Flavor Modulation

Components, formulation, evaluation and optimization

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Over the past 40 years at least two flavor houses have successfully commercialized a proprietary technology to identify and produce modulated flavor systems. Here "flavor" is considered the sensory response to the aromatic and taste components of that flavor. "Flavor modulation," then, is defined as the modification of perceived flavor intensity by a carrier consumed with the flavor.[1,2] This flavor modulation can be either an amplification of the flavor sensory signals, i.e. flavor enhancement, or the opposite response, amplification of a flavor muting response by the carrier, i.e. flavor masking. Masking responses can range from a muting of specific, undesirable flavor notes to their elimination in food ingredients and pharmaceuticals.

This enhancement functionality is analogous to a folding process with flavors wherein the active components of a specific flavor system are concentrated so that reduced use levels are employed but perceived as full, rounded flavors without distortion in character or intensity. The analogous flavor modulation system (enhancement) leads to flavor intensification, so lesser flavor levels are perceived as full balanced flavors. However, if used at normal flavor levels, the modulated flavor would lead to a distorted character and a rapid fatigue response.

The basis for the flavor sensory signals starts at the cellular level with the chemoreceptors found in the taste bud fungiform papillae. Receptors activated by taste agents can be classified by their signal response to sweet, bitter, and savory (umami, kokumi) agents. Sensory signals for salty and acidic tastes are based upon passage of either sodium ions or protons through specific ion channels within the cell membrane. Recently other sensory sensations have been detected in the somatosensory system, including heat (induced by a trigeminal nerve reaction), fattiness and cooling.[3,4]

The papillae chemoreceptors are cellular transducers for the sweet, bitter and savory tastes and belong to a class of membrane protein complexes known as G-protein coupled receptors (GPCR). These GPCR—also referred to as seven-transmembrane domain receptors, or G protein-linked receptors (GPLR)—comprise a family of transmembrane receptors (**See F-1**). They interact and bind flavor molecules outside the cell, activating internal signal transduction pathways, ultimately generating a signal cascade leading to the neural response of "flavor" perception in the brain.

During mastication, flavor volatiles, or aromatics, are released simultaneously within the oral cavity and sensed via the retronasal system. The GPCR transduce signals by a process of allosteric regulation. This combination of taste and aroma component signals is a target for amplification by the modulating system. Combining a membrane modifier with other key functional agents and a flavor then forms a multiple component complex to enhance neural signal cascades and sensory recognition.

Required Components for the Flavor Modulation Complex

Required components for a flavor modulation (enhancement) system include: a membrane modifier; an emulsifier; a relaxing agent; a flavor; secondary flavor enhancing agent(s) or adjuvant(s); food polymers; flavor-specific pH and ionic agents; and, optionally, spray dry carriers.

Membrane modifiers: The functional membrane modifying agents must strongly interact with the phospholipids, proteins or cholesterol that comprise the cell membrane structure and signaling GPCR pathways. These modifiers can be surfactants, lipoproteins, glycolipids or other agents that strongly intercalate into the cell bilayer membrane.

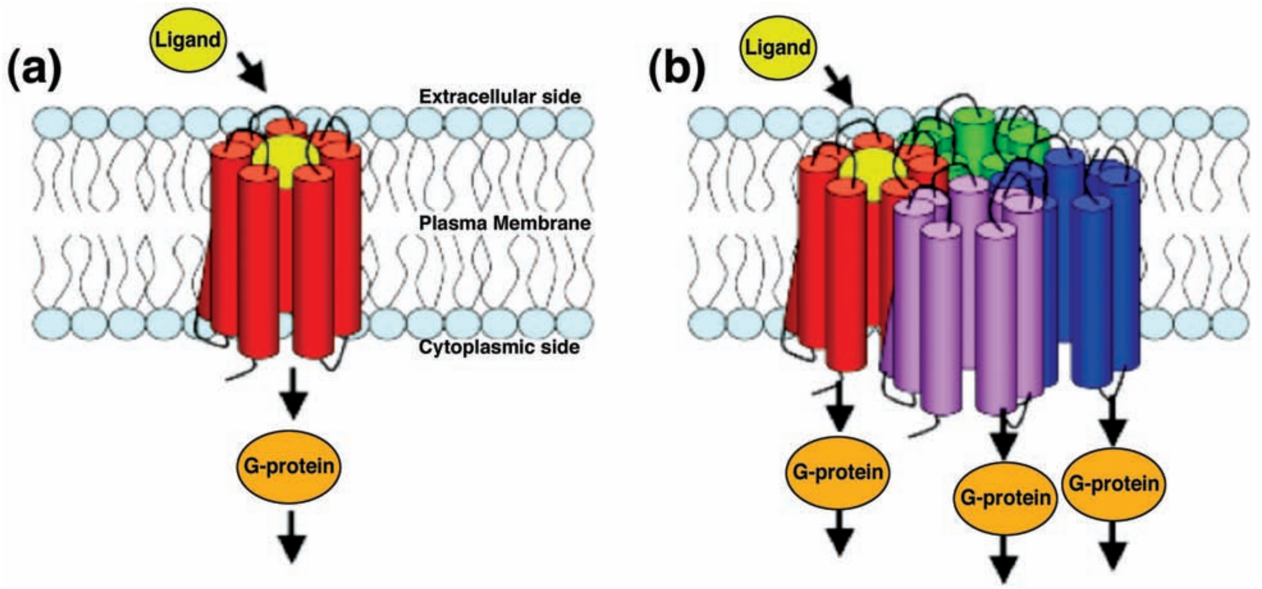
Emulsifier: The emulsifier(s) functions to form and stabilize a lyotropic mesophase with the membrane modifier. The ratio of modifier to emulsifier is critical, as is the absolute level of each in the formula. Generally the emulsifier is chosen to form a lamellar mesophase. Specific emulsifiers and their hydrated phases for consideration are noted.[5]

