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Flavour Technology: A Brief Review on Sources, Functions and Encapsulation Techniques of Flavours

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Abstract

Food flavors, a complex blend of natural and artificial compounds, are pivotal in shaping the sensory experience of consuming food. This paper explores the intricate world of flavors, covering natural sources such as plants, herbs, spices, and fermentation, along with extraction methods like distillation, solvent extraction, chromatographic separation, and pressing. Artificial flavors, created to replicate real ingredients, play a significant role in the food industry, utilizing compounds like terpenoids, phenolics, esters, ketones, and alcohols. Flavor enhancers, including MSG and nucleotides, intensify taste profiles. The production of flavors involves diverse processes, including liquid flavor production, emulsions, and dry flavorings. Notably, flavor encapsulation has emerged as a cutting-edge technology, enhancing stability, controlling release profiles, and improving product quality. Techniques like spray-drying, spray-chilling, molecular inclusion, and nanocarriers are discussed in detail. As flavor technology continues to advance, it not only drives innovation in food products but also emphasizes the intricate interplay between natural and artificial flavors. Consumers' evolving preferences for unique taste experiences further motivate ongoing developments in flavor science, promising an exciting future for culinary sensations.

Keywords: Food Flavors; Fermentation; Chromatographic Separation; Cutting Edge Technology

Introduction

Food is a complex combination of carbohydrates, fats, proteins, minerals and vitamins. Flavouring compounds are also major food ingredients and the most common type of food additive, consisting of a complex combination of a huge number of volatile chemicals. There are 1200 distinct flavouring agents used in food to add flavour or replace flavours lost during preparation. Flavour is a mix of taste and aroma [1]. The term flavour relates to a wide range of sensory experiences, including taste, touch, smell, sight and sound. These experiences involve physiological and physiochemical mechanisms that influence how subtleties are experienced Apurva, et al. [2] Flavours can be both natural and artificial. Natural flavour components are commonly found in foods, spices and herbs such as vanilla extract, yeast extract, cinnamon, ginger and citrus oils etc. Artificial flavours can be made from chemical or synthetic components. Other flavouring compounds include nature-identical flavouring agents which are chemically synthesized to be identical to natural flavouring agents (linalool and coumarin), processed flavouring agents which enhance their flavour or to create a new flavour, flavour enhancers and masking agents. Food and Drug Administration (FDA, USA) conduct frequent studies to limit the use of artificial flavouring and additives which are totally chemical based and mimic natural food flavours and extract [2]. Flavour compounds can improve the overall quality of food. They are added to foods or beverages to improve or change their flavour, aroma or texture. These can take several forms, including liquids, powders and extracts. Flavours are employed in a broad variety of food and beverage items, including baked goods, chocolates, soft drinks and processed meals. These are also utilised in pharmaceutical and oral hygiene [3]. Flavouring agents are used in the food industry to flavour food, conceal bad tastes and odours, standardise flavour, lengthen shelf life, and preserve food. This study briefly covered flavour applications and contemporary breakthroughs in flavour technology, such as flavour encapsulation.

Natural Flavours

Natural flavours extracted from plants, herbs, spices, animal or microbial fermentation. These compounds can produce aroma, not only by themselves, but also in combinations. Natural flavours has antioxidant activity, anticarcinogenic, anti-inflammatory and immunity enhancing properties [4].

Plant Sources

- Herbs and spices are fragrant and flavourful, and can be used alone or in seasoning blends.
- Citrus peels and other fragrant plant components are mostly utilised for essential oil production.
- Postharvest fermentation and curing are necessary for vanilla to develop its distinct flavour.
- Postharvest treatment is necessary for the flavour profile of coffee, tea, and cocoa, which are commonly used in drinks.

These materials can be utilized as is (whole or ground/ crushed) or processed into a new flavour form, such as an essential oil, oleoresin, or tincture.

