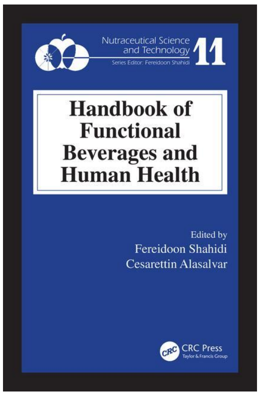


# Handbook of Functional Beverages and Human Health

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# Flavor Challenges in Functional Beverages

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# *Flavor Challenges in Functional Beverages*

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## 3.1 Introduction

Formulated functional beverages differ from traditional beverages in that they are produced using ingredients with scientifically proven physiological and health benefits. These products are often based on patents, industry trade secrets, or other type of proprietary knowledge. As with any food product, the ultimate goal is to make a product with an acceptable flavor profile that is characterized by the immediate impact of an identifying flavor (e.g., vanilla, chocolate, and strawberry), rapid development of a balanced and full-bodied flavor, compatible mouthfeel and texture, lack of off flavors, and a minimal (short) aftertaste. It is important that when consumers first open or taste a product, their first impression is that of the intended, desirable flavor. Functional beverages face many of the same flavor challenges encountered with pharmaceuticals due to the inherent off flavors associated with the ingredients used in their formulation. Products highly fortified with vitamins, minerals, and intensely bitter functional ingredients present a particularly difficult challenge.

Several excellent reviews provide an exhaustive overview of methods for masking off flavors in pharmaceutical products [1–5], and techniques for reducing bitterness in functional foods have recently been published [6]. This chapter highlights traditional and emerging technologies and discusses practical approaches to improve the flavor characteristics of functional beverages.

## 3.2 Flavor Perception

Flavor is the integrated response to the simultaneous perception of taste, odor, trigeminal, and tactile sensations and is often influenced by visual and auditory cues perceived during food consumption [7]. Although the peripheral sensory organs for detection of taste and smell stimuli are distinct, their signals are integrated in the orbitofrontal and other areas of the cerebral cortex of the brain to generate the perception of "flavor" [8]. It is the complexity of flavor perception that makes it particularly challenging to successfully modify the inherent flavor characteristics of a functional beverage to produce a highly acceptable product.

## 3.3 Off Flavors Associated with Functional Ingredients

Functional beverages often contain ingredients that cause undesirable flavors (odors and tastes), which can ultimately impact the flavor quality and consumer acceptability of the finished product. In order to develop an effective strategy for reducing or eliminating the perception of off flavors, it is critical that product developers know the nature of all ingredients used in the creation of the base formulation. Of particular importance is the flavor and off flavor potential, possible interactions (flavor binding), and process, storage, and shelf-life limitations (stability) of each functional ingredient.

### 3.3.1 Off Odors

Extracts made from herbs, spices, and medical plants often contain residual volatile compounds that can cause undesirable odors in the final product. Other sources of off odors include those caused by fortification with minerals, vitamins, omega-3 fatty acids, or healthy proteins (e.g., soy and whey). In addition, off odors may develop from the degradation of ingredients during manufacture (thermal processing) and storage.

### 3.3.2 Bitter and Astringent Substances

Many functional ingredients, especially plant extractives, have the potential to cause bitterness and astringency. These include herbal extracts containing caffeine, such as guarana, kola nut, yerba mate, green tea, and cocoa extract enriched in theobromine and caffeine. Polyphenolics represent the largest group of bitter and astringent substances used in functional beverages. These are derived in the form of extracts or concentrates from plant materials, including green tea, grape (skin and seed), berry fruits, apple (seed), soy, and citrus (peel and seed), among others. Structures of some bitter and astringent constituents of functional ingredients are shown in Figure 3.1.

The tastes elicited by polyphenols can range from mainly bitter (*trans*-resveratrol) to being both bitter and astringent (e.g., (+)-catechin and (−)-epicatechin). The taste properties of some phenolics depend upon the degree of polymerization. For example, the monomeric phenols (+)-catechin and (−)-epicatechin are perceived as more bitter than astringent, while their dimers and trimers illicit nearly equal or greater astringency than bitterness, respectively [9]. Not all polyphenolic compounds are bitter or astringent; occasionally, they can be sweet (e.g., neohesperidin dihydrochalcone) or tasteless (e.g., anthocyanins), in which case the use of these functional ingredients should not cause any bitterness issues.

