aromatic compounds.

The vanillin, the most commonly used flavor obtained from vanilla, is highly sensitive to heat and light. Encapsulating naturally extracted vanillin in β-cyclodextrin using the freeze-drying technique has shown that the encapsulated vanilla was more soluble in water than the free molecules. Also, it has shown greater stability against oxidation (Karathanos, Mourtzinos, Yannakopoulou, & Andrikopoulos, 2007). Noshad, Mohebbi, Koocheki, and Shahidi (2015) studied the effect of microencapsulation of vanillin using a spray drying technique. Response surface methodology was adopted to analyze the optimum process conditions of microencapsulation using soy protein and maltodextrin. The research findings state that spray drying of 8.5% maltodextrin with 0.36% vanillin at 184°C is the optimum parameters for moisture content, encapsulation efficiency and particle size. Cardamom is one of the most widely used flavors in confectionery, bakery, beverage, (coffee and tea) and the pharmaceutical industries. But the cardamom flavoring substances are highly

Table 8.3 Microencapsulation of flavors and aromatic compounds.

S. No	Plant extract	Carrier material	Encapsulation technique	References
1.	Turmeric extract	β-Cyclodextrin, Brown rice flour	Homogenization and spray drying	(Laokuldilok, Thakeow, Kopermsub, & Utama-Ang, 2016)
2.	β- pinene	Sodium caseinate	Complex coacervation	(Koupantsis & Paraskevopoulou, 2017)
3.	Menthol	Gelatin, modified starch and oil-gelatin emulsion	Fluidized bed coating	Sun, Zeng, He, Qin, and Chen (2013)
4.	Caffeine extract	Sodium alginate	Desolvation and spray drying	(Bagheri, Madadlou, Yarmand, & Mousavi, 2014)
5.	Cardamom extract	Whey protein isolate, guar gum and carrageen gum	Emulsification and freeze drying	(Mehyar, Al-Isamil, Al-Ghizzawi, & Holley, 2014)
6.	Vanilla oil	Chitosan	Complex coacervation	(Yang et al., 2014)
7.	Sweet orange extract	β-Cyclodextrin	Molecular inclusion complex	(Zhu, Xiao, Zhou, & Zhu, 2014)

Table 8.4 Nanoencapsulation of flavor extracts from plant.

S. No	Plant extract	Carrier material	Encapsulation technique	References
1.	Coffee oil	Poly lactic acid	Emulsification and solvent evaporation	(Freiberger et al., 2015)
2.	Vanillin	Poly lactic acid	Emulsification and solvent evaporation	(Dalmolin, Khalil, & Mainardes, 2016)
3.	Peppermint oil	Zein and gum arabica	Dispersion and freeze drying	(Chen & Zhong, 2015)
4.	Thymol-eugenol complex	Zein, sodium caseinate	Antisolvent precipitation; self-assembly	(Chen, Zhang, & Zhong, 2015; Wang & Zhang, 2017)
5.	Carvacrol	Corn starch, sodium caseinate	Emulsion electrospinning	(Tampau, González-Martinez, & Chiralt, 2017)
6.	Saffron extract	Whey protein concentrate, pectin, maltodextrin	Multiple emulsification	(Esfanjani, Jafari, & Assadpour, 2017)

unstable against air, moisture, light and elevated temperatures. Encapsulation of this flavor in skimmed milk powder and modified starch using spray drying and freeze-drying techniques was investigated. The research findings concluded that spray-dried microspheres had greater flavor retention as the freeze-dried product lost the 1,8-cineole component rapidly during storage (Najafi, Kadkhodaee, & Mortazavi, 2011). Natural menthol is a very major constituent of peppermint oil and mint flavor extracts. It is a cyclic monoterpene alcohol compound and is prominently used in chocolates, beverages, pharmaceuticals, candies, liquors, chewing gum, and cooling agents. The fluidized bed drying method was used to trap menthol in gelatin and modified starch using fluidized bed drying methods to study the flavor release kinetics by Sun et al. (2013). Gelatin emulsion was found to be potential coating material with an encapsulation efficiency of about 90.4%. It was also found that about 60% of the encapsulated flavor was released within 11 min. Santos et al. (2014) worked on developing chewing gum incorporated with xylitol and menthol in the encapsulated form to study the cooling effect concerning time and intensity. The compounds were double encapsulated using the coacervation method before incorporation in the chewing gum. The research findings state that the microspheres of the encapsulated compounds can gradually release the compounds during chewing, thus increasing the cooling effect by time and intensity.

