PERFUMER & FLAVORIST

Flavors and Fragrances as Functional Ingredients

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The original function of flavors and fragrances was largely hedonistic. The ancient Egyptians and Romans, masters of pleasure, captured the delicate essence of a rose or an orange to luxuriate in its perfume while bathing, or to give a touch of exoticism to their sweetmeats. Times have changed. In this article I would like to trace the changes that are reshaping our industry.

Flavors and fragrances have a shared heritage, a common raw material base (natural products) and common technologies (extraction and distillation). Until recently, however, the flavor and fragrance industries were moving in different directions. Now there is a coming together, with common challenges. Now we talk about "functional ingredients," as opposed to flavors and fragrances.

The Driving Forces of Change

To examine the major forces that have changed our industry, and to see how these have altered with time, we need to step back into history and explore how fragrance and flavor materials have developed. As long ago as 540 BC Heraclitus observed that "There is nothing permanent, except change."

Whether there was a flavor or fragrance industry as such in 540 BC I cannot say, but fragrance was certainly used, and foods were flavored. Herbs and spices were used as seasoning. Foods were preserved by drying or smoking, or adding salt, sugar or vinegar. And natural fermentations ensured a wide variety of milk, cheese and meat products. Essential oils were used as perfumes, as beauty preparations for the face and body, for massage, and as powerful incense in temples.

Change is inevitable, but can be anticipated by observing

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Presented at the 12th International Congress of Flavours, Fragrances and Essential Oils, Vienna, Austria, October 7, 1992 factors such as the available raw materials and technologies, the customers we serve, the consumers that we satisfy, and the legislation that we must abide by. Recent developments in the history of the materials used in our industry can be linked to these factors.

History

The late 19th century saw the first push toward synthetics; one example was the development of vanillin as a result of a shortage of natural vanilla beans, advances in organic synthesis and the industrialization of process technologies.

Twentieth century industrialization responded to a need for convenience and variety. The decade of the 1960s was the era of "you've never had it so good." While housewives clamored for state-of-the-art washing machines and processed foods, synthetic chemistry and process technologies provided the means to manufacture perfumed washing powders and mass market foods.

To the food industry, consumer demands signalled a move away from naturals toward synthetic materials. Flavors and food ingredients were needed to enhance the taste, texture and appearance of foods subjected to the extremes of processing conditions. Meanwhile, fragrances were satisfying the need for variety and were being used successfully to differentiate otherwise similar products.

The 1980s brought a new era in consumer need. This was the period of "you are what you eat," bringing concerns about health, fitness and diet. Fears about artificial additives rose to the fore, and consumer demands for naturalness began to be expressed with a fervor.

Fragrances were also in a period of change. The hypoallergenic properties of personal products, and biodegradability of washing powders became important issues. Fragrance and cosmetic ingredients also came under scrutiny. Would these trends sanction a return to more natural ingredients?

The New Generation

Today we can focus on the new generation of ingredients: those for the "nervous 1990s" and beyond. Our changing environment is providing both threats and opportunities for the flavor and fragrance industry. The trend toward naturalness can be divided into two main concerns: health/nutrition and environment. These concerns raise important questions: How do we react to the changes? What must be done to ensure that these factors become business rewards, not business risks?

New food products today present something of a paradox. Consumers are not prepared to sacrifice taste for fewer calories, less fat or more fiber. They are looking for products that can satisfy both taste and health requirements. Manufacturers are expected to ensure that their products taste good and are nutritionally balanced as well.

As the healthy eating trend continues, there is a growing impetus toward improving the nutritional content of food. On the market now are products claiming added benefits, good examples being isotonic sports drinks and "Bio" yogurts with beneficial microflora.

The environment is of concern to everyone. Issues such as pollution, recycling and biodegradability are hot topics for debate. To address concerns over the environmental impact of products, manufacturers have already removed some ingredients from washing powders and introduced new liquid concentrates and refill systems. Such market changes have meant alterations in product bases. Moreover, fragrances have had to be reformulated or, in many cases, redesigned to perform effectively in the new products.

In a fast changing world of high consumer expectations with an increasingly difficult economic climate, product development and ingredient innovation are imperative. Consumers have become more knowledgeable and more wary of important issues affecting themselves, their environment, and the products that they consume. And they want something more.

