Sealed in ~~Plastic~~ Edible Film

Can consumable coatings pass muster with finicky eaters?

By ELIZABETH PENNISI

For food scientists concerned with freshness and consumer satisfaction, moisture represents consumer enemy number one.

Water — moving into, out of and between foods — causes all sorts of problems. It forces manufacturers to package snack-pack cheese separately from the accompanying crackers; otherwise, the cheese hardens and the crackers grow stale. In cereals left too long on the shelf, raisins shrivel to tooth-chipping hardness. Frozen pizza crusts never taste quite right, because the sauce on top turns them soggy. Breaded shrimp shrink from water loss, sometimes so much so that they no longer meet size standards for legal sales. Celery wilts; fruit pie fillings get gummy.

All because water refuses to stay put.

Twenty years ago, most food scientists considered these problems too trivial — or too intractable — to warrant much attention. Today, however, the increased emphasis on global markets and higher quality means that foods need to stay fresh longer under more complicated conditions, says Ted P. Labuza, a food physical chemist at the University of Minnesota in St. Paul. In addition, concern about overflowing U.S. landfills has brought a clamor for reduced reliance on plastic and other containers.

"People complain all the time about how come you're wasting all the packaging," says Labuza.

Cheese-and-cracker snacks represent just one sort of "multitexture" product, in which differences between the components make packaging difficult. For frozen pizza, at least one company fries its dough slightly to give it a moisture-resistant coating of oil, "but that gives a crust that is more like a pie crust," Labuza says.

And moisture isn't the only threat to palate sensibility. Oxygen seeps into foods, and fat molecules slip across food boundaries, affecting texture and taste, notes John M. Krochta, a chemical and food engineer at the University of California, Davis. He and other food scientists and engineers work hard to slow the movement of oxygen into fruits and to keep concentrations of carbon dioxide at levels that extend the shelf life of produce. They also seek ways to help maintain the identities of the various foods mixed together in convenience products. "You want to keep the food different," he explains. "You don't want it to all become mush."

These problems have driven food researchers to take a fresh look at an ancient preservation technique: edible films.

By coating products with an invisible and virtually undetectable barrier against moisture and gas, researchers like Labuza seek to extend the foods' shelf life while helping to solve the nation's solid-waste problem. With edible films, food distributors could prepare large quantities of fresh produce and make them available to customers at less cost than if buyers sliced, diced and cut the fruits and vegetables themselves. And all the waste peelings would be concentrated in one place, making disposal more efficient, notes Labuza. Edible films could also improve the availability of prepared foods, such as fruit-and-nut cereals or frozen pies.

"Consumption of fresh fruits and vegetables could be higher if this service were provided," says Attila E. Pavlath, a food scientist at the USDA's Western Regional Research Center in Albany, Calif.

Two years ago, Pavlath made a presentation on consumable coatings to a group of industry food scientists. Afterward, he received some 200 inquiries from sources ranging from a fast-food chain seeking to precut its onion slices to an ice cream manufacturer who thought a digestible film would keep frozen sandwich bars tasty.

Labuza envisions edible coatings in the form of spray-on films. Just as hair spray keeps hair looking freshly combed, a spritz of edible film on freshly peeled celery or chopped fruit could keep these foods looking their best for guests arriving hours or even days later, he says. Pavlath suggests spraying edible film on bread to keep sandwich fillings from making the bread soggy. Owen R. Fennema, a food chemist at the University of Wisconsin-Madison, wants to create an invisible packaging for pie fillings that melts and disappears during cooking. "The consumer would never know it was there," he says.

These films "can reduce the cost and complexity of the packaging system," says Krochta. Because an edible film may partially protect a product, the plastic wrap could be a single layer rather than a laminate of different polymers. "It may make [the wrap] recyclable," Krochta suggests. And with the edible films themselves, "the human being becomes the waste disposal mechanism," he says.

Although consumable coatings date back hundreds of years, scientists have much research to do before modern-day diners routinely eat the packages that protect their food. In the 13th century, Chinese vendors coated fruits and vegetables with wax to keep water in and to cut down on scratches and bruises. And in the 16th century, the English practiced larding, sealing perishable foods in fat. Today, however, these "edible" packages don't rate very highly in terms of palatability.

Moreover, most current film formulations don't lend themselves readily to mass production. For example, a beeswax coating requires melting before application and often covers a material unevenly, says Krochta. And beeswax tends to crack, or to form a coating so thick that it disrupts respiration in the cells it encases, causing "off" flavors to develop.