8.6 Application of natural plant-based extracts as flavoring agents in the food industry

8.6.1 Beverage industry

The beverage sector is one of the most important aspects of the food processing industries. The beverage industries include the processing of fruit beverages, beer, non-alcoholic sugar beverages, carbonated drinks, tea, coffee and alcoholic drinks. The flavor is a very primary aspect of acceptance of any beverage. Most commonly, liquid flavoring agents are used in beverages. For instant coffee powder production, the coffee soluble solids are extracted from the ground roasted beans by washing underwater currents and separating the aroma compounds using distillation. This extracted coffee flavor is added to the powdered or granulated bean powder (free-flowing or freeze-dried or agglomerated) along with 0.2% of cold extracted coffee oil to give profound coffee flavor to the instant powder (Ashurst, 2012a, 2012b). In juice production industries, the juice extracted and reconstituted would be added with 0.5%−1% of trapped aroma volatiles of the same fruit to improve the aroma profile and sensory characteristics of the fruit juices. In citrus fruits, volatile aromatic oil is expelled from the fruits before extracting juice from them. This citrus oil is clarified and readded to the citrus juices for greater flavor and aroma (Ashurst, 2012a, 2012b). Natural oleoresin exudates from different plants like pepper, ginger, etc., are widely used as flavoring agents in different beverages like soft drinks due to their rich aroma and are widely used for medicinal value in households. Also, certain flavors like cocoa, coffee and tea are characteristically developed during roasting and are not originally occurred in the raw material.

8.6.2 Savory foods

For the flavoring of savory products, the base flavors used are spices and spice blends, whereas the top-notch flavors like caramelized or smoky flavors are formed during the processing and production steps. The obvious loss of the aroma components during the thermal processing of savories is complemented by flavor-rich oleoresins and essential oils from spices and herbs. The hydrolyzed vegetable protein (HYP) can be added to impart the meaty flavor to the products. Soy protein and okara are most widely used for the production of hydrolyzed protein from vegetable sources. An increase in the vegan and vegetarian market share has benefitted from the bulk production of HYP. Top-notch flavors like smoky flavor have been commercially added by using dry powdered flavor composites like smoked paprika, pepper and certain salts (Hall, 2012).

8.6.3 Bakery and confectionary industry

The bakery and confectionery industries are among the vastest food processing industries with a great scope of use of flavorings and volatile chemicals. Most of the ingredients used for producing baked goods like honey, nuts, caramel, chocolate, licorice, coconut, malt, dried fruits are aroma-rich and directly impart desirable flavor to the finished products. Also, the production and processing conditions like temperature and baking time significantly contribute to the development of flavors in bakery products. The most commonly used flavoring extracts in bakery goods are vanilla, chocolate, caramel, butterscotch, etc., essential oils like lavender, peppermint, rose, citrus and citrus peel, rosemary spices like cinnamon, clove, sage, etc., are added to the ingredients. One major problem in flavor induction in baked goods is that there is a possibility of losing the flavors and volatiles during processing due to the high baking temperatures. Encapsulated and dry flavors are most suitable for bakery goods to overcome this problem. In confectionery like soft boiled and hard-boiled candies, the flavoring agents need to be more stable and concentrated on being retained after processing. Most of the manufacturers use synthetic flavorings for this purpose.

Similarly, in jellies and gums, essential oils like citrus are used. In such products, the top notes of the flavors tend to get lost or degraded during storage. Oleoresins of vanilla, cinnamon, nutmeg, rosemary, thyme and ginger are used to impart more profound flavor in these products. The volatile flavors in bakery and confectionery products are generally added into the fat or lipid ingredients during production as they tend to trap the flavor and retain the aroma for longer periods. Also, the sugar in the bakery goods tend to undergo Maillard's reaction during baking, thus imparting its flavor to the product (Armstrong, Luecke, & Bell, 2009; Armstrong & Yamazaki, 1986; Dusterhoft et al., 2006; Lawrence & Ashwood, 1991; Paterson and Piggott, 2006).

