Odors and Packaging Materials

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Introduction: The off-odor problem

Smelly, unpleasant odors that originate from packaged products are interpreted by consumers as soiled, contaminated and/or unsafe. Plastic medicine bottles have received the majority of bad press, including: 60,000 bottles of Tylenol[1], 57,000 bottles of the Topamax[2], specific "lots" of Lipitor[3]. But this problem is by no means unique to plastic medicine bottles. An unpleasant odor resulted in the recall of donuts distributed in Arizona, California, Nevada and Utah[4] and a waxy odor from package liners caused the recall of 28 million boxes of cereal[5], resulting in a reduction of Kelloggs' profits by 10 cents per share[6].

There is risk when smelly, foul odors attract unwanted attention from regulatory organizations. Regardless of whether the odor caused a physical problem or not (some consumers reported gastro- intestinal problems after consuming medicine stored in musty smelling plastic bottles), the Food and Drug Administration (FDA) posts this on its website: The health effects of consuming 2, 4, 6-tribromoanisole appear to be minimal but conveyed the concern that musty odors may cause consumers to not take their medicines as prescribed[7]. Another likely result of product that smells musty/moldy is the perception that good manufacturing processes were not followed. Guidelines for good manufacturing processes are found in two FDA documents available online[8,9]. Although odor is not explicitly addressed, conditions that may have allowed the odor to develop are covered. For example, in the FDA document *"Guidance for Industry Manufacturing, Processing, or Holding Active Pharmaceutical Ingredients"*, guidelines for wood pallets are discussed.

An off-odor makes products look bad, regardless of whether a true health risk exists. Pre-planning for off-odor issues helps solve the problem before it is perceived outside the organization and before it creates unwanted attention in the marketplace. The alternative is to risk great expense in mitigation and damage control.

What is off odor?

Smell and taste, unlike vision, touch and hearing, are the only senses that are exclusively based on chemistry. A nose and a tongue are true chemical detectors. The nose detects certain volatile chemicals (not all have odor) that are in the air and that pass into the nostrils (nasal epithelium), where they come in contact with odor receptors that bind to odorants. Then, through a complex system of nerve signals and data interpretation, aroma is perceived. Interestingly, this system remained largely a mystery until pioneering work was conducted by Axel and Buck, for which they received the Nobel prize in 2004 (discoveries of odorant receptors and the organization of the olfactory system).

The tongue is for non-volatile compounds that elicit perceptions interpreted as sweet, sour, salty and bitter and a sensation related to MSG called umami. Our personal chemical detection systems provide early warning alarms to prevent consumption of something that may cause illness; for example, spoiled food. Microbial infestation of fish, chicken and beef results in the production of chemicals that our sense of smell detects. The result is poisons never make it past the lips, thus preventing food-borne illness from potentially deadly bacteria such as E. Coli 0157, Salmonella, Campylobacter, Listeria or others. The origin of many foul odorants is related to the presence of microorganisms. Rotting fish release biogenic amines. One example is trimethyamine (TMA), a chemical related to the simplest biogenic amine, ammonia, and which is responsible for the obnoxious odor characteristic of rotting fish. When exposed to high concentrations of TMA, the sensation is exactly like getting a burning whiff of ammonia. Unlike ammonia, however, TMA sticks to skin and clothing in a manner like getting sprayed by a skunk. The individual exposed will only be aware that there is an unusual fishy odor, but those who come in contact with this person will be repelled by the ghastly rotting fish odor.

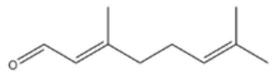
Short chain fatty acids such as butyric and valeric may originate in fat tissue, and are separated when microbiological activity occurs. These types of chemicals contribute to the aroma of such things as feces, rotting flesh, vomit, week-old sweaty athletic socks, and fungal-infected athlete’s feet. Interestingly, at specific levels, short-chained fatty acids are also important in the aroma of many cheeses (including limburger).