Multifunctional Ingredients

A great opportunity confronts our industry. But first we must look at our products differently—not just as fragrances and flavors, but as multifunctional products. We must change our way of thinking, creating total solutions for our customers and developing new raw materials with multifunctional properties which will add product value for our customers.

So what exactly are these multifunctional ingredients, and what can they do?

Quite simply, a *functional ingredient* is one that contributes to a product matrix one or more beneficial properties, such as odor, taste, texture, appearance, and skin or hair care. Within our industry attention is now being directed at finding *multifunctional ingredients* which provide extra product benefits, such as a fragrance that helps to extend product shelf life, or a flavor which also imparts mouthfeel.

Ingredients that traditionally provided only a taste sensation might in the future also add color, stability, texture or processing tolerance to products. Why should a flavor ingredient just provide taste? Similarly, although fragrances have generally been used for their hedonistic properties (communicating product attributes such as freshness), what about utilizing other ingredient characteristics? Fragrances can be designed to improve product stability, provide personal hygiene benefits or act as insect repellents.

Thickening agents which add flavor and stability, and flavor ingredients that add mouthfeel and taste enhancement, are two examples of food ingredients that are truly multifunctional.

The importance of xanthan gum in food applications is well known. While thickening/stabilization are key elements in a complex food system, consumer perception is influenced by a wider range of criteria, including mouthfeel, creaminess and flavor impact. But is it possible to incorporate all of these functional benefits into one product?

The answer is yes. We now have culturing processes producing exopolysaccharide, whereby selection of natural raw material and fermentation conditions has enabled us to prepare a range of ingredients with different combinations of flavors and texturizers. These products provide fat replacement without loss of mouthfeel or thickening, and are useful in applications such as ice creams, sauces and dressings. Their flavor impact and quality are as good as similar full-fat systems and they have accompanying health benefits.

Yeast in Food Systems

Yeast, and yeast extracts, are excellent examples of multifunctional ingredients. Yeast is a veritable factory for the production of sweet flavor ingredients, basic savory building blocks, enzymes, colors and more. Moreover, yeast ingredients are especially fitting, in light of the trends toward healthy eating and salt-reduced products. For example, yeast is used in meat systems. Historically, extracts of meat and bones were used to prepare soup, ensuring a strong meaty taste. Later flavors and taste enhancers, such as salt and monosodium glutamate (MSG), became widely used. Today typical meat stock components are provided by yeast-based products.

Yeast contains ribonucleic acid (RNA), providing natural taste enhancers and contributing to the Umami and salty taste impression in a huge variety of salt-reduced products. Yeast protein and carbohydrates can be broken down enzymatically to provide amino acids and sugars which can react further, via Amadori rearrangement or Maillard reaction, to produce flavor ingredients. Yeast specialties are also used for their nutritional value as fermentation aids and for human consumption.

Perfume Functionality

Let us not forget fragrance. Increased emphasis will also be given to exploiting the additional functional benefits of perfume. Whereas in the past we have produced fragrances which are compatible with an array of different products, today the fragrance can actually stabilize them.

To demonstrate the complexity of interactions between the product matrix and the fragrance, let us take the example of an all-purpose household cleaner. Problems can arise with the shelf-stability of these products due to changes in the physical structure of the base when stored for a period of time. A structured cleaner can contain up to 50% abrasive which, in order for the product to remain stable, must be evenly dispersed throughout the continuous phase. This can be achieved by using a surfactant to trap the abrasive in a crystal structure. Research has shown that this process can be improved by careful formulation of the fragrance, which can actually interact synergistically with the surfactant to help improve product stability.

Shelf Life Extension

In a similar vein, fragrances and flavors also have differing abilities to enhance the shelf life of products. The preservative nature of plants has been recognized for centuries, a variety of herbs and spices have traditionally been used to extend the shelf life of foods. Extract of rosemary, a natural preservative, is a powerful antioxidant, has good antimicrobial properties and is permitted in food applications (being classified as a spice).

Shelf life extension is not just an issue in food products. Preservatives are added to personal products and detergents in order to protect them from microbial contamination during production or, more importantly, when in use. Microbial contamination of products is a hazard to health, and can lead to malodor formation, discoloration and component separation.

By developing a strong scientific base in raw material research and microbiology, it has been possible to determine which perfumery ingredients are effective against a variety of microorganisms (typically those found in contaminated products) and to devise rules for combining perfumery materials in the most effective manner. This has led to the creation of perfumes which work effectively to provide shelf life extension for a variety of non-preserved products.