8.6.4 Alcoholic beverages

Alcoholic beverages are among the most varied food processing sectors, comprising beer, wine, distilled spirits, cocktails, flavored alcohols, and liqueurs. Beer is one of the most popular alcoholic drinks. It is consumed in both unflavored and flavored forms, making the flavored forms added with added flavor extracts. Also, in unflavored beer, hops are the most important additive that gives beer its characteristic flavor. Hops, a perennial plant, are generally added as an extract in essential oil or oleoresin. The extract of hops consists of terpenoids and nor-isoterpenoids abundantly, of which the terpenoids (myrcene, myrcene acid, myrcene, linalool, geraniol etc.,) are the primary aromatic compounds. Most beer manufacturers use various hops to give a consistent and constant flavor to their beer. However, a few manufacturers use two or three varieties of hop extracts to obtain a desirable aroma note to the beer. A large portion of hop extracts used currently in beer production is produced by supercritical fluid extraction. In naturally flavored beers, the flavors are added through whole fruits or concentrate, spices, seeds, oak, herbs, etc. The type of wheat, method of malting, time for fermentation also contribute to the development of the characteristic flavor of beer and are consistently maintained by the brewers for constant taste and flavor of beer produced in different batches (Buglass & Caven-Quantrill, 2012; Buglass, 2011; Tonutti & Liddle, 2010).

Wine is another alcoholic drink that is widely consumed in popular culture. It is produced by fermenting fruit juices, particularly grapes. The characteristic flavor of wine arises from the type of grapes and depends on the anthocyanin content. The traditional wine flavors are the result of the process of maturation done in old oak barrels. However, in current days, the oak flavor is imparted to the wines by adding small oak chips in the liquor. Herb and spice extracts have been employed in flavoring several wines and are maintained as a manufacturer's secret by several brewers. The typical wine called Vermont originated in Piedmont, Italy, is now produced in several parts of the world. The typical property of this wine is that it uses the extracts of about 30–50 botanicals for its specific wine aroma and taste. The most prominently used flavoring extracts in wine are floral extracts like lavender, rose; spices like clove, star anise, oregano; herbs like chamomile, basil, ginger, sage and unconventional flavors like acacia, wormwood, juniper, etc. The other alcoholic beverages like rum, vodka, gin, brandy, soju, tequila, and whiskey are neutral aroma-less liquors and can be used to produced cocktails, and flavored alcoholic drinks using fruits concentrates, extracts of several herbs, spices and beans. The essential oils, oleoresins, and extracts of citrus fruits and peels, rose, lavender, ginger, basil, etc., are widely used to impart aroma to the beverages (Buglass & Caven-Quantrill, 2012; McKay, Buglass, & Lee, 2011; Proestos et al., 2005; Takoi et al., 2009) (Table 8.5).

Table 8.5 Use of encapsulated plant flavors in the production of different processed food products.

S. No	Type of food product	Encapsulated flavor component	Type of encapsulation	Wall material	Remarks	References
1.	Biscuits	Shrimp oil	Microencapsulation	Sodium caseinate, fish gelatin and glucose syrup (1:1:4 w/v)	The encapsulated product can be incorporated in biscuits up to 6% without affecting sensory properties due to oxidation on light exposure.	(Takeungwongtrakul & Benjakul, 2017)
2.	Biscuits	Cinnamon essential oil	Nanoencapsulation	Maltodextrin	The results revealed the promising benefit of using the encapsulated cinnamon essential oil, as exogenous flavoring, on improving and keeping the overall qualities of biscuits.	(Fadel, Hassan, Ibraheim, Abd El Mageed, & Saad, 2019)
3.	Canned food	Wasabi extract	Microencapsulation	Octenyl succinylated waxy maize starch and maltodextrin	The findings showed that the encapsulated wasabi flavor produced under the studied conditions could be used in canned foods to protect degradation during storage.	(Ratanasiriwat, Worawattanamateekul, & Klaypradit, 2013)
4.	Chocolate-Vanilla dairy drink	*Terminalia arjuna* extract	Microencapsulation	Gum arabica	The final product properties indicated that encapsulation might be effective for incorporating herbal extract into dairy drinks intended for long-duration storage.	(Sawale, Patil, Hussain, Singh, & Singh, 2017)
5.	Extruded product	Lemon flavor extract	Microencapsulation	Sodium caseinate	Sodium caseinate capsules provided flavor protection against harsh extrusion condition (average flavor retention of 67.5%). The extrusion parameters have caused deterioration of the flavor and aroma.	(Yuliani, Torley, D'Arcy, Nicholson, & Bhandari, 2006)