Relaxing agent: The relaxing agent is designed to impede continuous firing of neural signals during the amplified sensory response to the flavor. In the modulating complex, the relaxing agent is a triglyceride oil. This triglyceride requires very specific acyl fatty acid groups and a specific substitution profile. The relaxing agent concentration is less critical than the modifier and emulsifier, but must be compatible with them.

Flavor: Desired flavors can be either compounded water-soluble (W/S) or oil-soluble (O/S) flavors, or extracts. If one prepares an O/S flavor, the co-solvent must consist of the relaxing agent triglyceride. For complex flavor systems, an initially compounded flavor formula may require reformulation at the end of the development cycle

Membrane with GPCR complex; (a) seven domain model with flavor as the ligand; (b) multi-domain GPCR with potential allosteric response*

F-1



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to rebalance the final sensory response to the modulating carrier system.

Secondary flavor agents/adjuvants: The secondary agents are selected from the group of FEMA GRAS flavors and other 21 CFR ingredients. Some of the flavor compounds may have already been formulated into the original flavor system. Agents with desirable contributions include ethanol, glycyrrhizin or licorice extracts, vanillin, ethyl vanillin or vanilla extracts, benzaldehyde, spice extracts, sugars, 5´-nucleotides, amino acids, hydrolyzed vegetable proteins (HVP), and autolyzed yeast extracts, among others.

Food polymers: The food polymers are bifunctional agents used in the preparation of emulsions for spray drying as well as sensory contributions. One example is the dairy protein group. These ingredients include whey proteins and whey protein concentrates, non-fat dry milk (NFDM), sodium caseinate, and buttermilk powder. They can be used to stabilize the emulsion consisting of the aqueous dispersion of membrane modifier, emulsifier, relaxing agent, acid, salt and flavors in the aqueous carrier. These proteins stabilize the dispersed lipid droplets and contribute significant gustatory attributes. A good example of a protein-flavor match would employ sodium caseinate, whey protein or NFDM in the production of a modulated cheese flavor system. Other flavor-polymer compatible pairs might include fruit flavor—pectin and sweet-brown flavors—soluble carbohydrates.

Spray dry carriers: When preparing a flavor modulating system for spray drying, standard carriers can be employed judiciously. Since both octenyl succinic anhydride (OSAn) starches and gum arabic are surface-active film-forming polymers, their use must be tested for sensory interactions and destabilization of the lyotropic mesophase in the dispersion. Maltodextrins and corn syrup solids are usually employed to increase total dissolved solids of the emulsion without any significant interactions with the remainder of the modulating compositions.

pH and salt modifiers: The pH and salt components of the target ingredient system must be matched in the modulating carrier. In dairy flavor systems, e.g. cheese or sour cream, the pH of the targeted product becomes the pH indicator for the modulating system. A good estimating rule is to bracket product pH by ± 0.3 pH units in the emulsion before drying. Similarly the sodium sensory character of a product should be evaluated. In the cheese model, pH, acidity, saltiness, protein, flavor and fatty acids aromatics all contribute to specific cheese's sensory character and must be balanced in the modulating system.

Formulating a Specific Modulated Flavor System

Formulation of the flavor modulating system includes levels and ratios of a large number of the primary components. There are two alternative approaches to optimize a formula—mixture experimental design (DoE) and the "random walk" model.

One should consider a multi-component phase diagram as a multidimensional plane with one small narrow elevated point to represent the modulation formula optimum (almost a discontinuity step function). This very narrow region relative to the whole surface is difficult to locate and optimize. Therefore, determination of the modulation formula is only possible by employing a very large number of data points (test formulas) closely spaced in order to confidently find the positive response of an exact solution (optimum formula).

A mixture DoE for the flavor modulation system must incorporate 10–15 components, is very complex and difficult to properly execute. Since there are many secondary effects—i.e. a single agent may supply multiple functionalities for the modulation response—the standard software mathematical models are somewhat limited due to this large number of components, in addition to the accuracy, reproducibility and statistical significance of sensory data used as the response variable for the design software.

An alternate formula testing strategy uses the random walk model in which formulations are evaluated as single variable experiments until a general direction is defined and an optimum found. This procedure can work if one understands the response target requirements and generates a very large number of experimental formulas for sensory response testing.

Sensory Evaluation and Formula Optimization

In identifying trends and optimized formulae, only response data from trained sensory panels can be utilized. This sensory data must be generated under carefully controlled conditions with rigid protocols as noted in **T-1**.