Hygiene

Microorganisms are all around us—on soiled clothes, on hard surfaces and even in the air. They often result in the formation of malodor. Hygiene is important in consumer products and has led to research into fragrance raw materials with an intrinsic antimicrobial activity, which together with those materials which are synergistic with traditional antimicrobials will have an important role in the future.

Malodors which cannot be prevented in this way need to be approached differently. It may be that they can be neutralized by a process where a soap base malodor (M) is neutralized by a designer molecule (NP), with the resultant formation of a perfume ingredient (P). NP is a multifunctional ingredient with malodor scavenging and perfuming action.

Insect Repellency

Another potential functional benefit of perfume is insect repellency. Citronella and its derivatives are the traditional ingredients widely used as insect repellents. However, there are many natural substances which are considered to possess repellent properties. Pyrethrum, eucalyptus, lemon peel, lavender, vetyver and clove are just a few examples.

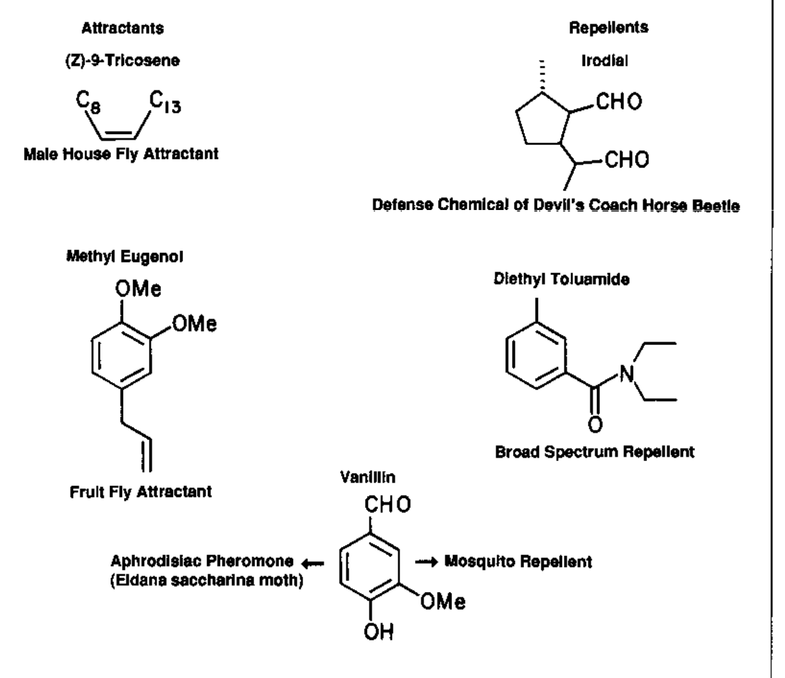


Figure 1. A perfume can also serve as an insect repellent.

Scientists (entomologists) have investigated the repellency (and attractancy) characteristics of traditionally used materials against a variety of insects, and have isolated components of essential oils for similar investigation (Figure 1). In the past, testing has often been carried out on the human arm and involved application of the test chemical directly onto the skin. Today more sophisticated in-vitro methods are used.

The interrelationship between repellent effectiveness and chemical-physical properties of a large number of perfume ingredients has been investigated. This work was carried out using an apparatus designed to mimic a human host. The approach uses targets and video techniques, and enables chemicals to be screened rapidly and effectively. Combinations can then be explored, and perfumes formulated which possess this additional functional benefit.

Triggered Functionality

Perfume activity, or functionality, can often be delivered from consumer products without further reference to the physical characteristics of the product. In many cases, however, these properties need to be taken into account. Traditionally this was achieved by selecting ingredients for their suitability. For example, to provide fragrance on dry cloth, the ingredients would have to be sufficiently stable in the washing powder, not be lost through evaporation during product shelf life, and they must transfer through the wash liquids to the fabric during washing. These problems have been overcome by using delivery systems which protect the fragrance and deliver it at the right time.