(*Continued*)

Table 8.5 Use of encapsulated plant flavors in the production of different processed food products. ***Continued***

S. No	Type of food product	Encapsulated flavor component	Type of encapsulation	Wall material	Remarks	References
6.	Flavored iced tea premix (instant)	Lemon essential oil	Microencapsulation	Gum arabica, modified starch and maltodextrin	Encapsulated lemon oil showed better results in instant ice tea premix for a beverage with a stability of 6 months.	(Sachin, Gadhave, & Jyotsna, 2015)
7.	Hamburger like meat products	Thyme essential oil	Microencapsulation	Casein and maltodextrin	The encapsulated thyme oil exerted antimicrobial and antioxidant properties along with incorporating flavoring into the product.	(Radünz et al., 2020)
8.	Hydroxypropyl β-dextrin (model food system)	Black pepper essential oil	Microencapsulation	Hydroxypropyl β-dextrin	Enhanced antibacterial activity of black pepper oil was improved by 4 times against both *S. aureus* and *Escherichia coli*.	(Rakmai, Cheirsilp, Mejuto, Torrado-Agrasar, & Simal-Gándara, 2017)
9.	Instant tea	Champaca flavor extract	Microencapsulation	Maltodextrin 20% (w/v) and trehalose 0.5% (w/v)	Instant green tea with 0.3% microencapsulated Champaca flavor has shown 96.7% product acceptance.	(Utama-Ang, Kopermsub, Thakeow, & Samakradhamrongthai, 2017)
10.	Milk-based matrices	Extracts of oregano (*Origanum vulgare* L.), citronella (*Cymbopogon nardus* G.) and marjoram (*Majorana hortensis* L.)	Nanoencapsulation	Skimmed milk powder and whey protein concentrate	The product has shown delayed release of flavor over storage time.	(Baranauskiene, Zukauskaite, Bylaite, & Venskutonis, 2006)
11.	Red wine (dealcoholized)	Grape pomace extract	Nanoencapsulation	Zein and L-lysine	The incorporated red wine was studied for pharmacogenetic studies using human subjects.	(Motilva et al., 2016)

12.	Soybean oil	Clove extract	Microencapsulation	Maltodextrin and gum arabica (4.8:2.4)	The soybean oil with encapsulated clove powder allowed the controlled release of the antioxidant, thus retarding oxidation and imparting flavor.	(Chatterjee & Bhattacharjee, 2013)
13.	Starch-based matrices (model food systems)	Peppermint essential oil	Microencapsulation	Chemically modified food starch from various sources	The subsequent retention and release of the flavor and aroma of starch matrices during encapsulation and storage has been studied.	(Baranauskienė, Venskutonis, Dewettinck, & Verhé, 2006)
14.	Yogurt	Red pepper waste extract	Microencapsulation	Whey protein	The final product (yogurt) showed good retention for polyphenol retention and carotenoids and flavor incorporation.	(Šeregelj et al., 2019)
15.	Yogurt	Grape seed extract	Microencapsulation	Whey protein concentrate and gum arabica (3:2)	The resultant product has shown enhanced functional activity and flavor.	(Yadav, Bajaj, Mandal, Saha, & Mann, 2018)