Extraction Methods

Distillation:

- **Water Distillation:** The plant material is placed into a still with a slow-speed paddle stirrer and covered with water, which is heated to a boil using submerged steam coils. Distillation is repeated until all the essential oil is extracted, and the condensed water is continually returned to the still (a process known as cohobation).
- **Water and Steam Distillation:** The plant material is put onto a frame within the still body and positioned above a layer of water that may be heated to a boil using submerged steam coils. This process is extensively employed for the distillation of green herbaceous materials, such as peppermint.
- **Steam Distillation:** The plant material is put into a suitable still, which allows steam to be injected from the base. A reboiler unit is frequently installed to allow condensate to be recycled. The still body's form is determined by the type of feed material. For example, in the western states of the United States, peppermint herb is distilled in stills made from the backs of container trucks that can be filled directly in the fields; these trucks are hauled to a central location where a still head is bolted on and steam injected. Static steam stills are typically tall and split internally by grids to guarantee even loading.

Solvent Extraction: Spice essential oils usually lack the full, balanced characteristics that get from using ground herbs and spices. In certain cases, they are completely devoid of the unique flavouring properties provided by nonvolatile components in the native substance. These can be recovered by extracting specific dried and crushed herbs and spices. In practice, organic solvents are selected to best dissolve both the essential oil and the desired nonvolatiles present. After extraction, the solvent is removed, and the concentrated extract is referred to as an oleoresin.

Chromatographic Separation: Braverman and Solomiansky developed a chromatographic deterpenation process for producing high-quality terpeneless orange oil, employing silicic acid as an adsorbent for the oxygenated fraction. The natural citrus oil is passed down a silica gel column before being eluted with a nonpolar solvent (e.g., hexane). This eliminates any remaining terpenes and permits the oxygenated fraction to be extracted from the silica gel using ethyl acetate or another low boiling polar solvent, which may then be removed using vacuum distillation. The procedure is exothermic, thus the column must be cooled and care used to guarantee minimal heat damage to the flavouring ingredients [5].

Pressing: Commercially, the citrus oils are recovered directly from the peels of fresh fruit. The methods used include:

- **Sponge Pressing:** The divided half peels are manually pressed, and the extruded oil is collected in sponges. This extremely arduous procedure is now seldom utilised, yet it is still touted to provide the best grade oil.
- **Machine Pressing:** There are two major types of machineries employed. (i) Sfumatrici machines press the divided peels automatically after removing the juice and pulp. Such devices can handle around 1 tonne per hour. (ii) Pellatrici machines are intended to handle entire fruits, with the oil extracted by rotational rasping of the fruit surface. Larger versions of these devices can handle two tonnes per hour. The freed oil is continually evacuated by a jet of water, and the oil is separated from the coarse emulsion while standing. Centrifugation separates extra oil from the aqueous phase, and any intractable emulsion is distilled to recover more low-

grade oil.

- **Combined Juice/Oil Presses:** This apparatus was created in the United States and is intended for the automated extraction of juice and oil in a single operation with no contact between the two products. Two basic systems are: (i) the fruit is halved, the juice is reamed out, and the cleaned peel is subjected to pressure between fluted rollers; and (ii) the surface of the whole fruit is grated first, and the oil is removed in a jet of water, while a hollow pipe is inserted into the base of the fruit and the juice is extracted under pressure [6].

Process Flavors

"Process flavors" are a class of flavors or flavoring components that are made from precursor materials using one or more processing technique(s). Flavor is an essential sensory component of food products like texture and aroma Kumar, et al. Thermal processing and enzyme modification are the two main processing methods used nowadays.

- Products whose intended aromatic characteristics flavor can be obtained through intentional processing (coffee).
- The flavor produced by Maillard (Meat-like flavor).
- Enzyme modified dairy products.
- resultant products of lipid thermal reaction.

Chocolates

Three essential steps are involved in converting cocoa beans into chocolate.

- Fermentation - Beans are separated from the pulp and shell by means of fermentation facilities.
- Drying- Drying takes off roughly 15% of the moisture
- Roasting - flavor develops by roasting.

Meat-Like Flavor

When heat is applied, the Maillard reaction is a key phenomenon that develops the flavor of the meat Sousa, et al. Meat that has been cooked or roasted has a distinct flavor; raw meat has no aroma and merely tastes of metal, salt, and blood.

