

Raj nibhas Sukeaw Samakradhamrongthai *Editor*

Aroma and Flavor in Product Development: Characterization, Perception, and Application

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*To every reader who finds a piece
of themselves
within these chapters
To my mother
To the person I was, the person I am,
and the person I will be*

Foreword

In the dynamic landscape of the food industry, aroma and flavor stand as pivotal elements, playing a vital role in research and development (R&D) endeavors. These attributes not only enhance palatability but also drive innovation in food formulations and product development. It is within this context that the author/editor, Rajnibhas Sukeaw Samakradhamrongthai, draws upon a wealth of experience and extensive research in aroma and flavor technology to present this comprehensive volume. As an experienced researcher in the field, Rajnibhas Sukeaw Samakradhamrongthai has devoted years to immersing himself in the nuances of aroma and flavor technology. Under the mentorship of esteemed supervisors, his journey in this domain has been guided and enriched. Their insightful guidance and encouragement propelled him to delve deeper into the intricacies of flavor science, culminating in the creation of this seminal work. Through painstaking investigation and scholarly inquiry, he has amassed a wealth of knowledge and insights, meticulously woven into the fabric of this completed book.

This book serves as a repository of knowledge, delving into the intricate realm of aroma and flavor substances found in natural products. From volatile to non-volatile compounds, each element serves as a stimulus to human perception, meticulously explored in Chap. 2. The technology of extraction, outlined in Chap. 4, facilitates the isolation of flavor compounds, followed by their identification and characterization in Chap. 5. Leveraging these insights, flavorists can craft unique aromas and flavors, driving innovation in product development, as elucidated in Chaps. 3 and 6. Recognizing the imperative of preserving flavor integrity over time, Chap. 7 underscores the significance of technologies for extending shelf life. Encapsulation technology, discussed in Chap. 8, emerges as a formidable tool for safeguarding flavor components against thermal processing and storage conditions. Furthermore, Chap. 9 explores controlled release technology, offering promising avenues for enhancing existing food processes and the development of functional foods. The intricate interplay between aroma, flavor, and food matrix is dissected in Chap. 10, shedding light on their profound implications for food product applications. Finally, the authors present an overview of current research trends in aroma and flavor, offering readers a glimpse into the evolving landscape of this dynamic field.

In summation, the contents of this book are invaluable to anyone seeking to deepen their understanding and proficiency in aroma and flavor aspects. It serves as a beacon of knowledge, guiding practitioners, researchers, and enthusiasts alike toward new horizons of sensory exploration and culinary innovation.

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Preface

Aroma and flavor are attributes that are among the diagnostic aspects of food quality. They are considered important properties that indicate the preferred quality of food products. There is no single knowledge or analytical technique that can be used for the investigation of aroma and flavor compounds, which include all volatile aroma compounds in both raw materials and food products.

In this book, the essential information related to the aroma and flavor of both chemistry and technology is compiled together to provide a comprehensive and up-to-date overview of the body of knowledge. The science and technology related to aroma, flavor, and volatile compounds is a section of general food science and technology that can provide an understanding of perception and cognitive functioning, the formation of food aroma and flavor, the extraction of volatile compounds, the determination of key volatile compounds and their characteristics, the encapsulation of flavor and volatile compounds, the interaction of food aroma and flavor, and flavor release.

The book is structured into 11 chapters that combine theory, methodology, science, and technological aspects with analysis, practical consideration, application, future developments, and a reference list. The aim is to provide a balance between theory and practice with enough theoretical aspects for readers, which include undergraduate and graduate students, to fully understand the background and underlying mechanisms of the techniques, and in many instances, enough detail to enable the reader to carry out the body of knowledge with appropriate methodology and practices.

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I would like to acknowledge the many individuals mentioned in all chapters for their efforts to provide an understanding of the field that is progressively revealing its mysteries. I would like to express gratitude to all my teachers for their contribution to their expertise and for guiding me along the right path which has been the most challenging and exciting. I also want to thank my students for teaching me in their unique research areas. I am confident they taught me more than I taught them.

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Chapter 1

The Overview



Raj nibhas Sukeaw Samakradhamrongthai 

1.1 Aroma and Flavor Components and Its Distinction

Regular consumers are primarily concerned with food quality in terms of both sensory quality and cost considerations. Farmers and manufacturers have worked very hard to meet consumer demands but research and innovation will still be needed to meet production optimization requirements resulting from energy conservation and environmental shortcomings. Consequently and in keeping with the notion and goal of compiling unique research on the sensory qualities and scent profile of foods. The combination of taste, odor and texture when eating creates an overall experience that is best described by the term “flavor” in English (McCrickerd et al. 2016). Such an all-encompassing word lacks an appropriate translation in German and a few other languages.

Compounds that produce flavor fall into two main categories: those that provide taste and those that produce scents, the latter of which are frequently referred to as aroma substances. Nonetheless, certain substances offer both experiences. At room temperature, most taste-producing compounds are nonvolatile. As a result, they only communicate with taste receptors found in the tongue’s taste buds. Sour, sweet, bitter and salty substances give the four essential fundamental flavor senses. They are discussed in different parts. The fifth fundamental taste is triggered by glutamate (Melis and Tomassini 2017).

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1.1.1 Aroma Components

Food aroma (smell, odor, fragrance) is one of the most essential sensory impressions and in most situations impacts the consumer's decision and acceptance of the product as well as allowing differentiation between different types of food such as bread, apple, honey and others. The scent is a sensory impression created by the stimulation of olfactory receptors by volatile substances released into the gas phase (aroma compounds, odorants, aroma volatiles, odor molecules). Most consumers identify it with a nice emotion, although it can also be interpreted as a bad attribute off-odor. The first impression of the substance is provided by the smell sensed orthonasally, i.e. inhaled by the nose with the mouth closed prior to the start of consumption. The molecules of aroma compounds that reach the fragrance receptors when eating or drinking (retronasally), coupled with taste and other sensations (touch, pain, etc.), form a complex of sensations known as the product's flavor. Many scholars believe that scent has a stronger impact on flavor perception than taste.

In recent years, there has been a lot of interest in the aroma composition of foods. The existence of volatile molecules and their composition are well recognized to determine the distinctive aroma of foods and the flavor of the ensuing goods. Many factors influence the content and amounts of volatile chemicals, including climatic and soil conditions, seasonal change, agronomical methods and processing. Sensory analysis on the other hand is used to objectively determine the intensities of the key sensory qualities and features of food as well as to assess preference. This type of analysis necessitates the use of a trained panel as well as ordinary consumers. Aroma substances are volatile compounds that are recognized by the odor receptor sites of the smell organ, i.e. the nasal cavity's olfactory tissue. They enter the receptors via the nose (orthonasal detection) and the throat after being released by chewing (retronasal detection). The concept of aroma substances like the concept of taste substances should be used with caution because a component may contribute to the usual odor or taste of one food while causing a defective odor or taste or both in another food resulting in an off-flavor.