## 3.4 Flavor Modification Techniques

### 3.4.1 Traditional Approaches

Several strategies are commonly employed to reduce the perception of undesirable odors, tastes, and mouthfeel characteristics of functional beverages (Table 3.1). Most involve the use of some sort of masking technology, which acts to suppress or interfere with the perception of undesirable flavors without actually changing their concentrations in the product.

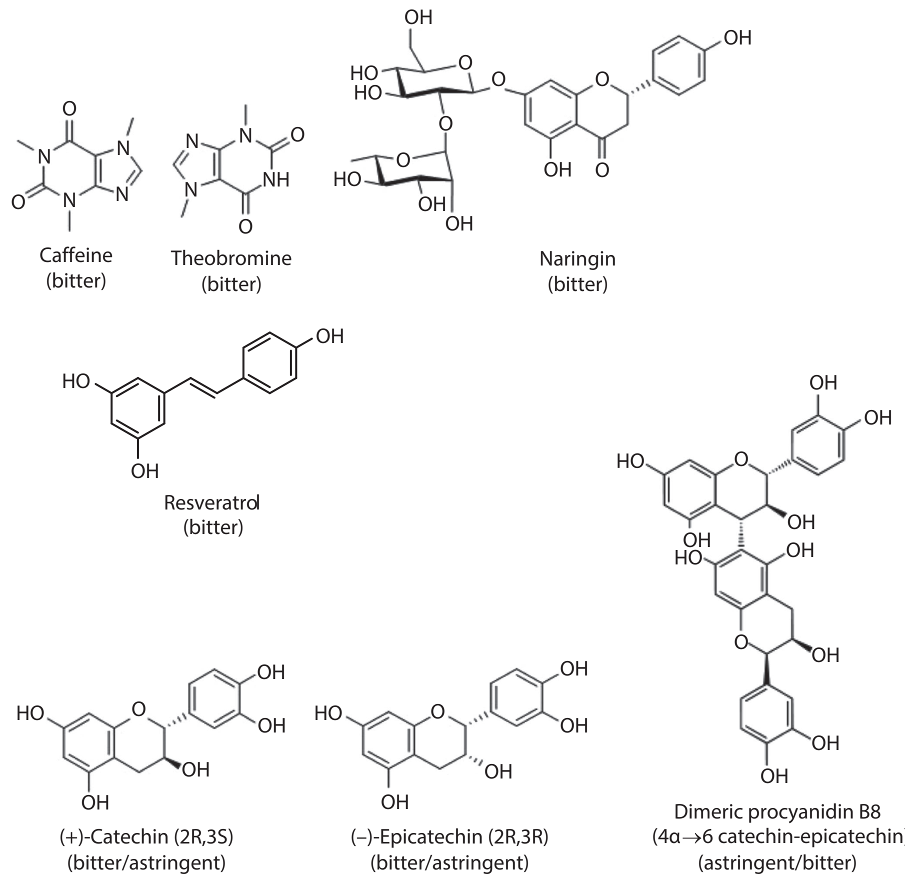


**FIGURE 3.1** Chemical structures of some bitter and astringent constituents of functional ingredients.

**TABLE 3.1**

Traditional and Emerging Methods for Improving the Flavor Characteristics of Functional Beverages