The same protective mechanism as that provided by the sense of smell holds true for the other chemical sense, which is taste. Some bitter and sour tastes denote poison. For example, many chemicals from the alkaloid family including strychnine (rat poison) are bitter, and for this reason, the natural response is to spit it and prevent ingestion. Acids are perceived as sour. Although pleasant when consumed in moderation, acids may be harmful if concentrated or consumed in high quantity.

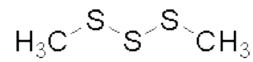
With our evolutionary relationship with aroma and the protection it affords us, it makes perfectly good sense that consumers are so averse to unpleasant odors, especially ones that may be linked to microorganism activity. The odor responsible for plastic medicine bottle recalls was described as “musty.” Musty is really a catch-all term that has multiple meanings: damp, decay, moldy, earthy, dirty, muddy, mildew, or even smoky (as in stale tobacco smoke). In this case, consumers’ noses were right on the mark. The chemical identified as responsible for the medicine bottle recall was converted from a chemical preservative used to treat lumber in wooden pallets. Several types of bacteria and mold can convert this toxic chemical (toxic to the bacteria and mold) into a harmless chemical. However, the harmless chemical has an odor threshold of less than 1 picogram/mL or less than 1 part per trillion[10].

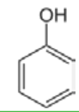
Another related musty odor problem involves farm-raised fish. The problem is that algae love the warm summer days in the south and grow prolifically in ponds saturated with fish food. When algae die, their cells release chemicals into the water that build up in the fatty tissue of fish. These chemicals, primarily geosmin and methylisoborneol (MIB), have an odor exactly like mud (wet soil or dirt). Geosmin and MIB tainted fish have a muddy flavor. The problem is so pervasive that some rural residents who were raised on catfish from local ponds and lakes are unaware the muddy flavor in catfish is not normal! Geosmin and MIB may also affect packaging materials if water sources utilized in a plant are contaminated with algae. The result could be the same muddy, earthy odor, at very low levels, is difficult to detect analytically.

Table 1 Examples of chemicals that may cause off-odor problems



Off-Odors





Odor descriptor	Chemical responsible	Potential sources
Musty -fruity	Nonanal, octanol, heptanal	Natural (plants)
Musty - earthy	TBA, TCA, geosmin, MIB	fungi, algae
Musty - burnt	Guaiacols, furans	heat generated
Sulfur - Garlic/ onion/foul	DMDS, DMTS, skunky thiol	Bacteria, petroleum
Sulfur - potato	methional	Natural, microbiological
Stinky - cheesy	Valeric, butyric acids/ aldehydes	Microbiological
Stinky – rotten	biogenic amines: TMA, putrescene	Microbiological, biological
Stinky - barnyard	P-cresol, phenol	Microbiological, biological
Green - Grassy	Hexanal, hexenol	Plants (wide variety of sources)
Solvent	Dichlorobenzene, toluene, styrene	Man made/ derived
Fruity	Geranial, neral, octanal	Plants (citrus, other fruit species)

Case study

In **Table 1** (above), some common odors are listed, along with the responsible chemical and potential sources. Some of these aromas are pleasant, when experienced in proper context. For example, the odor of garlic contributed, in part, by dimethyltrisulfide, enriches the flavor of Italian marinara sauce. Different forms of a class of chemicals called pyrazines are responsible for the delicious aroma of toasted bread, roasted meat, coffee and chocolate. However, the odor of sulfury garlic is not desirable if perceived in milk, nor is the roasted odor of pyrazines desirable in fresh orange juice.

Pleasant aromas become off-odors when they exist in environments where they should not. A case in point involved client that was experiencing puzzling odor problems with pizza boxes. Several complaints were registered from customers who ordered cheese pizzas packaged in the client's corrugated pizza boxes. Customers reported the pizzas had a spicy odor. Spicy did not belong with cheese pizza.