While aroma is the fragrance that an object has, odor, also referred to as the sense of smell, is the method that the olfactory system uses to detect stimuli as a reaction to volatile compounds passing through the nasal membranes (Sánchez-Rodríguez et al. 2018). Aroma compounds are these vaporous substances that give an object its scent. Despite the incredibly low concentration of fragrance molecules (10–15 mg/kg) found in food matrices (Yeretizian et al. 2019). The quantity of components is surprisingly substantial (coffee, for example, has over 1000 recognized volatile organic compounds). Among all the various fragrance components that can be found in food matrices, chemicals associated with the food's distinctive aroma receive particular attention; these compounds are referred to as “character impact compounds” (Yeretizian et al. 2019). The lowest concentration of a compound at which an aroma compound can still be recognized for fragrance purposes is known as its odor threshold; this information is crucial since it allows one to compare the

intensity or potency of different compounds that belong to the same matrix. Food scent, in addition to flavor, is the primary factor influencing a consumer's selection of a product (Sánchez-Rodríguez et al. 2018). The food processing industry prioritizes the conservation of these chemicals in order to influence customer decisions in a highly competitive market. The industry's current focus is on developing new technologies and optimizing traditional processing methods due to the potential loss of total aroma compounds that can arise from typical thermal treatments. Among the fragrance substances particular focus is placed on those molecules that give the food its distinctive aroma; these are referred to as key odorants (character impact aroma compounds). Table 1.1 provides examples. The ability to distinguish odorants from the remaining volatile molecules in key foods has advanced significantly.

Aroma is an important flavor characteristic for fruit quality appealing to both manufacturers and consumers (Lewinsohn et al. 2001). Odor detection is linked to about 1000 olfactory genes and the aroma components influence human odor perception (Baldwin et al. 2000). Nearly 2000 volatile aroma components have been isolated in recent years from various plant species, including apple (*Malus domestica*), pear (*Pyrus ussuriensis*), and strawberry (*Fragaria ananassa*), and are classified as esters, aldehydes, alcohols, ketones, olefins, and acids (Espino-Diaz et al. 2016; Fu et al. 2017; Yan et al. 2020; Luo et al. 2021). More than 300 scent components have been found in apples. In 'Honeycrisp' apple, about 51 scent components have been found with esters being the most prominent (Yan et al. 2020); similarly, 53 aroma compounds in 'Fuji' apple comprise 27 esters, 12 aldehydes and 5 alcohols (Qi et al. 2020). Secondary metabolites associated with aroma components are mostly produced via fatty acid, carbohydrate, and amino acid metabolism (Schwab et al. 2008). Straight-chain aldehydes, alcohols, and esters are mostly produced in

Table 1.1 Examples of key odorants

Compound	Occurrence	Aroma
(R)-limonene	Orange juice	Citrus—like
(R)-1-p-menthene-8-thiol	Grapefruit juice	Grapefruit—like
Benzaldehyde	Almonds, cherries, plums	Bitter almond—like
Neral/geranial	Lemons	Lemon—like
1-(p-Hydroxy phenyl)-3-butanone (raspberry ketone)	Raspberries	Raspberry—like
(R)-(-)-1-octen-3-ol	Champignons, camembert	Mushroom—like
(E,Z)-2,6-nonadienal	Cucumbers	Cucumber—like
Geosmin	Beetroot	Earthy
trans-5-Methyl-2-hepten-4-one (fibertone)	Hazelnuts	Nut—like
2-Furfurylthiol	Coffee	Roasted
4-Hydroxy-2,5-dimethyl-3(2H)-furanone	Biscuits, dark beer, coffee	Caramel—like
2-Acetyl-1-pyrroline	White-bread crust	Roasted

the fatty acid metabolism route from linoleic acid ($C_{18:2}$) and linolenic acid ($C_{18:3}$). Terpenoids and amino acids are also significant as they contribute to many of the odor active components. In apple fruit, branched amino acids such as isoleucine (Ile), leucine (leu), and valine (val) are precursors of branched-chain esters. In addition to these, a recent study revealed that the citramalate pathway is involved in ester production during fruit ripening (Sugimoto et al. 2021).

1.1.2 Flavor Components

Food flavor perception is a complex process that involves the senses of smell, taste and chemesthesis (the common chemical sense; sometimes known as pungency or irritant). Each sense contributes unique features to a flavor by interacting with various sorts of chemical stimuli or by brain interactions that may modify the responses of the other senses. In this overview, we describe the major characteristics of flavor perception in the context of flavor production during the eating process the mechanisms of flavor reception and perception the interactions of the chemical senses and briefly the influence or role of flavor in food acceptance and nutrient intake, as well as the possibility of replacing humans with instruments for objective flavor measurement.

Flavor is a very complicated feeling that includes responses to texture the warmth of spices like pepper and the chilling of menthol. Taste experience is relatively limited. Taste is normally thought to be confined to salt, sweet, sour, bitter and sometimes metallic responses. Aroma is the most important factor in flavor perception. It is thought that humans can distinguish between thousands of different scents. Because fragrance is so important to flavor it is not surprising that a considerable fraction of analytical flavor studies have focused on the volatile elements of meals. This focus on volatile elements can be harmful. Cheddar cheese will never be able to match the flavor of researchers who only study a product's volatile ingredients. The flavor (bitterness, astringency, and acidity) and texture (graininess) of a well-aged wine. Cheddar and cheese are essential elements of its taste. No exquisite clear container of fragrance ingredients could ever replicate the taste of cheddar. However, the focus of this chapter is on the olfactory aspect of food flavor, which has garnered the majority of the attention from flavor scientists.

The intricacy of food flavor is one area of initial attention. More than 700 volatile substances have been found in the flavor of beef. It is predicted that food products will eventually include more than 10,000 distinct volatiles (Rijkens and Boelens 1975). These volatiles are representative of a wide range of chemical classes and functional groups in compounds. The nose's extraordinary sensitivity to some smells is a second cause for concern. Some nitrogen-containing heterocyclics and sulfur containing compounds have odor thresholds measured in parts per billion or trillion. This necessitates the concentration of the flavor prior to examination. Concentration of the flavor requires that the flavor be isolated from the food in order for concentration to be achievable. Now we must extract an exceptionally large

number of volatiles spanning a wide range of functional groups from a food and concentrate this extract for instrumental examination. Once more separating, quantifying and interpreting the analytical data obtained from a flavor isolate is an amazing task. Gas chromatography (GC) is commonly utilized as the preferred technique for analyzing flavor isolates. Even with GC is exceptional sensitivity and resolving capability it can be challenging to separate and identify specific taste compounds. The nose's ability to distinguish differences in sensitivity and scent character complicates the significance of GC results. For instance, ethanethiol at a similar concentration would have a very strong and distinct aroma, but ethanol has little to no aroma at all. Using GC, a noncritical analyst might conclude that these two substances had an equivalent impact on food flavor.