| Flavor Challenge | Strategy | Methods |
|---|---|---|
| Off odor reduction | Odor masking | Mixture suppression by addition of complex flavorings. Assimilation masking by addition of flavorings that complement the odors already present in base formulation. |
| | Matrix modification | Subdue or modulate odor release (availability) by addition of fat, fat replacers, or bulking agents. |
| Bitterness and astringency reduction | Congruent or assimilation masking of bitterness and astringency | Choose flavoring that complements lingering or persistent bitter and astringent tastes (e.g., coffee, tea, or dark chocolate). |
| | Mask bitterness by suppression | Suppress bitterness perception by addition of NaCl, amino acids, sugar, or high-intensity sweeteners. |
| | Mask bitterness and astringency by decreasing (oral) diffusion | Addition of thickening agents (polysaccharides or gums). Addition of emulsifiers (lipids or lecithin). |
| | Mask by physical separation of bitter and astringent compounds | Encapsulation of bitter and astringent ingredients. Addition of cyclodextrins. |
| | Blocking of bitter receptors | Addition of substances (bitter-blocking agents) that suppress bitterness by interfering with bitter receptors and/or receptor signaling pathways. |

#### 3.4.1.1 Odor Masking by Mixture Suppression and Odor Synergy

Masking of off odors can be accomplished by addition of more complex flavorings. The effect is the result of mixture suppression, where the perceived intensity of an odorant mixture is less than that of the individual components [10]. Assimilation masking can also be accomplished by adding flavors that complement those already present in the product. Often, the individual flavor ingredients have limited masking capability, but in combination provide synergy to produce a unique odor, thus enhancing the masking effect [11]. Off odors may also be subdued by modulating or decreasing flavor release by addition of fat, fat replacers (polydextrose), and bulking agents.

#### 3.4.1.2 Bitterness Masking by Suppression

It is possible to suppress bitterness by the addition of sugar or salt (NaCl) [12,13]. For obvious reasons, sugar and salt are not generally used in functional beverages developed for health conscious consumers. Instead, nonnutritive and high-intensity sweeteners (e.g., sucralose and aspartame) have found practical application for bitterness reduction of functional ingredients and pharmaceuticals. However, the potential of these sweeteners themselves to illicit bitter and metallic aftertastes at higher use levels should be considered during product formulation.

Conventional taste masking strategies such as use of sweeteners, amino acids, and flavoring agents alone or in combination are often inadequate for reducing or eliminating off flavors associated with certain functional ingredients, especially those containing intensely bitter and astringent substances. In these cases, it may be necessary to employ more advanced techniques such as use of bitter-blocking agents and inclusion complexes.

#### 3.4.1.3 Taste Masking by Viscosity Modification

It is possible to reduce both the bitterness and astringency by increasing viscosity of a functional beverage. This can be accomplished by the addition of thickening agents such as natural gums or carbohydrates or by addition of certain lipophilic substances (lipids, lecithin, and so on). The increased viscosity acts to slow the diffusion of bitter and astringent compounds to the surface of the tongue and oral cavity, thus reducing the perception of these substances. Chalkiness, grittiness, and other mouthfeel characteristics may also be modified by addition of modifiers such as gums (e.g., pectin) that provide lubricity, creaminess, and fullness. The use of natural, plant-based gums to increase viscosity offers the additional advantage of serving as source of dietary fiber, thus potentially increasing the nutritional value of the product.

### 3.4.2 Advanced Approaches

#### 3.4.2.1 Taste Masking by Inclusion Complexation

In addition to protecting flavors, microencapsulation can be used to help mask the unpleasant sensory characteristics of functional ingredients such as bitter herbal extracts and fishy smelling omega-3 oils. A multitude of encapsulation technologies exist. These vary in the materials and processes employed in their manufacture. Most produce dry, free-flowing powders designed to release their payloads under specific conditions (e.g., hydration, heating, and shearing). The use of inclusion complexation (or molecular encapsulation) is a particularly attractive and effective method for masking of functional beverages and is based on the molecular inclusion of an odorant or taste substance inside the cavity of another molecule. This prevents perception of the substance during consumption. The most often used inclusion complexation systems are based on the use of cyclodextrins as the host material [14].

Cyclodextrins are cyclic oligosaccharides composed of D-glucose units. There are three types of cyclodextrin, which contain either six (α), seven (β), and eight (γ) glucose units. β-Cyclodextrin is the most widely used complexation material due to its ability to form inclusion complexes with a variety of molecules, especially bitter and astringent compounds, its availability, and reasonably low cost [15].