The odor proved elusive because it did not persist, or did not readily develop in all circumstances. A pizza box that reeked of the odor and was returned by a customer the night before smelled like day-old pizza and soggy corrugated the following morning. When fresh, hot cheese pizza was placed inside implicated pizza boxes from the same lot as those that were returned, and these were housed in pizza delivery jackets, no unusual odor was perceived. Restaurant employees reported the odor after pizzas were placed in boxes and stored on top of a kitchen oven. These conditions were duplicated exactly, but no unusual odor was perceived either by a team of odor experts or by the same employees. After considerable time and money were spent attempting to duplicate the problem, it was realized the odor required a certain space to develop. The space was larger than the interior of a pizza delivery jacket, but smaller than an average-size kitchen. The number of pizzas also impacted the size of space needed for odor to develop. An explanation for this phenomenon was related to odor thresholds of chemicals responsible, headspace concentrations, and the effects of heat and humidity.

After the odor was duplicated, the volatile chemicals responsible were identified as hexanal and several other related aldehydes. Hexanal has a strong freshly cut grass, or green, aroma. The other aldehydes contributed related herbaceous aroma. Further investigation revealed that paper utilized in corrugated manufacture (used in pizza boxes) contained an abnormally high amount of aldehydes due to both the paper type and a processing abnormality. The corrugated manufacturer made changes in type of paper utilized, and was able to correct the processing error. No odor problem related to spicy or hotdog has been reported since then.

The original pizza box complaint odor descriptor was spicy. Although spicy aroma (unlike spicy taste, which is often hot from capsaicin) could mean anything from cinnamon to curry to basil to chili powder, in hindsight the spicy odor was a combination of green and herbaceous. This point emphasizes the importance of getting an accurate complaint odor descriptor. By knowing what the odor description is, a class of chemicals quickly can be identified as a likely source. In the case study presented here, the descriptor "spicy" did aid in the identification of abnormally high aldehyde levels. If the odor was described as solvent, sulfur, burnt, rotten or barn yard, a different class of chemicals would be responsible.

Recommended steps

As with most problems, preparation is the best damage control tool. A thorough understanding of what constitutes normal chemicals and odors allows for rapid identification of the abnormal. When an off-odor problem does occur, the goal is to gather as much information as possible to reconstruct odor and conditions in which it was perceived. The following steps are recommended for a successful outcome.

1. Validate –were one or more customers/complaints involved?
2. Verify the complaint odor descriptor(s) from client and/or client customer(s).
3. Identify conditions / circumstances at time of complaint.
4. Determine if complaints were from same lot of product, and note the lot numbers involved.
5. Review internal production records to ascertain if anything unusual was reported for the implicated product.
6. Collect complaint product samples.
7. Store samples in clean glass jars with foil-lined lids in cool conditions and protect them from direct light.
   - Otherwise, wrap the saples in clean aluminum foil and place them in an airtight container. Store them under cool conditions and protect them from direct light.
   - Label jars with dates, lots numbers, reels or any other identifying data available.
8. Identify components of suspect samples (paper, liner, etc.) and gather these for assessment.
9. Obtain comparison samples from “good” lot(s).
10. Conduct organoleptic and analytical analyses to identify chemical odorants (see **Figure 1**, which is representative of a GC-MS/O analysis).
11. Compare results with chemicals and odors of normal product.
12. Based on the identified odorous chemicals deemed responsible, determine how and where chemicals were introduced in the manufacturing process, and implement appropriate corrective actions.