1.2 Source of Aroma and Flavor

Goods with flavor that come from plants or animals. They can be utilized unprocessed or transformed into consumable forms such spices and herbs for human consumption. Fruit extracts are used as natural flavorings in most cases. These flavors are combined with sugar, organic acids, water and other ingredients. They emit a distinct smell. The amount of flavors, sugar and acid in the final food product determines how it tastes. One of the most significant senses of food is smell. There might be just one kind of odorant present in food. However, the majority of them include a variety of flavors. Substances that readily evaporate into the atmosphere are known as odor substances. However, flavors are only specific kinds of volatile chemicals found in food.

1.2.1 Source of Aroma and Flavor from Plant

It is difficult to distinguish between excretion and secretion processes in plants since the products of both are typically stored in the same plant compartments. In general secretion is defined as the accumulation of secondary products of metabolism that are not immediately consumed and primary metabolites that are immediately involved in metabolic events in the cell. Secretory cells occur when epidermal or parenchymal cells differentiate and do not form real tissues. The structures responsible for the secretion have highly diverse morphologies and are located in different parts of the plant. In fact they can be found in both internal and external parts of the plant and can be a single secretory cell or multicellular secretory structure. In addition, they can produce a wide variety of products. Classify secretory structures according to their location in the body of the plant: external (the surface) or internal.

1.2.1.1 Internal Secretory Structure

Internal secretions are products that are kept within plant tissues sometimes for the entire life of the plant. Internal secretory structures are found in the cortical parenchyma of stems, leaves, roots and fruits, distant from the epidermis. Internal secretory structures are classified into three types:

Secretory cell Hardening cell that died after deposition or was detached from the protoplast's live cell. These are single cells that are unique from the cells around them. Some internal secretory structures produce oil, resin, latex, mucilage, tannins, oils, gums, and even crystallized substances. Many secretory cells contain mixtures of substances but the contents of many others have yet to be discovered. When the secretory cells appear as specialized cells, they are sometimes referred to as idioblasts more especially secretory idioblasts.

Secretory space Secretory cavities and ducts (canals) are distinct from secretory cells because they secrete substances into intercellular spaces. Secretory cavities are relatively short secretory spaces, whereas secretory ducts are rather lengthy secretory spaces. These gaps can emerge anywhere in the plant due to two different cellular processes: schizogeny and lysogeny. They are typically formed by the separation of cells from vascular or ground tissues which results in an intercellular space lined with secretory epithelial cells. As with most resin ducts these regions are known as schizogenous secretory cavities and ducts. They can also be originated by the disintegration and dissolution (autolysis) of the glandular cells. In this case the secretory product is formed in the cells that eventually break down, but the compounds remain in the resultant space. These spaces like the citric fruit is lysogenic cavities are known as lysogenic spaces. Some writers also regard schizolysogeny as a third form of development. The creation of schizolysogenous cavities and ducts is initially schizogenous (separation of intact cells) but later phases are lysogenous with autolysis of the epithelial cells lining the cavity increasing the space. The resin ducts in the bud scales of *pinus pinaster* are an example of ducts that develop in a schizolysogenous pattern (Fig. 1.1).

Laticifers Individual cells or groups of connected cells that contain a latex-like liquid. They can construct complicated tube-like structures when made up of many cells. They are divided into articulated and nonarticulated laticifers based on their structure. Nonarticulated laticifers are made up of long tube-like single cells, whereas articulated laticifers are made up of longitudinal chains of joined cells. Laticifers are a diverse group of plants that range from herbaceous to woody. Latex is a heterogeneous secretory substance that varies widely in appearance (color) and composition (it may contain carbohydrates, organic acids, salts, sterols, fats and mucilages) resulting in many different forms of latex (Fig. 1.2).

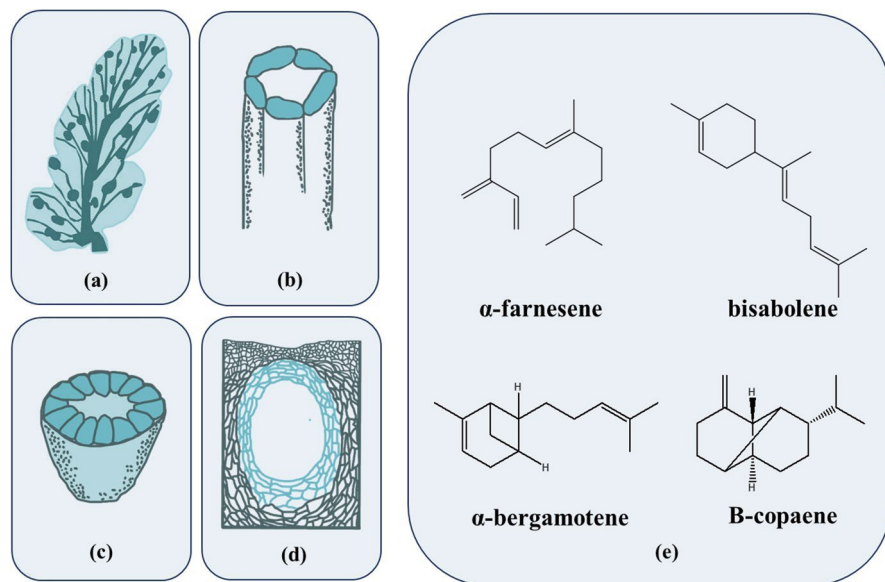


Fig. 1.1 The representations of secretory ducts and cavities: secretion bodies in fossilized pinules of seed ferns (panel **a**), a conifer resin blister (panel **b**), a conifer resin duct (panel **c**), and a secretory cavity of Citrus peel (panel **d**). (**e**) Structures of different classes of sesquiterpenes that occur in gymnosperm oleoresins

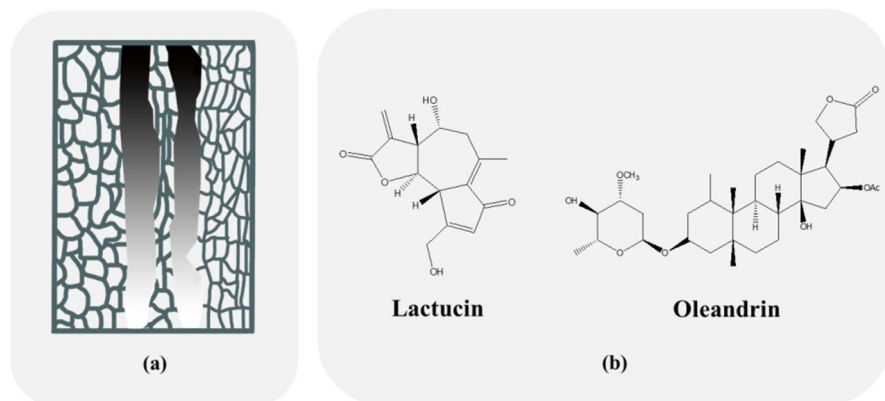


Fig. 1.2 The representation of articulated laticifers (red) (**a**) in the genus *Lactuca* (Asteraceae), (**b**) Representative structures of terpenoid classes commonly found in laticifers