Complexation using various types of cyclodextrins has been shown to be effective in reducing or eliminating bitterness in a variety of foods and beverages. These include the use of β-cyclodextrin to reduce the bitterness of naringin and limonin in citrus juice [16] and use of either β- or γ-cyclodextrin for the reduction of bitterness of ginseng solutions [17]. In addition to reducing bitterness, cyclodextrins can alter the sensory profile through flavor encapsulation and could interfere with the action of masking agents or bitter-blocking agents [18].

#### *3.4.2.2 Bitter-Blocking Agents*

Bitter-blocking agents function by occupying (or blocking) bitter taste receptors or signaling pathways without initiating a sensory perception. Certain umami substances exhibit bitter-inhibiting activity. For example, adenosine monophosphate, a naturally occurring bitter-blocking agent with generally recognized as safe (GRAS) status, suppresses bitterness by interfering with the bitter receptor signaling protein gustducin. Other naturally occurring bitter-blocking agents include phosphatidic acid and tannic acid [19] and riboflavin-binding protein (RBP) from chicken egg [20]. RBP inhibits the binding of various bitter substances including quinine HCl, naringin, theobromine, and caffeine.

The recent elucidation of the TAS2Rs group of about 25 bitter receptors has aided the development of more effective bitter-blocking/bitter-masking agents. In general, bitter-blocking agents have fairly narrow bitter-blocking capabilities since they do not block all 25 receptors, but instead they are designed to block receptors for specific bitter substances. For example, probenecid (a uricosuric drug used primarily for treating gout and hyperuricemia) has been shown to block bitterness of salicin by inhibiting the activation of the subset of bitter taste receptors involved in its detection [21]. Several proprietary or patented bitter-blocking agents have been developed by flavor companies. Givaudan flavors offer the bitter-blocking agents (GIV3727 and GIV3616), which reportedly block the bitter and metallic tastes associated with the consumption of high-intensity artificial sweeteners. Senomyx offers the patented (US7939671) bitter blockers (S6821 and S7958), which effectively block the bitter tastes associated with beverages containing soy or whey proteins, or caffeine. A potential drawback to using taste-blocking agents is that they may cause the suppression of some other desirable or characterizing flavors. For this reason, it might be necessary to adjust or rebalance any added flavoring agents to compensate for this change.

## 3.5 Masking and Flavoring of Functional Beverages

First, it is of utmost importance to have intimate knowledge about the off flavor potential of each ingredient and of the base formulation, including any potential effects of processing or storage. Product developers must not only consider the functional or bioactive aspects of the ingredients but also any negative sensory qualities these may possess. They must work with the inherent flavor attributes of the base formulation and not try and create an incompatible flavor. That is, the target flavor and residual flavor of the base formation cannot be totally incongruous.

Ideally, one would consider masking or neutralizing any off-notes before attempting to apply the target or characterizing flavoring. Sometimes, it is necessary to adjust the ingredients in the base rather than to rely solely on the addition of masking agents and flavors. When optimizing flavor use level, it is important to consider both the effects of any flavor interactions (flavor interactions of functional ingredients) and other reactions that might occur during processing or storage. Especially, problematic is flavor fade that is often encountered in high protein (soy, whey, and so on)-containing products. Flavor fade is the perceived loss of flavor caused by the nonspecific binding of flavor compounds to the protein. It does not occur equally among the added flavor compounds, thus in addition to a decrease in overall flavor intensity, a shift in the flavor profile or flavor imbalance may result [22].

Depending upon the company's research and development (R&D) resources and capabilities, the product developer may elect to partner with a flavor company or develop the technology in-house. Both approaches have several advantages and disadvantages as discussed in the following sections.

### 3.5.1 Partnering with a Flavor Company

Flavor companies are well adept at providing custom solutions to solve off flavor problems. They offer products and technologies that not only serve to mask undesirable flavors but also provide a desirable flavor in the finished product [23]. The advantage of involving a flavor company is they have the expertise, resources, and know-how needed to successfully flavor even the most difficult functional beverages. They also have enough experience to know if a flavor or masking agent will complex or react with any of the functional ingredients. Partnering with a flavor company is especially attractive to small companies that possess only limited R&D capabilities. An obvious disadvantage to this approach is that intellectual property is owned and controlled by the flavor company and the client may have no knowledge about the composition of the masking agents, flavorings, and technology used to flavor the finished product.