Enzymes Modified Dairy Products

One of the most significant food sensory aspects is flavor. Enzymes such as lipases, proteases, esterases, lactases, and catalase are widely used in dairy and food technology. Different types of proteases are used to change the milk protein to reduce the allergic effects of cow milk products in baby feeds, as well as to accelerate the aging process of cheese Fox, et al. The main application of lipase is flavor enhancement during the maturation of cheese. Typically, lactase is used to hydrolyze lactose into glucose and galactose sugars, improving the solubility and sweetness of various dairy products.

Flavor Produced by Fermentation

Many cultures across the world attribute the flavor and appreciation of some of their most delectable meals to taste compounds that are created during fermentation and aging processes, which may involve the use of yeast, bacteria, molds, enzymes, or mixtures.

Artificial Flavor and it's Material

Artificial flavors are flavor compounds created to simulate the flavor of real ingredients. Artificial flavors are made out of compounds that weren't originally found in nature. The most widely utilized artificial flavoring compounds include phenolics, terpenoids, alcohols, esters, ketones, and pyrazines.

- Terpenoids have a citrus or pine flavor, terpenoids comprise the majority of essential oils. D-carvone from caraway has a spicy, bread-like scent; citral from lemongrass (Cymbopogon citratus) has a strong, minty scent; and menthol from wild mint (Mentha arvensis) has a strong, minty scent.
- Phenolics have a smoky flavor,
- Ester has a fruity flavor, the smell of allyl hexanoate is similar to pineapple.
- ketones and pyrazines taste like caramel, and
- Alcohol is bitter and medicinal. The flavors of fruits, baked goods, dairy products, meat, alcoholic beverages, and roasted foods all include n-amyl alcohol. 1-octen-3-ol, which is present in tomatoes and mushrooms, and trans-2-hexenol, which is found in apples, citrus, strawberries, wine, beer, and tea, give a green leafy, fresh, fatty, grassy flavor.
- Another broad class of heterocyclic nitrogen-containing flavorants are pyrazines, which usually have characteristics resembling popcorn, coffee, cocoa, roasted coffee, or nuts.

Flavour Application in Food Industries

Flavor applications is a key function in flavor companies, specializing in tailoring flavors for specific food products and assessing their performance. Over the past decade, these laboratories have experienced significant growth. Food companies now rely on flavor suppliers not only for flavor creation but also for broader product formulation and market studies, shifting product development responsibilities. Some flavor companies are expanding their teams to include marketing and packaging expertise. The industry trend of forming strategic relationships has strengthened the collaboration between flavor companies and their customers, necessitating them to operate as small-scale food processors with both skilled personnel and processing equipment.

Soups and Stocks

Manufactured soups occur in three forms: (i) canned, either single strength ready to eat or concentrates, (ii) dry mix for reconstitution as required with or without the need for cooking, and (iii) frozen. Each of these calls for a different approach to flavoring so as to achieve quality and consistency in the end product [7].

Canned Soups

Canned soups typically contain a mix of vegetables, meats or meat-like flavorings, starch, fat, seasonings, and noodles or rice. They can be single or double-strength, with concentrated products having higher solids levels. Ingredients are blended, preheated, and sterilized, often through retorting in metal or polymer cans or pouches. Continuous aseptic processing is an alternative, but it poses challenges for soups with particulates. Aseptic processing with direct steam injection requires a vacuum cooling step that can strip flavor. Consequently, flavorings for canned soups must be formulated and delivered with encapsulation for optimal heat stability [8].

Dry Soups

Dehydrated soups come in two types: instant and those requiring cooking. Instant soups use thickeners like starch for lower-temperature performance and agglomerate problematic ingredients for easier dissolution. Regular dry soups lack these specifications, with similar ingredients as liquid soups but in dry form. Dry soup preparation involves blending and packaging. Flavorings for dry soups include dry process flavorings, dry vegetables, ground spices, herbs, and encapsulated or plated spices [9].

Frozen Soups

These products offer the finest quality to the consumer. Due to their price, they are generally made from fresh vegetables and premium ingredients. Many of the same types of flavorings are used in the formulation of these products as the canned or dry soups. The low processing temperatures and frozen storage conditions result in a high quality product.