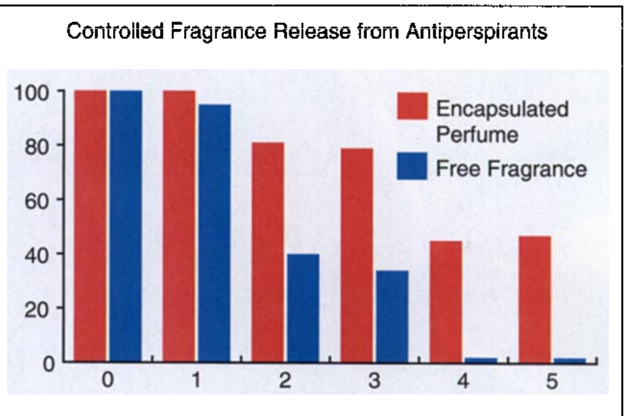


Figure 2. Timed release delivers functionality when it is needed.

In Figure 2, a deodorant fragrance in an underarm product is released from an encapsulate every time it is wetted, thus providing protection when required. The encapsulate is designed to recapture the fragrance on drying and retain it until wetted again. This is shown for consecutive wettings over a period of five hours.

Triggered release of flavor is also important. The cooking of convenience products is increasingly achieved by the use of the microwave. White meat products do not work well in these systems, as the meat remains pale and water loss through evaporation is high. This leads to reduction in size and weight, restricts development of the roast flavor notes associated with oven cooking and generally limits consumer acceptance of the product.

The solution is to provide a coating mix containing a dynamic flavor system in which the meat flavor, triggered b heat, develops during cooking. Maximum flavor impac occurs when needed, with release of the oven-roaste aroma at the end of the cooking period. The coating also act as a browning agent, adding color to an otherwise pal product, and as a sealant to minimize evaporation an weight loss.

The Search for New Ingredients

I have offered a variety of examples illustrating multi functional ingredients within the context of total produc formulation. I would now like to look at some of the technologies currently available, or likely to be of use, in the search for, and production of, such ingredients.

Nowadays, in this search for novel ingredients, we can improve efficiency by the use of molecular modelling. This saves time, increases the accuracy of prediction and stimulates new ideas. Physiological properties of molecules (such as odor, antimicrobial activity and insect repellency) require sophisticated molecular modelling techniques. Prediction of physical-chemical properties of molecules (such as bleach or detergent stability) can be achieved with a less sophisticated approach.

Soap Bars

Structure activity correlation has been used in the development of high performance fragrance materials. It is well known that creation of a soap fragrance with a stable vanilla note is difficult, as most vanilla-type ingredients turn white soap base a brown color. Using structure activity correlations, organic chemists were able to target the Ultravanil molecule, which has good vanilla odor and excellent soap stability. The prediction of odor character and strength of novel molecules is still difficult, however. For a number of odor areas, such as musk, amber, jasmin and sandalwood, there is some qualitative understanding of structure/odor relationships, but a quantitative understanding is still a long way off, and serendipity continues to play an important role in finding new ingredients.

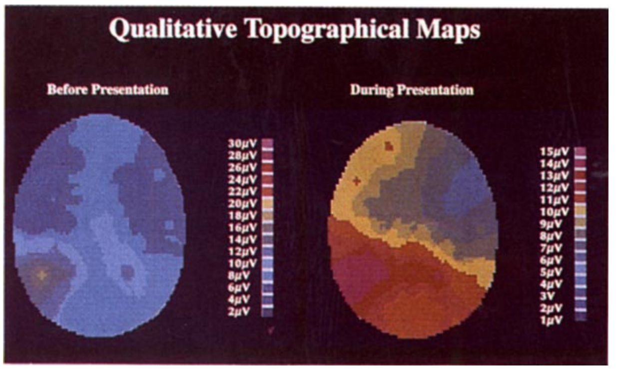


Figure 3. The smelling of an odor causes changes in brainwaves.

Biotechnology

Together with the trend toward more technically sophisticated products (requiring multifunctional ingredients and a total food approach), biotechnology will blur the boundaries between flavor and food ingredients, and will become increasingly important. We will see new enzyme systems for food which are cost effective and stable to processing conditions. Yeast, bacteria and fungi will be used as molecular factories, producing not only flavor ingredients and specialty flavors, but also proteins, polysaccharides, colors, emulsifiers and combinations tailored for "total food systems."