### 3.5.2 In-House Product Development

Internal R&D of masking and flavoring solutions has the key advantage in that the intellectual property (formulation/technology) is owned and controlled by the company. Prior to formulation of the base, the flavor and mouthfeel attributes of the individual ingredients should be identified by descriptive sensory analysis (DSA) using trained panelists. During the initial stages of product development, it is important to minimize the number of functional ingredients with off flavor potential, since the taste synergy from too many ingredients may create a base that's nearly impossible to flavor.

Any of the aforementioned masking technologies can be applied to help neutralize the off flavors of the base. It is also possible to obtain masking agents from flavor companies. DSA should be used to aid in the development of the masking technologies and to identify and characterize any residual odors, tastes, and mouthfeel properties in the finished base. Ideally, masking technologies should be applied before overlaying the base with added flavoring (mask first, then flavor). The main advantage of flavoring after neutralizing the base is that it helps prevent the over flavoring of the product. It is important that the target flavor be chosen such that it complements the residual flavors in the base. Certain combinations are impractical or nearly impossible. For example, you cannot take a bitter base and expect to make an acceptable banana flavor. Instead, it is more practical to consider a more compatible or congruent flavor, such as cola, citrus, dark chocolate, or coffee, in which a bitter note is expected or at least tolerated to some extent.

It is possible that the masking ingredients might also cause the suppression or modification of the added flavorings. Therefore, it might be necessary to later rebalance or adjust the flavoring to correct for these changes. It is also important to consider other factors that might cause flavor changes, such as flavor binding, thermal processing (pasteurization), and storage.

#### *3.5.2.1 Flavor Considerations*

The goal of the product developer should be to produce a functional beverage that is highly acceptable to a wide range of consumers. Some flavors may appear healthier or more wholesome to consumers. For example, products with citrus or berry flavors might be perceived as healthier than products with more indulgent flavors, such as vanilla and chocolate. Flavors such as chai, exotic/tropical fruit, citrus (lemon–lime), and berry flavors work well for energy beverages, while vanilla and chocolate flavors are more appropriate for protein-fortified beverages. Whenever feasible, complementary (congruent) flavoring strategies should be used to produce the most acceptable finished product.

It is well established that olfaction can influence taste perception in both simple and complex matrices [24]. The result of integration is product dependent and related to food experience. For this reason, it may have either desirable or negative consequence with respect to product quality. Labbe et al. [24] showed that olfactory–taste interactions in a cocoa beverage caused an enhancement of bitterness induced by the cocoa flavoring and an increase in sweetness from the vanilla flavoring. However, in caffeinated milk, the addition of vanilla flavoring did not significantly impact sweetness, but unexpectedly bitterness perception was enhanced. The aforementioned results highlight the need for congruency in flavoring of functional beverages.

Use of a flavoring that complements residual or lingering or persistent aromatics and tastes is referred to as congruent or assimilation masking. An example of this approach is the use of a coffee and dark chocolate flavoring to complement the bitter taste and astringent mouthfeel and green, beany, and cereal aromatics associated with soy-fortified beverages. Similarly, the earthy note of St. John's wort blends or assimilates well with chocolate or coffee.

## 3.6 Conclusion

It is the ultimate goal of the product developer to provide consumers with functional beverages that not only deliver the intended health-promoting benefits but also taste great. Various strategies can be used in functional beverages to decrease off odors, bitter tastes, and astringent mouthfeel characteristics. Traditional methods can be effective, but recent advances in the development of bitter-blocking agents offer new and potentially more effective ways to inhibit bitterness. These may have particular appeal for the targeted blocking of intensely bitter functional ingredients, especially polyphenolics that are commonly used in functional beverages. The use of several approaches, for example, traditional masking strategies combined with inclusion complexation and bitter binding agents, is the most effective option for the effective flavoring functional beverages.

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