1.2.1.2 External Secretory Structure

There are many secretory cells on the surface of plants either as unicellular or multicellular glandular trichomes in the epidermis or as part of the epidermal layer. These secretory cells are formed through the division and differentiation of

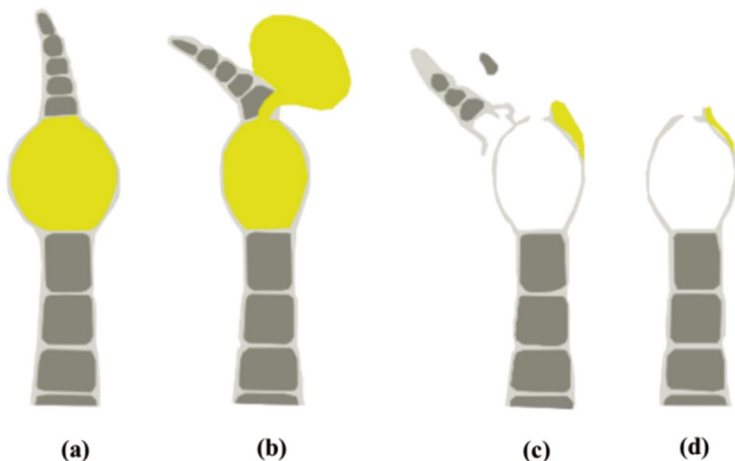


Fig. 1.3 Schematic representation of a suggested mechanism for the function of touch-sensitive glandular trichomes in seed ferns. A glandular trichome is shown (a) before an attack, (b) during the initial opening after insect contact, (c) during the exudation of secreted contents, and (d) at the postsecretory stage

epidermal cells. Some of them only release hydrophilic (water-loving) compounds whereas others release both hydrophilic and lipophilic chemicals. Stems, leaves, fruits and flowers all have surface secretory cells. For example there is a lot of secretion in petals and the molecules released generate the aroma of flowers. Although these cells are highly specialized in secretion all epidermal cells secrete chemicals that are deposited on their walls or released to the environment.

Glandular trichomes are external secretory structures found in around 30% of plant species. The scent of plants, for example is primarily due to the volatile compounds emitted by these structures. Glandular trichomes are often multicellular with glandular cells at the distal end linked to the epidermis by basal cells and others creating a stalk or peduncle. Some trichomes, however are unicellular. Glandular cells feature a main cell wall which is sometimes covered by a cuticle at the junction with stalk cells and a cytoplasm containing several organelles such as mitochondria, endoplasmic reticulum and Golgi cistern stacks. Glandular trichomes contain cells that release substances with different functions to the environment either volatile or substances that remain on the surface of the plant. Glandular cells can synthesize the molecules to be released even they have sometimes the ability to perform photosynthesis. It means that some glandular cells may live as rather independent units. However in other cases the molecular building blocks for synthesizing the compounds to be release are coming from the underlying plant tissues through the stalk cells of the trichome (Fig. 1.3).

Osmophores Secretory structures that secrete volatile compounds to produce the aroma of flowers. Plants that thrive in saline environments (halophytes) contain salt glands that produce ions, which is the best known mechanism for controlling the salt content of plant shoots.

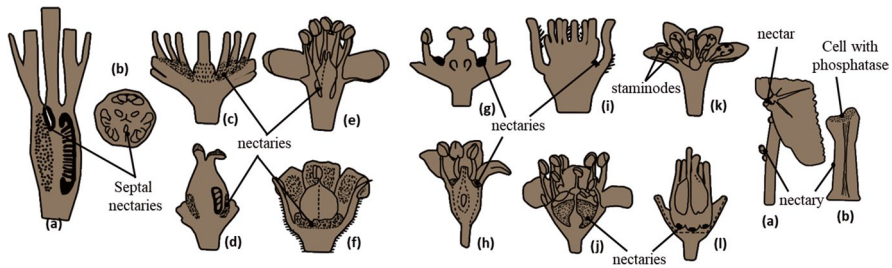


Fig. 1.4 The representation of nectaries structure; a glandular nectaries is shown (a) Nectarles. Longitudinal (a, c–l) and cross (b) sections of flowers. Septal, in Liliales, *Narcissus* (a) and *Gladiolus* (b), (c), external, at base of stamens (*Thea*, Theales). (d), ring at the base of the ovary (*Enydra*, Theales). (e), ring below stamens (*Coccoloba*, Polygonales) (f), disc below ovary *Jatropha*, Euphorbinles). (g), disc between ovary and stamens (*Perrot-fetia*, Celestrales). (h), disc above inferior ovary (*Mastixio*, Umbellales). (i), cushion of hair at base of sepal (*Corchorus*, Tiliales). (j). Jining floral cup (*Prunus*, Rosales). (k), modified stamens, staminodes (*Cinnamomum*, Laurales). (l), grand at bases of stamens (*Linum*, Geraniales)

Nectaries Secretory structures that produce sugar-rich solutions from phloem-supplied substances. There are two types of nectaries: floral nectaries, which are directly connected with pollination and extrafloral nectaries, which are found on the plant's vegetative portions. Nectary structure varies greatly from simple epidermal glandular surfaces to complex structures (Fig. 1.4).

Hydathodes Structures that release water with some substances from the interior of the leaf to its surface. This process is called guttation and occurs by water pressure coming from the root. Hydathodes are leaf modifications that can be seen along the margins or near the apex of the leaf. Structurally, hydathodes consist of (a) terminal tracheids of leaf nerves, (b) the epithem, which consists of thin-walled and few chloroplasts parenchyma cells located at the leaf nerve endings, (c) a sheath or envelope that is continuous with the epidermis (the sheath cells may be suberized and may even have Caspary bands), (d) a watery opening or pore (watery pores are small nonfunctional stomata who have lost the ability to regulate opening and closing). Although this is the general structure there may be changes such as the absence of the sheath or the epithem or the presence of an opening that is not a stoma. Although hydathodes are generally found at the margins and tips of leaves, certain species have them on the surface, which is known as laminar hydathodes. Although hydathodes are commonly linked with the release of water from plant tissues, several xerophytic species are specialized in the absorption of condensed fog or dew water, i.e. the reverse process. Active hydathodes, also known as trichome-hydathodes have been characterized by certain writers as glandular trichomes that discharge water. These structures would discharge water without being impacted by osmotic pressure hence they are called active as opposed to passive structures.