Sauces, Seasonings, and Marinades

Thermal processing, common in sauce creation, doesn't significantly affect the product during additional mild processing for shelf stability. Flavor application in sauces mirrors that of soups, utilizing process flavors, comminuted vegetables, thickening agents, ground spices, salt, fat, sugar, and unique ingredients like wine or sherry for specific sauces. In essence, sauces can be seen as thick soups, emphasizing their role in flavor enhancement [10].

Meat Product

In savory dishes, salt plays a crucial role as the primary taste enhancer, impacting both the shelf life and overall flavor profile, affecting product palatability significantly. To further enhance flavor, seasonings such as marinades or topical powders are often employed. The term "seasoning" encompasses ingredients that, individually or combined, contribute flavor to meat products. Typically, seasonings consist of blends of natural herbs and spices, sometimes mixed with other flavor enhancers like MSG, ribonucleotides, process flavors, hydrolyzed vegetable protein, and yeast autolysates [11].

Baked Goods and Bakery Products

This product category encompasses diverse items like bread, sweet yeast dough products, biscuits, cookies, crackers, pies, pastries, cakes, and breakfast cereals. Typically, these products consist of a mix of ingredients: flour (9 to 12% protein, mostly carbohydrate), liquid (eggs, milk, or water), leavening (yeast or chemical), shortening (fat), sugar (various options), optional flavoring, and salt (0.2 to 1%) [12].

Flavoring Baked Goods

Flavor additions to dough before baking often involve ground or whole spices, essential oils, cheeses, or encapsulated/controlled release forms. In yeast-leavened products, caution is needed to avoid inhibiting yeast growth during proofing, as certain flavorings can act as microbial inhibitors, impacting loaf volume. Graf and Soper recommend using coacervated flavors, like garlic oil, to address this issue by delaying flavor release until later in the baking process [13]. Alternatively, for some products, flavoring may be dispersed or slurried in oil (in liquid or dry forms) and sprayed onto the finished product, suitable primarily for thin goods. This method, however, adds oil to the product, requiring a label declaration. Another approach is applying dry seasoning by dusting it onto the product, particularly effective for thin goods.

Heat Resistant Flavorings

Commercially available heat-resistant dry flavors, created through multistage encapsulation, prove highly effective under harsh baking conditions. This process involves applying a fat coating to water-soluble encapsulated flavoring, ensuring the flavor does not dissolve during dough preparation. The secondary water-insoluble capsule delays flavor release until later in the baking cycle, preventing full release during the low-water-content stage. Studies adding esters to sugar cookie dough in various forms revealed that fat-coated spray-dried versions retained flavors better, offering protection against evaporation during baking. The decision to use controlled-release encapsulated flavorings is cost-driven, with cheaper options chosen unless a unique property justifies the added expense, such as delivering volatile aromas not achievable in other forms [14].

Means of Applying Flavorings

Snack foods may be flavored by either incorporating a flavoring into the dough prior to thermal processing or topically applying the seasoning after heat treatment. Due to the severe heat treatment given most snack foods, topical seasoning is most common.

Topical Flavorings

Topical flavorings for snacks can be in liquid or dry form. Liquid, oil-soluble flavors, dissolved in vegetable oil, are sprayed onto hot snacks post-baking, reducing the dry mouth feel in baked snacks. However, liquid flavors lack protection against storage losses or degradation. Dry flavors are applied directly to snacks post-spraying with hot oil or a gum acacia solution, using a seasoning drum. While cost-effective and providing immediate impact, dry seasoning has drawbacks, including dusty plant conditions, hygroscopic ingredient challenges, messy application, surface-only flavor, and high usage levels needed for desired sensory properties [15].

Internal Flavoring

Adding internal flavor to snacks for enhanced or uniform taste is often impractical due to major losses and flavor degradation during processing, particularly in high-heat treatments like extrusion where about 98% of volatile components may be lost. Heat-stable flavorings like smoke, meat, sweet brown, and certain spices may have some success in this regard, and stable compounds like capsaicin or piperine pose no issues. However, using internal flavorings can limit fryer usage to specific flavors and may adversely affect fryer oil stability, posing manufacturing challenges [15].