Aromagram - combination of analytical and sensory

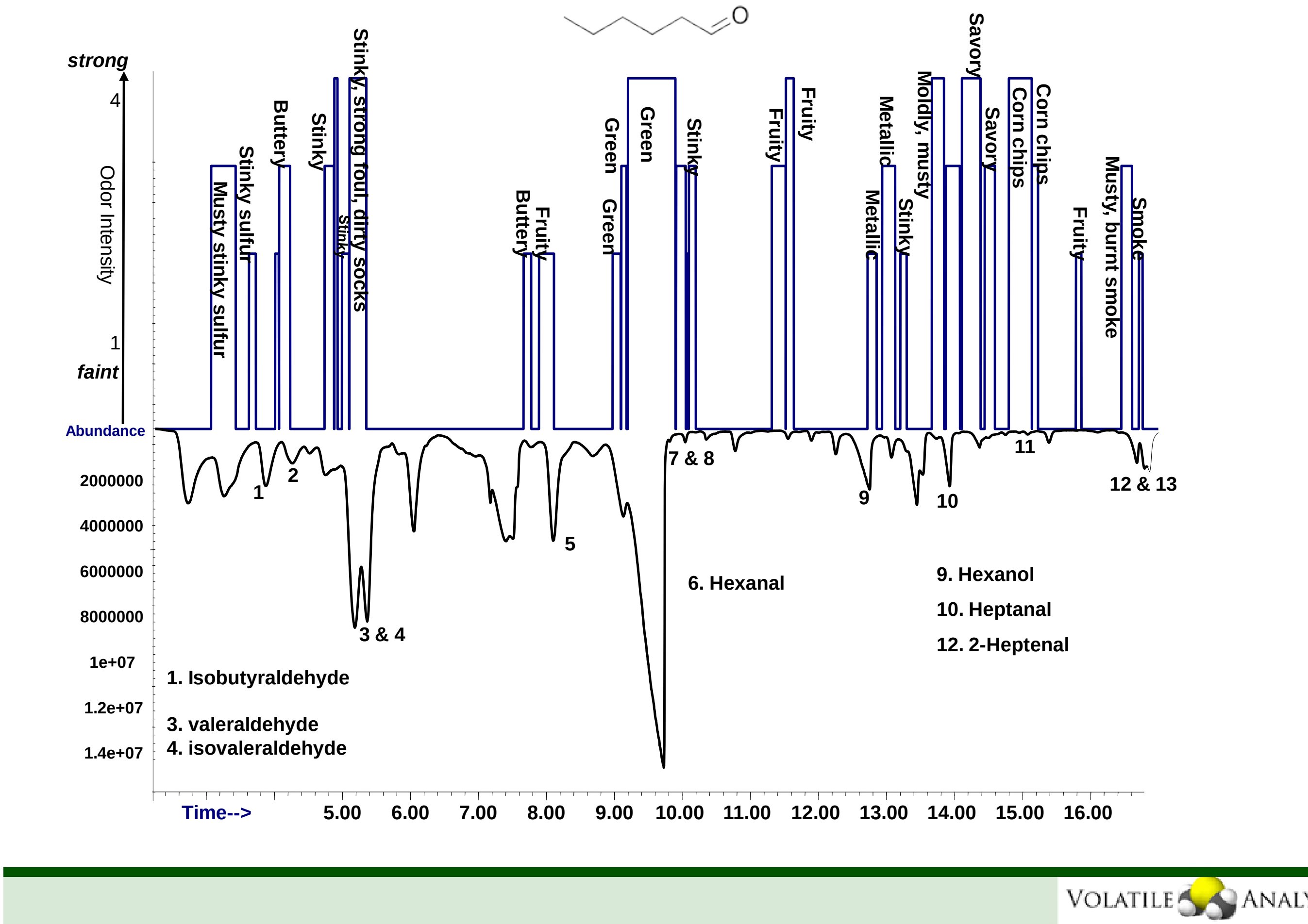


Figure 1 An aromagram is a combination of aroma intensity vs. time (top) and a mass spectrometric total ion chromatogram (bottom). It allows for rapid screening of odorous chemicals and is useful for determining baseline volatiles and off-odors

Conclusion

Off-odors in packaging materials have resulted in millions of dollars in lost revenue, damaged corporate reputations and unwanted scrutiny from regulatory organizations. Besides the most publicized cases involving medicine bottles and pharmaceutical products, off-odors affect just about every industry because chemicals are part of the production process and because we all have a sense of smell. It is good business practice to be prepared by understanding what chemicals and odors are normal for a given product, and then developing a plan of action to mitigate potential odor problems.

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