Chapter 1

Herbs and Spices in Food Industry

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Abstract

Herbs and spices are aromatic products, either fresh or dried, derived from plants, utilized to enhance the flavor of both plant and animal-based foods. Herbs are typically derived from the leaves of plants, whereas spices originate from seeds, roots, bark, fruits, berries, arils, pods, and flowers. Herbs and spices have played a fundamental role in the evolution of global food cultures. Beyond culinary applications, they hold religious, economic, medicinal, and political significance. Their trade shaped empires, and their aromatic and preservative qualities enriched home cooking and industrial food production deeply. In ancient civilizations, spices and herbs were regarded as superfoods endowed with mythical medicinal properties.

1. Introduction

The Codex Alimentarius defines spices as aromatic seeds, buds, roots, rhizomes, bark, pods, flowers or their components, berries, or other fruits from various plants, utilized in modest amounts to enhance the flavor of foods (CODEX, 2015). They are predominantly utilized in their dried form as seasonings. It is logical to categorize all plants whose leaves are utilized for their aromatic qualities. Herbs may be utilized fresh in domestic kitchens or restaurants, where their delicate aromatic qualities are optimally preserved; however, the predominant portion of the market relies on dried herbs. Herbs primarily pertain to the Lamiaceae and Umbelliferae families (Lai & Roy, 2004; Vázquez-Fresno et al., 2019).

Spices and herbs have been accessible to humans for an extensive period. Recent archaeological discoveries in the Swiss Jura mountains have revealed

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fennel seeds from the Neolithic period (5000 B.C.). Chile peppers, a fundamental seasoning in contemporary cuisines, originated in the Andes and were utilized as early as 10,000 years ago. Archaeological excavations in Mexico have uncovered chile pepper remnants that date to 7000 B.C (Raghavan, 2006).

Herbs and spices have traditionally functioned as crucial flavoring agents and important food preservatives owing to their inherent phytochemical properties (Alicozaman et al., 2024; Norris & Dahl, 2013). Their incorporation into culinary traditions spans millennia, with evidence indicating that spices like pepper and cinnamon were exchanged along the Spice Road and regarded as currency. The consistent rise in global production and consumption of herbs and spices over the last twenty years underscores their sustainable significance in modern diets (Blanton, 2020).

Since the early ages, the main trade route from South Asia to Europe is known as the 'Spice Road'. The spice route in history encapsulates a multifaceted and transformative trade network. It was not merely a passage for spices but a dynamic system that stimulated economic prosperity, fostered intercultural dialogue, and reshaped global political and social structures over many centuries (Torr, 2021; Xu, 2021;Winter, 2021).

Consumer demand for dried products that retain most of the original characteristics of fresh products is increasing. To meet this consumer demand, it is essential to consider drying methods that preserve the taste, aroma, color, nutrients, and texture of the plants to the greatest extent possible (Crivelli et al. 2002; Hossain et al., 2022). In addition to quality concerns, drying efficiency is a crucial factor for evaluating drying performance, encompassing total energy consumption, drying duration, drying rate, and related metrics.

Numerous conventional drying techniques have been employed in the processing of herbs and spices, including solar drying (Özcan et al., 2005), hot air drying (Demiray & Tulek, 2014), vacuum drying (Wang et al. 2018), and microwave drying (Arslan et al. 2010). Nonetheless, nearly all these methods necessitate prolonged drying times and substantial energy expenditure, consequently yielding processed samples of subpar quality (Moses et al. 2014; Karam et al., 2016; Hossain et al., 2022). They must be processed under appropriate drying conditions due to their high sensitivity to heat.