Sugar-Based Confectionery Products and Chewing Gum

Except chocolate and chewing gum, the foundation of most confectionery items is sucrose (sugar), and their distinctiveness comes from the inclusion of other ingredients. These additional elements might encompass gums or starch, marshmallow, nuts, cocoa powder, pectin, or fat, among others. Although the thermal breakdown of sugars and additional ingredients contributes some flavor during the manufacturing process, these products usually rely on elevated levels of flavor usage [16].

Dairy Products

Flavoring materials play a significant role in the dairy industry, with flavored milks, yogurts, and frozen dairy desserts experiencing extensive sales in the U.S. Due to their inherently mild taste, these products constitute a substantial and expanding market for the flavor industry. Flavored milks, especially single-serving sizes, have witnessed considerable growth, evolving from traditional chocolate, vanilla, or strawberry flavors to a diverse range including root beer, coffee, banana, cappuccino, blueberry, and various fantasy flavors. The ice cream sector has undergone a similar transformation, moving away from conventional flavors to innovative and successful concoctions. Flavored coffee creamers also present a growing segment, catering to those seeking non-coffee flavors in a low-calorie, hot beverage. The evolution of flavor profiles in these mainstream dairy products reflects the dynamic trends in flavor application within the industry [17].

Carbonated Beverages

Carbonated beverages dominate the beverage market, with production starting by creating a Bottlers Syrup. Typically made by the parent company to control formulation, it's then sold to local bottlers. The syrup comprises sugar, optional fruit juice solids, acidulants, flavoring, coloring, and preservatives (Na Benzoate, max 0.1%). Local bottlers use this syrup to craft finished bottled beverages, mixing it with a prepared sugar syrup, homogenizing the blend, and filling bottles with carbonated water before capping. This process ensures a uniform, ready-to-drink carbonated beverage [18].

Legislation and Rules

Legislation Limiting the use of Flavor Compounds: Multinational companies face challenges in flavor formulation due to varying laws on flavor chemicals across countries. While trade agreements like the European Union (EU), NAFTA (Mexico, U.S., and Canada), and Arabian Standardization and Metrology Organization (ASMO; Jordan, Iraq, Bahrain, Kuwait, Quatar, Osman, Saudi Arabia, and the United Arab Emirates). Standardize food laws in some regions, many areas, including Asia, Central and South America, and Africa, lack such agreements, requiring companies to navigate diverse and complex regulations in each country [6].

U.S. flavor-Related Legislation: The 1958 Food Additives Amendment reshaped regulations on food additives, shifting from the FDA demonstrating harm to the food industry proving safety. Recognizing the impracticality of withdrawing all additives in use, the amendment introduced "grandfathered approval" for additives with prior sanction. Another clause exempted additives deemed Generally Recognized as Safe (GRAS) by the scientific community. These became GRAS substances, listed in CFR Title 21 Part 170–180. This concept allowed the flavor industry to establish its safety panel for approving flavoring substances, bypassing petitioning and mandatory safety testing [19].

In 1959, the Flavor Extract and Manufacturers Association (FEMA) established an expert panel comprising various experts to assess the Generally Recognized as Safe (GRAS) status of flavor compounds. The panel published the first GRAS list in 1965, featuring over 1100 flavoring substances, and subsequent lists have expanded to include over 2000 compounds. Around 125 compounds are added annually to align with EU-approved flavoring compounds. Evaluation criteria include expected exposure in foods, natural occurrence, chemical identity, metabolic and pharmacokinetics, toxicological data, and adherence to FDA's safety principles outlined in the Red Book. The assessment data are published as Scientific Literature Reviews (SLR) by FEMA for open evaluation [20].

The idea that flavoring materials can be used without extensive petitioning and safety testing is scientifically valid for several reasons. Unlike other food additives, the use of flavoring materials is self-limiting as it's challenging to overdose a food, considering it would adversely affect taste. Flavor compounds are often identical to those found in nature, contributing to authentic flavor representation. Most aroma chemicals in use today have natural counterparts, and the flavor industry adds minimal amounts to our diet compared to natural foods. Additionally, flavoring materials are typically used at extremely low levels in foods, resulting in very low exposure to any specific flavor chemical.