8.7 Safety evaluation and legislation for food flavorings

Food flavorings have been considered as unique food additives and have been excluded by legislation safeguarding the usage of food additives. However, most of the legislation systems have developed a separate protocol for the addition of flavoring agents (natural or synthetic) into food systems. The increase in awareness among the consumers about food labeling and safety has made it mandatory to declare all the additives in food products and the concentration. Most food industries declare the food flavorings generically as "contains flavors" or "contains natural-identical flavors." One advantage of flavoring substances is that they can be self-limiting and can restrict their addition due to their overpowering flavor properties even at low concentrations (Schrankel, 2004). The US-FDA has brought a Food Additives Amendment to the Food, Drug, and Cosmetic Act, 1938 in 1958. This amendment has brought into force to act on the safety of all food additives, including food flavorings that are permitted in the US (Hallagan & Hall, 1995). With the introduction of the concept of "Generally recognized as safe (GRAS)," US-FDA established a scientific panel FEMA, to determine standards for food flavors in food products. The FEMA evaluated the flavoring compounds based on the chemical structure, activity, natural occurrence, sources, rate of metabolic activity and level of toxicity of the particular extract (Woods & Doull, 1991). The FEMA-GRAS list of safe and permitted flavorings have been accepted by US-FDA ever since. The FEMA expert panel committee not only analyses new compounds for their safety and permissible limits, but it also revises the previously declared safe flavorings periodically (Smith et al., 2003).

The JECFA is an international scientific expert panel committee administered cooperatively by the Food and Agriculture Organization (FAO) and the WHO. The JECFA expert panel analyses the risk assessments of different chemical compounds in food and advice several countries to revise their safety guidelines in accordance. Though JECFA was initially concerned only about chemicals and food additives, it slowly expanded its assessment towards food flavorings as it is a very diverse category and needs attention for safe utilization. JECFA has considered the chemically defined flavoring compounds and flavor complexes obtained by physical processes like distillation or extraction using solvents as an important separate category. These complexes may contain oleoresins, esters, essential oils, and plant extracts along with the core flavoring compounds that may or may not have been chemically characterized (Schrankel, 2004). JECFA has adopted a flavor complex scheming protocol given by Feron et al. (2003) based on the safety evaluation procedure, only for the natural flavoring complexes (Smith et al., 2004).

8.8 Conclusion

Flavor is the amalgamation of aroma and taste. The uniqueness of any food substances is directly influenced by its texture and flavor. The flavor of any food matrix is influenced by the sensations like pain, heat, cold, and tactile because of volatile components. At the time of thermal processing, most of the food components lose their flavor or aroma. This can be recovered by the addition of flavoring agents that are synthesized either artificially or naturally. Synthetic flavoring components are carcinogenic and health-threatening due to the presence of chemicals. To overcome such health-threatening risks from synthetic flavors, plant-based flavoring agents are considered as an alternative and boon to humankind because of their health-benefiting properties. Plant-based flavoring compounds are naturally occurring in fruits, leaves, roots, spices, herbs, etc., enhancing the esthetic and organoleptic properties of the foods and improving the shelf-stability and quality of the foodstuffs by fighting against food-spoilage microbes. The extraction of flavoring substances has been practised from ancient times by humankind, and natural flavors like vanilla, banana (ethyl acetate), cocoa, coffee, pineapple, berries, orange, mango, mint, cardamom, etc., have been excessively used in traditional as well as in contemporary foods. The industrial production of flavor matrix from the spices like cinnamon oil from cinnamaldehyde was done during the 19th century. Various extraction methods have been practised so far to recover the flavor matrix from the plant-based substances like direct isolation to separate the essential oils from the plant sources like spices, in which the essential oils are the aromatic compounds followed by SLE, which works based on the osmosis and diffusion of aromatic compounds, super-critical fluid extraction of aromatic compounds by the utilization of liquid CO_2 at atmospheric pressure of >74 bars at 31°C, ultrasound-assisted SLE at lower frequencies from 18 to 40 MHz for the isolation of volatile components like cineole, thujone, and borneol from sage and microwave-assisted extraction by the generation of electromagnetic radiation with frequency ranging from 0.3 to 300 GHz for the recovery of volatile components from leafy herbs like cinnamon, garden mint, basil, and thyme.

Various other novel technologies like isotopic ratio mass spectrometry, radio dating, and microencapsulation have been adopted for the isolation of flavoring matrix from plant sources like vanillin from vanilla. The encapsulated powder flavors can be used in several industries like chewing gum, powdered drinks, instant beverages, and bakery and confectionery products. Flavors obtained from the plant sources are generally recognized as safe, and as per the food regulation acts, it is mandatory to label clearly on the packages the details of the flavoring agents used, whether it is "synthetic" or "natural," the amount and permissible limits of the flavoring substances added in food substances like bakery, confectionery to create the consumer awareness and as a part of food safety.

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