Mechanism for release Secretory chemicals can be released in a variety of ways. When the trichome is contacted and the cuticle is detached the secretory materials stored between the cell wall and the cuticle are released. In other circumstances, the

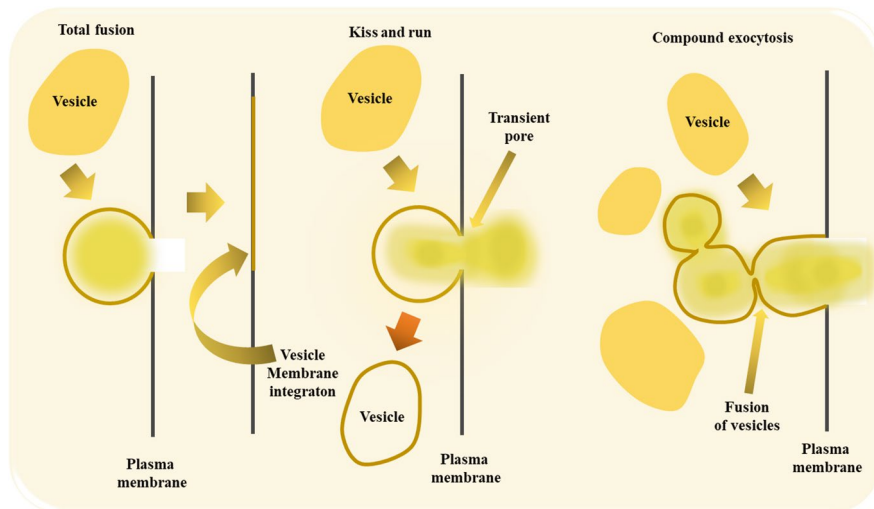


Fig. 1.5 Schematic representation of mechanism for release

cuticle contains tiny channels that allow chemicals to enter the environment. Some glandular cells store the chemicals in their cytoplasm for release when the cell ruptures. The precursor molecules are initially delivered to secretory cells via the stalk cells of the trichome however the final secretory products generated in the secretory cells do not return to the plant organs (Fig. 1.5).

1.2.2 Source of Aroma and Flavor from Animals

1.2.2.1 Secretion

Secretion is the transfer of material from one location to another, such as a chemical compound secreted by a cell or gland. Excretion, on the other hand, is the elimination of specific chemicals or waste products from a cell or organism. Cell secretion is traditionally accomplished through secretory gateways at the plasma membrane known as porosomes (Lee et al. 2012). Porosomes are lipoprotein structures embedded in the cell membrane that secretory vesicles dock and fuse with to discharge intra-vesicular contents from the cell. In bacterial species, secretion refers to the transport or translocation of effector molecules. Proteins, enzymes, or toxins can move from a bacterial cell's inside (cytoplasm or cytosol) to its outside. One of the most crucial mechanisms for bacterial survival and adaptation in their environmental surroundings is secretion. The secretion from animal can be categorized into 3 types.

Merocrine secretion Merocrine (or eccrine) is a term used in histology to classify exocrine glands and their secretions. A cell is defined as merocrine if its secretions are expelled from secretory cells into an epithelial-walled duct or ducts and then onto a body surface or into the lumen via exocytosis. The most prevalent type of secretion is merocrine. The gland discharges its product with no loss or injury to the gland (compare holocrine and apocrine). Although the terms eccrine and merocrine are frequently used interchangeably the term eccrine refers to merocrine secretions from sweat glands (Melo and González-Mariscal 2010).

Apocrine secretion The term apocrine is used for classifying exocrine gland secretion mechanisms. Apocrine secretion is the process by which material accumulated at the apical ends of secretory cells branches out from the cells to form extracellular vesicles. As a result during the secretion process the secretory cells lose some of their cytoplasm. Breast milk-secreting mammary glands are a prime example of real apocrine glands. Apocrine glands can also be located in the axillae and anogenital area. Compared to merocrine secretion (exocytosis), which destroys a cell, apocrine secretion causes greater damage to the gland than holocrine secretion (Murphy et al. 2022).

Holocrine secretion In histology, the term holocrine refers to the mechanism of secretion in exocrine glands. Holocrine secretions are created in the cell cytoplasm and released by the rupture of the plasma membrane which destroys the cell and causes the product to be secreted into the lumen (Yoshizawa 2018). Holocrine gland secretion is the most damaging sort of secretion, while merocrine secretion is the least damaging and apocrine secretion is in the middle. The sebaceous glands of the skin (Sundberg et al. 2018) and the meibomian glands of the eyelid are examples of holocrine glands. The sebaceous gland is an example of a holocrine gland since its secretory product is produced with dead cell remains (Fig. 1.6).

1.2.2.2 Excretion

Excretion is the process by which animals eliminate waste and nitrogenous byproducts of metabolism. Organisms control osmotic pressure (the equilibrium of inorganic ions and water) and maintain acid-base balance through excretion. As a result, the process promotes homeostasis, or the consistency of the organism's internal environment. From the smallest protist to the greatest mammal, every organism must clear itself of potentially dangerous by-products of its own important functions. This process is known as elimination in living things, and it can be thought of as including all of the numerous systems and processes by which life forms dispose of or fling off waste products, harmful compounds, and dead components of the organism. The nature of the process and the specialized structures generated for waste removal vary substantially depending on the organism's size and complexity (Ramsay and Kelley 2023) In contrast, secretion involves the material performing specified duties after it leaves the cell. Excretion is a necessary step in all living things. In mammals for example urine is ejected by the urethra which is part of the