Labelling of Food flavorings: Food labelling serves informational and safety purposes. If a significant population is interested in knowing specific ingredients (e.g., MSG or artificial flavors), they must be listed on the product label. Religious designations like kosher or halal must comply with FDA regulations. Listing an ingredient doesn't imply inferiority; it caters to consumer preferences. Safety concerns mainly focus on allergens, necessitating clear labeling of potential allergens for consumer awareness [21].

Bulk Labelling Requirements: Bulk labelling aims to furnish food processors with essential information for proper consumer product labeling. Flavor components need only be labeled for their natural status (natural, natural/artificial, artificial, natural type flavor, or artificial but noncharacterizing flavor). Listing nonflavor ingredients, allergens, and relevant religious designations is mandatory [21].

Labelling for the Consumer: Flavor relevance on a food product's label is in two areas: the Principle Display Panel (PDP) and the Ingredient Statement (IS). The PDP communicates the product, its flavor, natural status indicated by name or image, and any adherence to religious laws. The Ingredient Statement lists detailed ingredients as per legal requirements, governed by CFR Title 21 Section 101.22, "Foods; labeling of spices, flavorings, colorings, and chemical preservatives." This section outlines clear labelling laws for flavors [21].

Flavors Enhancer: Flavor enhancers, when strictly defined, refer to compounds devoid of inherent flavor at effective concentrations yet capable of intensifying or enhancing the taste of food. However, in the industry, these terms are sometimes used more broadly, encompassing any substances that improve the overall taste or aroma of a flavor profile.

Traditionally, genuine flavor potentiators include table salt, monosodium glutamate (MSG), and specific nucleotides such as adenosine-5′-monophosphate (ADP), guanosine-5′-monophosphate (GMP), and inosine 5′-monophosphate (IMP). Both MSG and 5′-nucleotides are commonly found in foods, imparting their distinctive umami taste at industry usage levels [22].

MSG, initially a byproduct of the sugar industry, is now predominantly produced through fermentation [23]. Originally sourced from fresh fish muscle, 5′-nucleotides faced challenges in maintaining freshness and economic recovery from fish muscle. This led to their current production via enzymatic hydrolysis of RNA or fermentation. While table salt is conventionally classified as a basic taste agent, it also functions as a flavor potentiator. The absence of salt renders foods bland, emphasizing its crucial role in sensory perception. However, concerns about salt's association with health issues, such as hypertension and cardiovascular diseases, have prompted research into salt substitutes, with potassium chloride being a notable example, despite its bitter taste.

Additional compounds classified as flavor potentiators include Beefy Meaty Peptide (BMP), Umami Tasting Glutamate Conjugates, Alapyridaine, dioctyl sodium sulfosuccinate (providing freshness), N, N′-di-O-tolylethylenediamine, and cyclamic acid. These compounds have found applications in specific dairy products. Sweetness potentiators, such as Maltol, Ethyl Maltol, and Cyclic Enolones [24], also contribute to enhancing the sweetness of certain food products.

Flavor Production

Liquid Flavor Production: The production of liquid flavors involves a chemical blending operation in a dedicated production area equipped with raw material storage, weighing, mixing, and packaging equipment. While some volatile chemicals are refrigerated and potent flavor chemicals are stored in well-ventilated rooms, the majority are kept at room temperature. Mixing tanks, ranging from 5 to several hundred gallons, equipped with air-driven motors, are used to minimize fire or explosion risks. Electronic weighing and computerized controls, introduced as recent innovations, enhance the precision of this process, crucial for avoiding costly errors in flavor formulation [6].

Emulsions: Emulsions play a vital role in the flavor industry for carrying product flavor or imparting turbidity to a product. They are employed in various applications, including beverages, baker's emulsions, and the manufacturing of oil-soluble dry flavorings. Emulsions provide cost advantages for delivering water-soluble flavorings, although they are physically unstable and require preservation against microbial spoilage. Emulsions are categorized based on particle size, with microemulsions having an average small particle size. Homogenizers, such as valve homogenizers, rotary colloid mills, ultrasonic vibrators, and Microfluidizers, are utilized to create emulsions efficiently. These devices contribute to breaking down oil droplets and ensuring a fine emulsion, with each type offering specific advantages in terms of efficiency and particle size control (Figure 1).