Processing Requirements

A modulating flavor system can be utilized either as an emulsion or a spray dried powder. In both process systems several key issues should be addressed. The water used in emulsion preparations—ideally deionized or distilled—should be completely odor- and contaminant-free. If municipal water sources are employed, the water must be checked continuously to insure no contaminants.

In making an emulsion, the homogenization process must generate lipid particles in a specific size range of 0.5–2.5 μ. Excessive homogenization pressures will result in smaller droplet particles with a concomitant increase in droplet surface curvature and total surface area. Both conditions can deviate from the desired optimum functionality. For spray drying, good manufacturing practices (GMP) must be established. The spray dryer unit should be supplied with an outside air stream to avoid volatiles/odors from nearby commercial or pilot plant operations that easily contaminate the modulation flavor system being dried. The dryer should be dedicated to the program in order to prevent carry-over flavor from previous flavor runs.

Flavor Modulation (Masking)

The basic modulation technology can be modified to mask specific sensory notes. Starting with the general formulation noted earlier, the membrane modifier and, to a lesser degree, the emulsifier component must be rebalanced. Flavors are eliminated, but in some cases the flavor adjuvants may still be required. The key is in identifying and selecting specific masking compounds to produce an amplified masking effect for the specific off-character note.

Masking compounds can be selected from a large group not limited to polyhdroxybenzoic acids and their sodium and potassium salts, amino acids, glycyrrhizins, cooling agents, vanillin, lactic acid, taurine, hydoxyflavones and their glycosides, lactisole (sodium 2-(4-methoxyphenoxy)propanoate), pyridinium betaines, methoxyphenylacetic acids, quillaia extract, CMC and 5' and 3' nucleic acid phosphates.[6,7]

Formulas can be designed to mask a large variety of specific sensory off notes such as:

- potato earthy/musty/starchy notes (restructured potato snacks)
- liver or warmed-over meat flavor notes
- grain off flavors
- beany notes
- rancid flavors
- metallic off notes arising from certain emulsifiers used in whipped toppings, icings and frozen products such as custards and soft-serve ice creams
- caffeine bitterness/astringency
- preservative off notes (sorbates)

Sensory evaluation protocols **T-1**

- Prospective panelists must be selected, evaluated and trained to form an expert panel dedicated to a specific flavor modulation project.
- The number of panelists in any single tasting must be large enough to yield statistically significant responses ($n \geq 12$).
- Sample tastings are limited to three or four formulas and rated against a gold standard target flavor or product.
- Samples are blind coded and tasted under red light; panelists are supplied with mouth-clearing agents as needed (water, apple slices or crackers).
- Panel reproducibility is randomly checked with double-blinded identical samples (two, three or four in a single panel).
- Panelists are checked for drift over time with sensory responses against gold standard flavors or products.
- Panelists are limited to two panels per day (AM/PM) and restricted from tasting at other panels.

- metallic notes
- KCl bitterness
- lingering bitterness from acesulfame K
- off flavors associated with sugar alcohols (glycerine, propylene glycol, sorbitol) in nutrition bars
- peanut off flavors
- bitterness of pharmaceutical actives
- nutraceutical bitter/metallic/astringent notes

The modulating masker formula utilizes very low levels (2–50 ppm) of masking agent(s) in the initial formula. When added to a product, the masking powders can then be functional at 0.2–5 ppm in a seasoning blend, or as a surface dusting agent.

Conclusion

Flavor modulating systems can reduce flavor usage costs by 50–95% when replacing liquid or encapsulated flavors in specific products. Of equal importance is the ability to replace, in part or whole, cheese powders and other dairy and fruit ingredients. In addition to cost reductions, there are benefits with these replacement ingredients such as the ability of a user to decouple from supply chain issues, avoid tariffs, obtain improved quality and functional reliability, and provide technical insulation for specific flavor systems.

Among the most valuable flavor enhancement systems are salt enhancing agents. The unique salty note of sodium ions can be amplified and reduce sodium intake levels by 50–85% while retaining a desirable, balanced equivalent salt note in some limited, specific applications. Similarly, somatosensory principles such as capsaicin heat can also be enhanced many fold. Modulated flavor masking has obvious applications, and the system has already been employed by some in the pharmaceutical industry.

Once a final formula has been developed, a number of strict quality assurance measures must be established. Lot variability of emulsifiers, milk proteins, gums, triglycerides, flavor components, starches and hydrocolloids can unbalance and degrade the sensory quality of the product. A disciplined ingredient quality control program and close cooperation with vendors is needed, in addition to carefully drawn product specifications, certificates of analysis (COA), and continuous sensory profiling of incoming ingredients.

Two key requirements must be considered before planning any development of a flavor (or masking) modulating product: time and resources. Developing a single product type from laboratory through commercialization can take on the order of three to five man-years, comprising the aggregate contributions of flavorists, delivery specialists, process manufacturing staff, sensory staff and analytical support personnel (but excluding sensory panel resources). This expenditure of resources is only justified by high volume and/or high margin flavor business opportunities.

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