1.1.Herbs and Spices

1.1.1.Herbs

Herbs are fragrant components of a plant utilized for seasoning, fragrance, medicinal purposes, or ceremonial practices (D. Ibáñez & Amparo Blázquez Ferrer, 2019). Commonly utilized herbs encompass basil, bay, borage, chamomile, chervil, dill, fennel, garlic, mint or peppermint, oregano, parsley, rosemary, sage, tarragon, and thyme. Herbs may originate from leaves, flowers, or stems and can be utilized in either dried or fresh forms. Certain herbs, such as basil, are prevalent in Asian culinary practices. Herbs differ from spices as spices originate from various parts of a plant. Dried herbs or whole leaves frequently possess a distinctive flavor due to the presence of essential oils.

Fresh herbs are also known as culinary herbs. They possess a significant water content, and their aromatic qualities are most pronounced when fresh. Certain herbs, such as parsley, chervil, and chives, endure freezing effectively when minced, preserving their color and aroma, thereby allowing for their continued domestic utilization during winter. Nonetheless, their industrial application is confined to restaurants. Oregano and thyme both possess elements that enhance their flavors. Herbs are utilized to enhance the flavor of numerous dishes. In Asia, fresh herbs are predominantly utilized in culinary practices, whereas in the West, dried herbs are more prevalent Kumar Saini et al., 2021. Certain plants, including rosemary and bay, are predominantly utilized in their desiccated state akin to spices. Fresh herbs are typically incorporated at the final moment or immediately prior to serving to preserve the volatile oils. These oils enhance the flavor and fragrance of the food. The desiccated and pulverized form of mint is prevalent in mint tea and occasionally utilized in lamb dishes. Dried herb powders are similarly incorporated into the majority of curries (Kumar Saini et al., 2021).

1.1.2.Spices

The Food and Drug Administration (FDA) defines spices as “aromatic vegetable substances, in whole, broken, or ground form, whose primary purpose in food is seasoning rather than nutrition” (Vázquez-Fresno et al., 2019). The term spice originates from the Latin word ‘species,’ which denotes plants utilized for both medicinal and flavoring purposes.

Spices are generally used in foods to give flavour and aroma, and they are also used to prevent food spoilage because they contain antioxidant substances in their structure. They are also effective as antimicrobial agents

in preventing the development of microorganisms due to the essential oils they contain. Spices are also widely used in the food, pharmaceutical and cosmetic industries due to their essential oils and components.

Spices are the desiccated components of plants primarily utilized for enhancing the flavor of food, particularly in cuisines characterized by robust flavors, as well as in sauces, gravies, pickles, pastes, curry powders, and preparations of fish and meat (Ayoade et al., 2023). They are utilized in medical applications and have a historical precedent for preserving meat, augmenting consumer appeal, and functioning as antioxidants. Whole spices possess significant health benefits, including antioxidant, antimicrobial, antifungal, anti-tumor, anti-inflammatory, and antidiabetic properties. They are recognized for alleviating unpleasant food odors, enhancing thirst, salivation, and appetite, and are deemed carminative. Spices such as clove, nutmeg, cumin, and saffron are recognized for their stimulatory qualities (Puvača, 2022; Dhulipalla et al., 2023; Modupalli et al., 2022). Spice tea is typically prepared using spices like cardamom, ginger, and cinnamon to alleviate cough, cold, and flu symptoms

Spices contain mineral elements that support normal bodily functions and promote bone health. Calcium, phosphorus, potassium, magnesium, zinc, and sodium are essential in regulating blood pressure, oxidative stress, energy production, and metabolic functions. The presence of sodium and calcium in specific spices may aid in the prevention of kidney stones. Iron present in spices is crucial for hemoglobin formation, red blood cell production, and DNA synthesis. Iron supplementation results in weight gain and enhanced hematological parameters (Ayoade et al., 2023).

The human tongue is capable of perceiving five fundamental tastes: sweet, sour, salty, bitter, and umami (savory). Spices can affect these tastes in multiple ways, not only by directly stimulating taste buds but also through their aroma, which can modify flavor perception. These compounds are released when a spice is ground, cooked, or chewed (Raghavan, 2006).