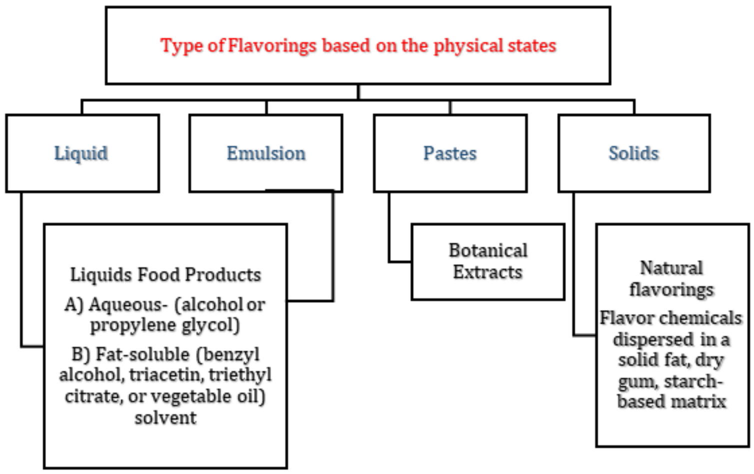

Figure 1: Type of flavourings based on the physical state.

Dry Flavorings: The food industry often requires flavorings in a dry form, achievable through plating or encapsulation methods. Plating involves spreading flavoring substances onto edible bases like sugar, salt, or whey. Encapsulation, on the other hand, incorporates flavor ingredients into a solid matrix using various materials such as starches, gums, proteins, lipids, or cyclodextrins. These processes may serve to convert liquid flavorings into a more convenient solid form, provide protection against factors like evaporation, oxidation, light, moisture, and achieve controlled release in a food product.

Flavor Encapsulation and its Objectives: The primary goal of flavor encapsulation is to improve the stability of flavor compounds, protecting them from oxidative and thermal damage during the processing of foods. This not only helps in preserving the original taste but also enhances the overall quality of the product. Additionally, encapsulation aims to improve the functionality of food products by manipulating particle size, shape, and structure [25]. Microencapsulation and nanoencapsulation are two advanced techniques that have gained prominence in the field of flavor encapsulation. Microencapsulation involves enclosing flavor compounds within micro-sized particles. Microencapsulation different techniques were mentioned in Table 1 [26].

Mechanical Techniques	Spray drying
	Fluidization bed coating
	Spray cooling/chilling
	Extrusion
Chemical Techniques	Molecular inclusion
	Interfacial polymerization
	Coacervation
	Co-crystallization

Table 1: Different techniques for microencapsulation of flavours.

- **Spray-Drying:** is favored for its equipment availability, simplicity, versatility in encapsulating agents (80-90%), large-scale production capabilities, efficiency, and cost-effectiveness. However, it poses challenges, such as potential aroma loss due to chemical reactions or volatile diffusion during the process. Spray-drying is extensively used for microencapsulation of Essential Oils (EOs), employing materials like polysaccharides (e.g., chitosan, carrageenan). The process involves dispersing the ingredient in a carrier, atomizing the mixture in a spray-drying chamber, and utilizing hot air for efficient drying [27].

- **Spray-Chilling:** akin to spray-drying, is employed for microencapsulation, particularly with lipid-based wall materials. It requires a cooling chamber instead of a drying chamber, providing an alternative with lower flavor loss and controlled particle size [28].
- **Melt Extrusion:** a traditional technique, involves melting the polymer with a plasticizer and mixing it with the compound to be encapsulated [29]. The resulting melt is forced through an extruder, forming solid particles upon quick drying. Co-extrusion allows the formation of core-shell particles, offering versatility for carbohydrates and starch-based polymers.
- **Coacervation Process:** Coacervation, have been extensively employed since the 1950s for micro- and nanoencapsulation of various compounds. Coacervation involves phase separation, forming a polymer-rich phase (coacervate) under specific conditions. It can be categorized as simple, where the polymer is salted out or desolvated, and complex, primarily driven by attractive forces between oppositely charged polymers [30].