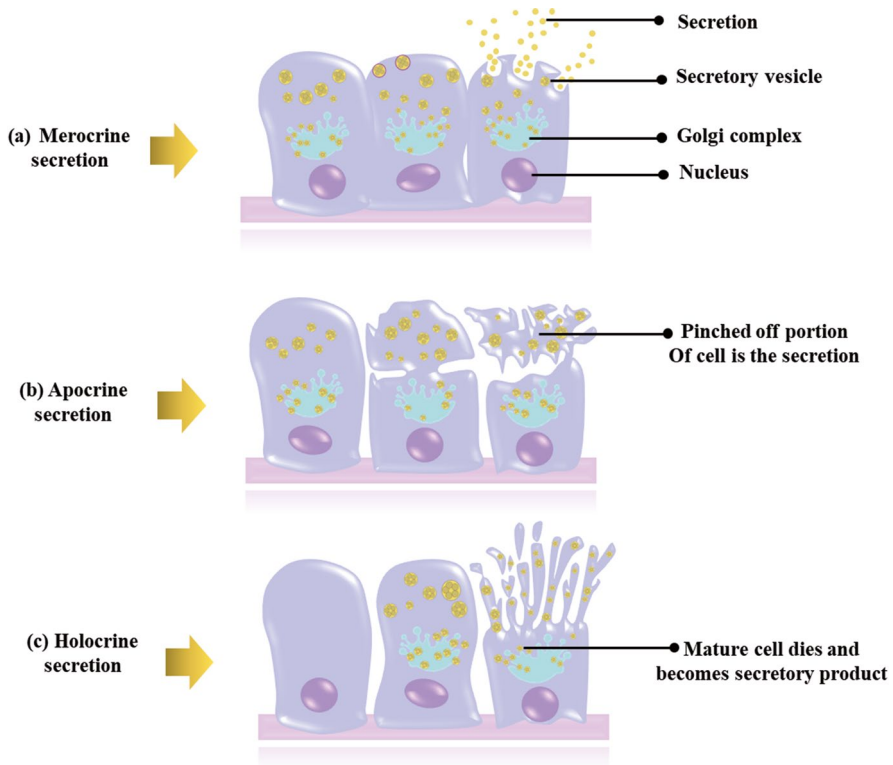


Fig. 1.6 Type of cell secretion; (a) merocrine, (b) apocrine, and (c) holocrine

excretory system. Waste products are expelled straight through the cell surface in unicellular organisms. Several chemical processes take place in the body during life activities such as cellular respiration. These are referred to as metabolism. Waste products of these chemical processes include carbon dioxide, water, salts, urea and uric acid. The accumulation of these wastes within the body above a certain threshold is damaging to the health. These wastes are excreted via the excretory organs. Excretion is the process of removing metabolic waste from the body. Carbon dioxide, ammonia (in ammonotelics), urea (in ureotelics), uric acid (in uricotelics), guanine (in arachnida) and creatine are the most common excretory products in animals. Many compounds are cleaned from the blood by the liver and kidneys (for example, in renal excretion) and the cleared substances are ultimately expelled from the body in the urine and feces (Peters 2017). Because ammonia is highly soluble and there is plenty of water available for dilution, aquatic creatures normally excrete it straight into the environment. Ammonia-like molecules in terrestrial organisms are transformed into other nitrogenous materials, such as urea, which are less damaging because there is less water in the environment because ammonia itself is dangerous. This is known as detoxification. Birds excrete their nitrogenous waste as a paste of uric acid. Although this method is more expensive metabolically, it provides for

more effective water retention and easier storage in the egg. Many avian species, particularly seabirds may expel salt through specialized nasal salt glands with the saline solution exiting through nostrils in the beak. In insects, metabolic waste is excreted via a system comprising malpighian tubules. Metabolic waste diffuses or is actively carried into the tubule where it is delivered to the intestines. The metabolic waste, together with fecal debris is then expelled from the body.

1.2.2.3 Microorganisms and Its Characteristic Odor

Microorganisms can produce a variety of volatile chemicals which might have a pleasant perfume or a strong odor. The generation of these volatile compounds is determined by the metabolic variables of that particular organism. The odor created by these microbes can sometimes provide important hints in the identification of microorganisms. Giardiasis is distinguished from bacterial or viral diarrhea for example by foul-smelling diarrhea and the absence of blood or mucus in the stool. Microorganisms do not have their odor but they may create a variety of metabolites with characteristic odors. For example, the odor of rotten seafood is mostly caused by trimethylamine oxide (TMAO) which is created by bacteria. Streptomycetes produce a sequence of complex compounds termed geosmin which give soil its earthy odor. Many cyanobacteria are also responsible for the earthy scents and flavors found in freshwater. Based on the analysis of the smells generated by microorganisms and the identification of bacterial isolates from samples of fresh-cut apples, *Citrobacter freundii*, *Staphylococcus warneri*, *Pseudomonas oryzihabitans*, *Alcalinogenes faecalis*, *Corynebacterium jeikeium*, *Micrococcus spp.*, *Pantoea agglomerans*, and *Bacillus spp.* were the most common species. Additionally, it was shown that during the period of storage at chilled temperatures, there was an increase in the microbial diversity (Madureira et al. 2023). The research indicates that bacteria from the genera *Corynebacterium*, *Pseudomonas*, *Erwinia*, and other Enterobacteriaceae are commonly linked to the spoiling of minimally processed fruit and vegetables (Sequino et al. 2022). The apple samples contained bacterial isolates from these genera as well as the Enterobacteriaceae family. However, at the end of the storage time, these were not the most common microorganisms.

Anaerobes have a strong odor because they rely on sulfhydryl chemicals to maintain redox balance. Anaerobic infection is suspected the specimen is frequently offensively odorous. Gram-negative anaerobes are frequently to blame for morning breath. While degrading organic waste (putrefaction) anaerobic bacteria create fatty acids and other odoriferous chemicals. Hydrogen sulfide (H₂S) methyl mercaptan (from sulfur amino acids), cadaverine (from lysine), putrescine (from ornithine) and ammonia are the most important of these chemicals. At low concentrations in the air H₂S smell like rotten eggs. Cadaverine and putrescine have the odor of rotting flesh, methyl mercaptan has the odor of rotten cabbage, and ammonia has the odor of urine or sweat.

1.3 Type of Aroma and Flavor

Aroma and flavor are the sensations felt when a volatile material enters the nose. It travels to the brain via the olfactory nerve (olfactory bulb) via the nerve to the brain. There are various sorts of odor-causing chemicals, as follows: Many different types of chemical molecules emit various scents. These chemicals are used in synthetic flavors esters which are acid-alcohol complexes. It's made by eliminating water from a molecule. Low molecular weight fatty acids have a harsh pungent and sour odor. Among the substances that release odors are those with hydroxyl groups, such as aldehydes, ketones, acids, esters, and nitrogen compounds. Sulfur-containing compounds and molecular oxygen are also referred to as spherical compounds.

1.3.1 Flavor Elements

The periodic table of chemical elements is a well-known scientific tool. Its elegance and simplicity may make it easy to overlook the richness of information stored inside. The periodic table tabulates all known elements in order of increasing atomic number. The tabular format (left to right and top to bottom) is crucial for highlighting key patterns and commonalities. The periodic table can teach students a lot about chemistry in the classroom, and they should become acquainted with it. The periodic table in its current form was developed in 1869 by a Russian chemist named Dimitry Mendeleev, notwithstanding previous attempts to classify elements based on similarities. The periodic table, as we know it today, was first introduced in 1869 by Russian chemist Dmitri Mendeleev, although there had been prior attempts to classify elements based on their similarities. Commemorating the 150th anniversary of the periodic table in 2019, the scientific community designated the year as “The International Year of the Periodic Table” (International Union of Pure and Applied Chemistry [IUPAC], 2019). In celebration, PubChem launched the PubChem Periodic Table and corresponding Element pages, which serve as valuable resources for chemical education at the high school, undergraduate, and graduate levels (Kim et al., 2016). The organization of elements on the periodic table significantly facilitates the explanation of the relationships between their properties. By analyzing the periodic trends and the properties of known elements, scientists can predict the characteristics and composition of elements that have yet to be identified or synthesized. This approach enables researchers to anticipate the properties of new elements based on the similarities to existing ones. The periodic table not only displays the properties of elements but also provides a framework for understanding how these properties are related to the structure and behavior of the elements at the atomic level. Each element's unique qualities and differences are determined by the number of particles within an atom. There are currently 118 elements, ranging from element 1 (hydrogen) to element 118 (oganesson). All 98 elements can be found in nature. The remaining 16 elements are only generated in scientific laboratories.