Spices give characterizing tastes and aromas (Table 1). They give six basic taste perceptions: sweet, salty, spicy, bitter, sour, and hot. The other descriptive terms include pungent, umami (brothy, MSG, or soy-sauce-like), cooling, and floral, earthy, woody, or green. Most spices have multiple flavor profiles. Fennel has sweet, bitter, and fruity notes; tamarind exhibits fruity and sour notes; whereas cardamom features sweet and woody notes (Raghavan, 2006).

Table 1. The Sensory Characteristics of Spices (Raghavan, 2006)

Sensory characteristic	Spices or other flavourings
Bitter	Clove, Fenugreek, Thyme
Cooling	Spearmint,Basil, Anise
Earthy	Turmeric, Saffron, Turmeric,
Floral	Lavender, Lemongrass, Sweet basil,
Fruity	Coriander, Tamarind, Star anise
Herbaceous	Fennel, Rosemary, Parsley
Hot	Mustard, Pepper, Chile peppers
Nutty	Cumin seed, Sesame seed, Mustard seed
Piney	Rosemary, Thyme, Bay leaf,
Spicy	Ginger, Cumin,Ginger,
Sour	Sumac, Kokum, Caper
Sulfury	Chives, Garlic, Onion
Sweet	Cinnamon, Anise,
Woody	Juniper, Cassia, Rosemary

Spices are utilized in various forms. Certain varieties are utilized as components in curry powder, while others are employed as toppings for fruits, nuts, and pastries. Certain spices with distinct characteristics impart varied flavors; for instance, caraway and poppy seeds provide sweetness, while pepper contributes heat to dishes. Mint and basil represent a distinct category of herbs that impart a cooling effect to chilled dishes. Spices are frequently boiled to extract their flavor while discarding the solid remnants. Saffron is the most expensive spice (Kothari et al.2021; Álvarez et al.2024).

1.2.Chemistry and composition of herbs and spices

Herbs and spices represent a remarkably diverse category of plant-derived substances whose composition and chemistry have been extensively studied. Their chemical composition consists of various bioactive compounds, such as polyphenols, flavonoids, essential oils, terpenoids, and trace elements, all of which contribute to their distinct sensory attributes and health advantages (Shan et al., 2005).

The overall flavor, taste, aroma, texture, or color imparted by a spice to food or beverage dictates its efficacy in a recipe or formulation. Each spice or flavoring comprises dominant chemical constituents that produce these sensory attributes. The chemical compounds of a spice can impart

flavors ranging from mild to strong. The composition of these chemical compounds imparts a spice its distinctive flavor profile (Raghavan, 2006).

Polyphenols and flavonoids present in herbs and spices are essential for their antioxidant activity and potential disease-modifying effects. Phenolic diterpenes, including carnosic acid, carnosol, and rosmanol—found in *Labiatae* family spices such as rosemary and sage—substantially enhance the antioxidant capacity of these plants (Shan et al., 2005). Simultaneously, the analysis conducted by Yashin et al. (2017) emphasize the antioxidant properties of spices, highlighting the function of polyphenols in neutralizing free radicals and safeguarding against lipid peroxidation. Supporting these findings, Opara and Chohan (2014) highlighted that the various polyphenolic compounds may function synergistically, indicating that their bioactive properties could manifest even at the low concentrations commonly found in herbs and spices.

Besides polyphenols, herbs and spices are distinguished by volatile essential oils and terpenoids, which contribute to their unique aromas and flavor profiles. The composition of these essential oils is known to fluctuate based on factors including geographical origin, plant variety, age, and processing techniques (Sospedra et al., 2010). Essential oils not only enhance flavor but also exhibit antimicrobial properties, as evidenced by studies demonstrating inhibitory effects against pathogenic bacteria (Vitullo et al., 2011). The interaction between these volatile compounds and other antioxidants is essential for culinary purposes and the modulation of gut microbiota, as polyphenols from herbs and spices have been demonstrated to promote a healthy intestinal environment (Wilson et al., 2024).