Molecular Inclusion: The process of molecular inclusion, especially with cyclodextrins, involves trapping flavor molecules within cavities, providing a unique method for achieving stability, solubilization, and flavor modification. Cyclodextrins (CyDs), cyclic oligosaccharides derived from starch, form inclusion complexes with guest molecules [31]. These complexes offer benefits like flavor modification, stabilization, and solubilization. While CyDs have been known for some time, their use in food applications faced regulatory challenges. The cost of CyDs remains a significant factor limiting widespread industry adoption. Their unique ability to isolate one compound from others, providing unparalleled stability, makes them suitable for niche applications [32]. Nanoscale delivery systems, particularly nanoencapsulation, have gained greater interest due to their superior functional properties. Nanoencapsulation involves the creation of particles with dimensions at the nanoscale [26].

Nanocarriers

- Lipid-based nanocarriers (nanoemulsions, nanolipid carriers).
- Nature-inspired nanocarriers (caseins, cyclodextrins, amylose).
- Special equipment-based nanocarriers (electrospinning/electrospraying, nanospray dryer, micro-/nanofluidics).
- Biopolymer-based nanocarriers (single biopolymer nanoparticles, complex biopolymer nanoparticles, nanogels, nanotubes/nanofibrils).

Electrospinning and Electro-Spraying: are electrohydrodynamic processes utilized for flavor encapsulation. These methods produce micro- or nanofibers using a high voltage potential or liquid atomization through electric forces. Different polymers, such as cellulose derivatives and biodegradable polyesters, have been explored, offering promise for encapsulating heat-sensitive compounds [33].

Benefits of Advanced Encapsulation Techniques:

- **Increased Encapsulation Efficiency:** Both microencapsulation and nanoencapsulation techniques provide higher encapsulation efficiencies, ensuring more effective preservation of flavor compounds.
- **Controlled Release:** These techniques allow for controlled release profiles, influencing the timing and intensity of flavor perception during consumption.
- **Improved Stability:** Nanoencapsulation, in particular, offers superior stability, preventing flavor degradation even under challenging conditions.
- **Enhanced Bioavailability:** The advanced techniques contribute to increased bioavailability of encapsulated ingredients, improving their absorption and utilization within the body Premjit, et al [34-36].

Conclusion

In conclusion, the intricate world of flavors in food represents a captivating blend of natural and artificial elements, each contributing significantly to the sensory experience of consuming food. Natural flavors, derived from plants, herbs, spices, and fermentation processes, not only add aroma but also offer potential health benefits. Artificial flavors, while crafted to replicate real ingredients, have become indispensable in the food industry, utilizing compounds like terpenoids, phenolics, esters, ketones, and alcohols. Moreover, flavor enhancers like MSG and nucleotides play a pivotal role in enhancing the overall taste profile of foods. The production of flavors involves complex processes such as liquid flavor production, emulsions, and dry flavorings. Furthermore, flavor encapsulation, particularly through microencapsulation and nanoencapsulation techniques, has revolutionized the food industry by providing effective solutions for preserving and enhancing flavors [37-39].

Scope of Flavour Encapsulation

Looking ahead, the future of flavor encapsulation holds immense potential, particularly in the realm of food technology. Advancements in encapsulation techniques will enable flavors to be securely locked into various matrices, leading to enhanced shelf stability, controlled release, and improved product quality. This technology is poised to drive innovation in the food industry, facilitating the development of new products with intense and long-lasting flavors. Moreover, as consumer demand for natural and clean-label products continues to grow, flavor encapsulation offers a sustainable solution for delivering authentic flavors without artificial additives or preservatives. Additionally, the rising popularity of personalized nutrition and functional foods presents an opportunity for tailored flavor encapsulation to meet individual preferences and dietary needs, opening up new avenues for product customization and innovation. Overall, the future of flavor encapsulation appears promising, with potential applications across various sectors including food, beverage, pharmaceuticals, and beyond.

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