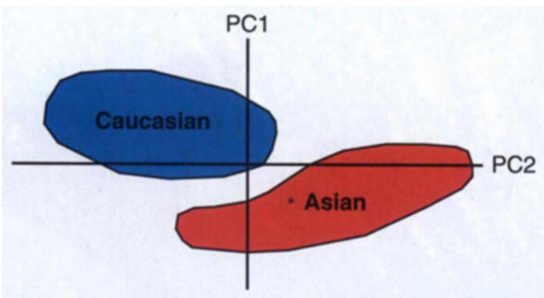
We may also see the emergence of a third generation of food ingredients, produced in-situ by genetic manipulation of raw materials. To illustrate this point, let me use the example of tomatoes, an economically important crop.

Genetic engineering of crop plants, such as tomatoes, has brought a wave of improvements in yield, quality and resistance to disease. The U.S. Department of Agriculture, for example, has announced the successful development of a new and denser tomato. The solid content of this tomato is 15% of total weight (three times the density of a normal tomato) and, as it contains proportionally less water in its structure, it can be more economically viable for producers and manufacturers alike.

The next step will be to engineer important food crops in terms of their protein, polysaccharide and flavor content.

Tomatoes are processed and fermented to provide a

Principal component analysis of fragrance ingredient behavior on Caucasian and Asian skin.



Levels of perfume ingredient differences in the headspace above the skin. Principle components (PC) 1 and 2 represent over 80% of the variance in the data.

Figure 4. The behavior of a fragrance ingredient applied to the skin varies from one skin type to another.

product having both flavor and texture, for application in sauces and dressings. Imagine carrying out the equivalent of upstream processing and bioconversion in a genetically modified tomato. Only down stream processing is then required to provide a product which is suitable for direct application in sauces and dressings.

As yet, biotechnology has found limited application in fragrances, although we can expect that plants will be engineered to provide higher yields of ingredients.

The majority of aroma chemicals are still produced synthetically, with fewer new ingredients being introduced as a result of the escalating costs of safety testing. Increased emphasis has been placed on process research. In terms of cost, raw materials and waste, we are fast moving toward an age of optimized production.

As a balance is struck between consumer demands for "natural," the cost of biotechnological production and the realities of environmental waste, the balance between organic synthesis, biotechnology and natural extraction will change. Production processes with low energy consumption and zero effluent may soon be the only environmentally acceptable target.

The Future

Looking farther into the future, aromachology and skin headspace analysis are enabling technologies which may well give direction to the search for new ingredients with novel functional benefits.

Aromachology can be defined as the study of the effects of fragrance on the state of mood or mind. This definition distinguishes aromachology from the less scientific though more established practice of aromatherapy, which seeks to promote good health and even offers to cure disease. Such physiological effects are not implied by aromachology.

It is possible to measure human brainwave activity in response to odor by a technique called Brain Electrical Activity Mapping (BEAM). We are now able to demonstrate reliable and statistically significant trends in differentiating activity in discrete areas of the cortex during perception of odors, and their subjective evaluation. This is the first time that such correlations have been reported. It represents an important step toward unravelling and understanding how olfactory input is represented on the surface of the cortex. Figure 3 shows brain activity prior to, and directly following, the smelling of an odor material. Different patterns of activity have been found to be typical of different odors.

A desire to understand the molecular detail of skin/perfume interactions has led to the development of a unique headspace methodology (Figure 4). The dynamic nature of the skin surface, and differences in skin type or color, all influence the performance of fragrance in products that are applied to the skin. Environmental factors such as air temperature and humidity, and physiological factors such as the subject's activity can also significantly affect fragrance release.

Headspace technology allows reliable monitoring of the composition of fragrance ingredient molecules in the vapor above the skin surface. Measurements can be made, both in-vitro and in-vivo, to assess substantivity and diffusion characteristics of different ingredients. Similarly, the performance of a fragrance creation can be analyzed in terms of the behavior of its component ingredients. Principal component analysis of fragrance ingredient behavior on different skins can be used in the formulation of fragrances to perform on a specific skin type (such as Asian, Hispanic or European).

Summary

The changing demands of our customers, legislation, higher consumer expectation and improved technologies are all factors which point us as an industry firmly in the direction of multifunctionality.

We are already moving fast toward this age of ingredients which will bestow more than one benefit to a product. Working in an ever closer partnership with our customers we can provide a total package, a complete system, whether we are fragrancing a moisturizing cream or flavoring a microwaveable meal.

This is not only a challenge. It is also a huge opportunity to add value to our products, allowing exploitation and development of our research strengths, application skills and product innovations.

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References

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