Moreover, specific herbs and spices possess unique compounds like kynurenic acid (KYNA), with significant concentration variability across various species. Turski et al. (2015) indicated that basil possessed KYNA concentrations approximately 140 times greater than those present in black pepper, underscoring the diverse array of bioactive chemical compounds inherent to these plants. These findings elucidate the intricate chemical ecology of herbs and spices, wherein minor constituents may exert considerable physiological effects.

Table 2 summarizes the primary flavor compounds present in the principal herbs and spices utilized by the food industry. Certain flavor compounds in spices are water-soluble, while many others are soluble in oil or fat. Typically, the flavors of a spice require time to permeate the food; therefore, spices are incorporated early in the cooking process. This differs

from herbs, which are typically incorporated later in the preparation process (Sharangi et al.,2019).

Table 2. Main Flavor Compounds in Herbs and Spices (Sharangi et al.,2019)

Type of herbs and spices	Flavor compound
Allspice	Eugenol, caryophyllene
Anise	(E)-anethole, methyl chavicol
Basil, sweet	Methylchavicol, linalool, methyl eugenol
Bay laurel	1, 8-cineole
Black pepper	Piperine, S-3-Carene, β-caryophyllene
Caraway	d-carvone, carone derivatives
Cinnamon, cassia	Cinnamaldehyde, eugenol
Chili	Capsaicin, dihydro capsaicin
Coriander	d-linalool, C10-C14–2- alkenals
Cumin	Cuminaldehyde
Fennel	(E)-anethole, fenchone
Ginger	Gingerol, Shogaol, geranial
Marjoram	e- and t-sabinene hydrates, terpinen-4-ol
Mustard	Allyl isothiocynate
Origanum, Oregano	Carvacrol, thymol
Parsley	Apiol
Peppermint	1-menthol, menthone, menthfuran
Rosemary	Verbenone, 1–8-cineole, camphor, linanool
Saffron	Safranal
Sage, Clary	Salvial-4 (14)-en-1-one, Linalool
Thyme	Thymol, carvacrol
Turmeric	Turmerone, Zingeberene, 1,8-cineole
Vanilla	Vanillin

1.3.Health benefits and nutritional value of herbs and spices

Spices and dried herbs are commonly consumed items integral to the diets of individuals worldwide. Fresh aromatic spices, spice extracts, and spice oils are utilized in various culinary preparations, particularly in ethnic cuisine. Mexico, India, and numerous Latin American and Asian nations are renowned for their abundant traditions of spices and dried herbs. In recent years, there has been a significant rise in the production value of fresh spices and dried herbs, accompanied by rapid expansion in the global trade of these commodities. Herbs and spices, although ingested in minimal amounts, have garnered considerable interest due to their rich bioactive compounds that provide various health advantages and improve nutritional quality (Rakhi et al., 2018; Tapsell et al., 2006). They are abundant in phytochemicals,

including polyphenols, flavonoids, essential oils, and vitamins, which contribute to a wide range of biological activities.

Data-driven analyses demonstrate that spice consumption correlates with antimicrobial and anti-infective properties, alongside a reduced risk of various chronic diseases (Rakhi et al., 2018; Tapsell et al., 2006). This bioactivity is primarily ascribed to compounds that mitigate oxidative stress and inflammation, processes associated with numerous degenerative conditions (Serafini & Peluso, 2017).

The antioxidant capacity of herbs and spices is among their most significant nutritional attributes. Research has shown that numerous prevalent spices contain significant amounts of phenolic compounds and flavonoids, which mitigate oxidative damage in biological systems and enhance food stability by inhibiting lipid peroxidation (Kähkönen et al., 1999). Thyme, characterized by its significant thymol and carvacrol concentrations, exhibits strong antioxidant and antimicrobial properties, thereby fulfilling dual functions in food preservation and health enhancement (Kähkönen et al., 1999; Witkowska et al., 2013). Culinary research indicates that the effectiveness of bioactive compounds is affected by cooking conditions; moderate heat can preserve or enhance the availability of antioxidants in herbs and spices, while excessive temperatures may degrade these beneficial components (Aphrodite et al., 2021).