In the periodic table standard. Each element is ordered from left to right and top to bottom based on its atomic number which is the number of protons in the nucleus. All elements are divided into 18 groups along vertical lines in the present periodic table. The elements belonging to the same group will share similar features. All 18 groups in the periodic table are represented by Roman or Arabic numerals ranging from 1 to 18, as well as letters like IA or 1A, based on the arrangement of valence electrons (valence electrons) or having the same number of electrons in the outermost orbital. The other 7 periods horizontally indicate the number of electron shells (electron shell). By the element's number of electrons and protons in the same period. The count will rise by one layer. Accompanied with a decrease in metallicity from the left to the right side of the periodic table. Meanwhile, the electrons are rearranging themselves into new layers. When the initial layer is completely arranged a new era in the periodic table begins. This configuration, as the atomic number grows, generates a repetition of elements with identical chemical properties. Elements names and symbols in the periodic table the number in the upper left corner represents the number of protons in the element's atoms, also known as the atomic number. The middle letter sign represents an abbreviation of the element's name. (Abbreviation) Symbols with English names such as hydrogen frequently utilize "H" to represent the element's symbol. The values below represent the element's atomic mass, or the number of protons and neutrons in its nucleus. Figure 1.7 depicts one example (Liu et al. 2017; Kim et al. 2019).

1.3.1.1 Hydrocarbon Compounds

Hydrocarbon compounds is used to describe organic molecules made up solely of the element carbon and one element is hydrogen. Hydrocarbon compounds can be found in nature in a variety of places. Based on their structural characteristics they are divided into two categories: aromatic and aliphatic compounds, which include glycosides. As seen in Fig. 1.7 free fragrance molecules (glycone) are closely linked to the origin of grapes.

1.3.1.2 Aliphatic Compound

In organic chemistry, an aliphatic chemical is a combination of hydrogen and carbon. One kind of hydrocarbon compound is one without an aromatic ring in compounds with aliphatic compounds. Carbon atoms can form straight, branching, or non-aromatic chains by forming bonds with one another. Single bonds (alkanes), double bonds (alkenes), or triple bonds (alkynes) can be formed by them. Propane, acetylene, isooctane, ethylene, and propane are aliphatic chemical examples. Polyethylene and squalene are two examples of aliphatic compounds.

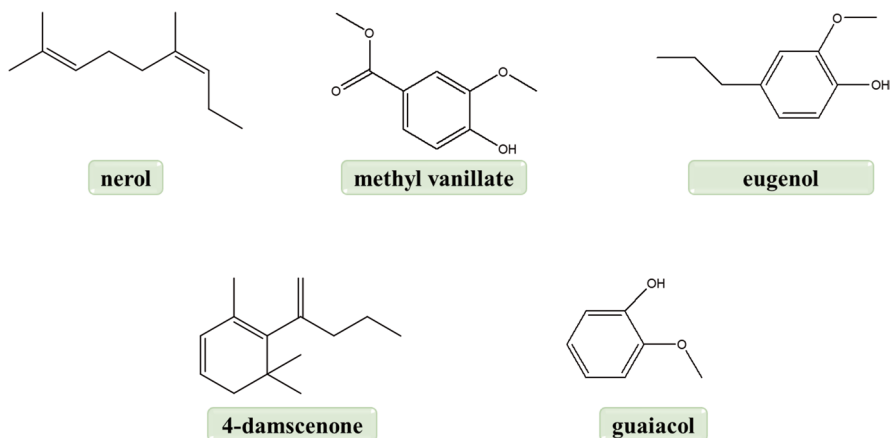


Fig. 1.7 The selected glycone forms of several chemical kinds found in grape aroma glycosides

1.3.1.3 Aromatic Compounds

It is a hydrocarbon compound containing the element carbon and hydrogen is a chemical element They have a ring structure with one or more rings surrounded by branching pi-electrons. Some aromatic substances however do not have a sweet odor. Only certain sweet-smelling chemicals are fragrant. Aromatic hydrocarbons also known as Arenes are aromatic organic molecules made up of just carbon and hydrogen atoms. The benzene ring is the structure of six carbon atoms in an aromatic molecule. As indicated in Fig. 1.8 BTEX is composed of mono-aromatic hydrocarbons such as benzene (Benzene), toluene (Toluene), ethylbenzene (Ethylbenzene), and xylenes (Xylenes).

1.3.2 Aromatic Compound

Taste, flavor and scent are all examples of organoleptic properties of food products. The most noticeable feature that influences consumer approval is smell as well as market success (Berger 2009). Flavor and odor Acids, hydrocarbons, aldehydes, alcohols, ketones, esters and lactones are the different types of odor compounds (Bicas et al. 2010). Figure 1.9 depicts the classification of fragrance molecules based on their chemical structure.