In addition to offering antioxidant advantages, herbs and spices enhance metabolic health by influencing the gut microbiota. Recent evidence indicates that specific spice extracts possess prebiotic properties, thereby fostering a balanced gut microbiota, which is crucial for comprehensive digestive and immune health (Lu et al., 2017). The interplay between dietary elements and gut microbiota enhances the functional advantages of integrating herbs and spices into the diet, presenting a promising supplementary approach for the prevention of diet-related diseases (Serafini & Peluso, 2017).

Herbs and spices have long been acknowledged for their capacity to enhance the sensory attributes of food, as well as for providing substantial health benefits that surpass fundamental nutrition. Their concentrated profiles of bioactive compounds—comprising polyphenols, flavonoids, essential oils, vitamins, and minerals—exhibit a variety of pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, anti-diabetic, cardioprotective, and anticancer effects (Spence, 2024; Jiang, 2019; Khanal et al., 2021).

The nutritional value of herbs and spices primarily stems from their elevated levels of phytochemicals, which function as powerful antioxidants. These compounds can mitigate the harmful effects of oxidative stress by neutralizing reactive oxygen species and binding pro-oxidant metals. Research has shown that spices like cinnamon, clove, and turmeric are abundant in polyphenols and flavonoids, which aid in reducing cholesterol levels and regulating blood glucose (Jiang, 2019; Khanal et al. 2021; Paswan et al. 2021). Moreover, incorporating these ingredients into the diet has been demonstrated to interfere with pathways that contribute to chronic inflammation, a significant factor in the onset of cardiovascular diseases and other metabolic disorders (Spence, 2024; Khanal et al., 2021).

In addition to their potent antioxidant properties, herbs and spices offer multifaceted health benefits via various mechanistic pathways. Their bioactive compounds can influence critical signaling pathways related to cellular proliferation and apoptosis. Recent research has underscored the significance of these compounds in the prevention and treatment of colorectal cancer by modulating signaling molecules such as BCL-2 and K-ras, thereby demonstrating anti-tumorigenic potential (Hossain et al., 2022; Kaefer & Milner, 2008). Furthermore, the antimicrobial properties of herbs and spices not only aid in food preservation by suppressing microbial proliferation but also bolster the immune system by diminishing the load of pathogenic microorganisms in the gastrointestinal tract (Khanal et al., 2021; Bukvički et al., 2020).

The nutritional composition of these ingredients is enhanced by the inclusion of trace elements and additional micronutrients. Investigations employing scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) have demonstrated that herbs and spices may harbor diverse trace minerals—including magnesium, aluminum, potassium, and molybdenum—that, despite their low concentrations, enhance both their nutritional significance and biochemical functionality (Hashim & Embong, 2022). Concurrently, research has emphasized supplementary nutritional components, including carotenoids and other antioxidants, which augment their advantageous attributes beyond simple flavor enhancement (Drewnowski, 2024).

The conventional application of herbs and spices in diverse medical systems has substantiated their potential as functional foods and nutraceuticals. Reviews of ethnobotanical data across various countries have systematically recorded the antimicrobial, antidiabetic, antihyperlipidemic, and hepatoprotective properties of indigenous herbs and spices (Khanal

et al., 2021). This ancient knowledge is currently being corroborated by contemporary scientific research that emphasizes its role in regulating essential biochemical pathways associated with chronic diseases. The integration of herbs and spices into functional food products has emerged as a trend to enhance conventional foods with supplementary health benefits, thereby connecting traditional practices with contemporary nutritional science (El-Sayed & Youssef, 2019).

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