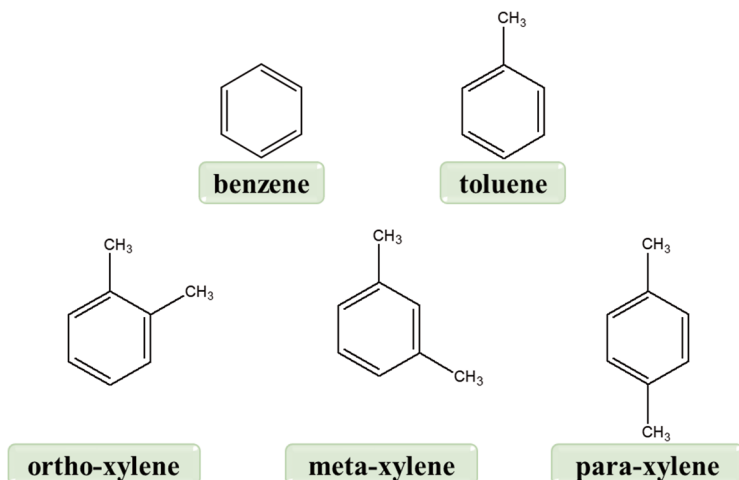


Fig. 1.8 Structure of BTEX compounds

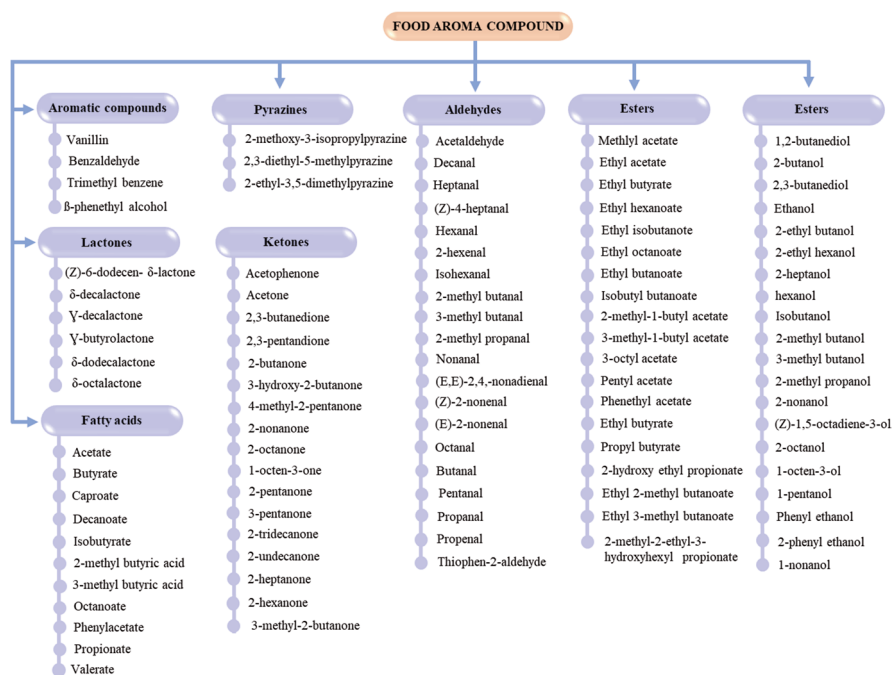


Fig. 1.9 Chemical structural classification of flavor chemicals

1.3.2.1 Alcohols

Alcohol, an organic compound derived from hydrocarbons, features a distinctive hydroxyl functional group ($-\text{OH}$) in place of a hydrogen atom. With a general formula denoted as $\text{R}-\text{OH}$, in which R represents the alkyl group and $-\text{OH}$ signifies the hydroxyl group, alcohols are often referred to by their common names when they possess simple molecular structures. Nomenclature convention dictates stating the alkyl group linked to the $-\text{OH}$ group first, followed by the term “alcohol”. When alcohol undergoes dissolution in water, the $-\text{OH}$ group remains intact without dissociating into hydroxide ions (OH^-), reflecting the covalent nature of the bond between the $-\text{O}$ group and the alkyl group in alcohol. This behavior contrasts with the ionic bonding characteristic of hydroxide ions in metal hydroxides like NaOH . The coexistence of polar ($-\text{OH}$) and nonpolar (alkyl group) characteristics within alcohol molecules underscores their unique chemical properties. In classifying alcohol compounds, a key criterion lies in the number of hydroxyl groups present in their molecular structure, categorizing them into distinct groups for systematic study and analysis. There are several forms of alcohol, which are classified into four categories based on the amount of hydroxyl groups in the molecule:

Monohydric alcohol These alcohols are characterized by the presence of a hydroxyl group in their molecular structure, are commonly referred to as monohydric alcohols. Within this category, distinctions can be made among three types of hydroxyl groups: primary alcohols, secondary alcohols, and tertiary alcohols. The differentiation between these types is predicated on the specific carbon atom to which the hydroxyl group is attached (Sharma et al. 2006).

a) Primary alcohol A primary alcohol is characterized by a hydroxyl ($-\text{OH}$) group attached to a primary carbon atom. The general formula is RCH_2OH , where R represents an alkyl group. A primary carbon atom is bonded to only one other carbon atom (or none in the case of methanol). For example, methanol (CH_3OH) and ethanol ($\text{CH}_3\text{CH}_2\text{OH}$) are primary alcohols. In these compounds, the $-\text{OH}$ group is attached to a carbon atom bonded to one carbon atom (in ethanol) or no other carbon atoms (in methanol). Figure 1.10 provides additional examples of primary alcohols.

b) Secondary alcohol The secondary alcohol is typically represented by the general formula R_2CHOH , signifying an alcohol wherein a secondary carbon atom is bonded to a hydroxyl group ($-\text{OH}$). An illustration depicting a carbon atom engaging in bonding with two neighboring carbons can be observed in Fig. 1.11, accompanied by its corresponding generic formula.

c) Tertiary alcohol The tertiary alcohol is denoted by the general formula R_3COH , representing an alcohol where a hydroxyl group ($-\text{OH}$) is linked to a tertiary carbon atom. This type of alcohol features a chemical structure where the hydroxyl group is connected to a carbon atom that is surrounded by three other carbon atoms. Fig. 1.12 illustrates an instance of such a carbon atom forming bonds with three neighboring carbons.

Fig. 1.10 Primary alcohol structures

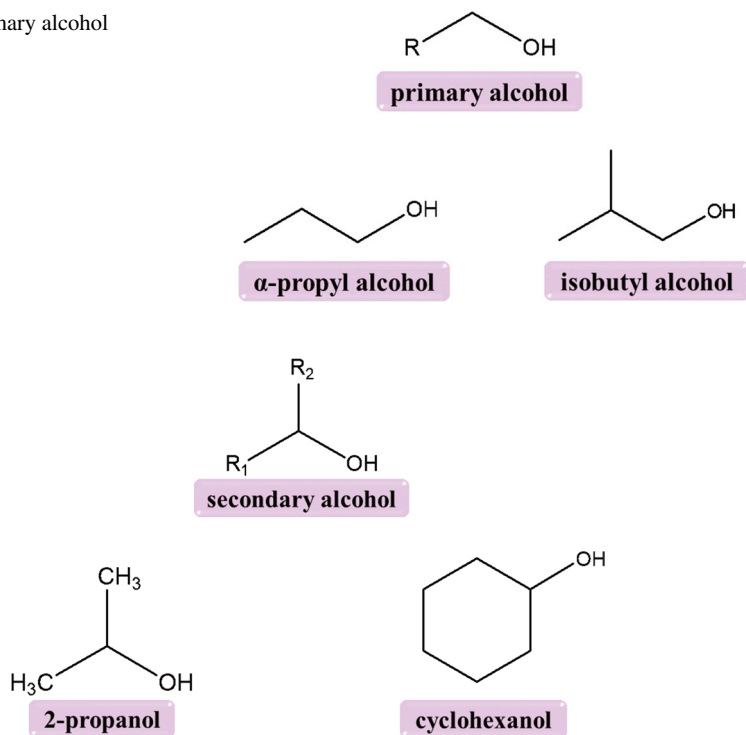


Fig. 1.11 Secondary alcohol structure

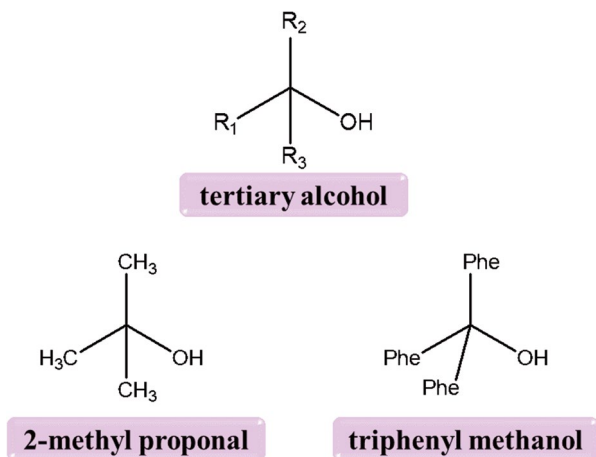


Fig. 1.12 Tertiary alcohol structure