To succeed in 20th-century cuisine, edible films must be thin, transparent and flavorless. "People are generally finicky," Pavlath says. "They would not accept a thick coat."

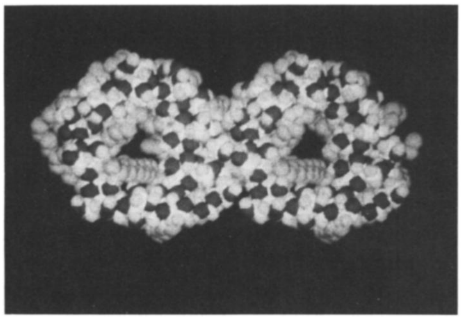
Films also need to stick to the food surface. This means that the chemistries of the food and the film must match, but it also means that the film must possess water-conserving properties that the food surface lacks. In addition, films must slow or stop the transfer of water and gas under various storage and transportation conditions. And, since not all foods are alike, researchers may have to create different coatings for different foods.

Modern food scientists readily accept these challenges, and several of them have begun taking a more systematic look at the range of possibilities for edible films. They've discovered better film ingredients, including whey protein, cellulose derivatives and purer forms of a corn protein called zein. "We're getting a feel for what the barrier properties are," says Krochta. "It's an era of relating molecular structure to function."

For the most part, these investigators started off with stuff people eat: proteins, starches, fats. Each of these food components proved to have strengths and drawbacks as edible coatings. Fatty substances, for example, seemed the logical first choice because they repel water quite effectively: Fatty acids have a structure that allows them to line up closely, forming a tightly knit coating that allows very little water to get through. "But coating fat on materials is very difficult," Labuza says.

Initial studies showed "there's no one material that seems to do it all," says Krochta. So in the past few years, researchers have concentrated on combinations of substances from the three candidate nutrient groups. Krochta developed several films that incorporate a lipid and casein, a milk protein. Labuza discovered he could make an effective moisture barrier with an emulsion of fatty acids, protein and starch.

Now Labuza says his goal is to make a very thin, undetectable film. Toward that end, he has begun evaluating how well ever-larger fatty acid molecules (as measured by their number of carbon atoms) slow the transfer of moisture. In tests of films containing fatty acids with six to 24 carbon atoms, he found that stearic acid, with 18 carbon atoms,



Pavlath/USDA

worked best. Using fluorescence microscopy, he also determined that "particle size distribution [of fatty acid in the emulsion] is very critical to the prevention of water migration."

Pavlath wants to take edible films a step farther – for use on produce that has already been peeled, chopped or sliced. There the challenge increases.

"It's easier to take an apple and put a coat on it outside, but once you cut the surface, you have moisture oozing out," he explains. "It's much more difficult to coat the [cut] fruit and much more difficult to protect it."

Yet that's when produce needs these coatings the most, because prepared fruits and vegetables are even more susceptible to drying out, browning and spoilage, Pavlath says.

So, like Labuza and Krochta, he began his search with the basic food nutrients, trying them one at a time, then in combinations. He found that carbohydrates kept oxygen from reaching the fruit and turning it brown but did not stem water loss; in time, the fruit shriveled. Fat kept water out but did not readily form a solid, stable film. "That's where the proteins come in," Pavlath says. Although proteins did not protect against water loss, they proved an important ingredient for maintaining the integrity of a film.

Univ. of Minnesota

At the University of Minnesota, Claire Koelsch uses a digital calorimeter to analyze a sample of an edible coating, while USDA researchers made this computer image (left) to study how chitosan and lauric acid fit together in an edible film.

"When we combine any two compounds, we don't get a good result," says Pavlath. "You need a combination of all three materials." After two years' work, he and his colleagues made a film that slowed water loss and discoloration when placed on apple pieces. The apple slices continued to look fresh for up to four days.

"Unfortunately, three to four days is not enough," Pavlath says. "We need something that [makes the fruit] last about two weeks."

The need to achieve longer-lasting freshness led Pavlath and USDA colleague Dominic W.S. Wong to look beyond standard ingredients. Like others, they found that chitosan, a material derived from the shells of shrimp and crabs, showed a lot of promise when combined with fatty acids. With their chitosan-based film, the USDA team gets about five days of protection. While that's still not as long they hope for, "it allows us to look for other possibilities," Pavlath says.

They then began trying films with different fatty acids, expecting that the bigger the fatty acid, the more water-repelling its structure. Instead, they discovered that lauric acid, a fatty acid with 12 carbon atoms, worked far better than smaller or bigger fatty acids.

The researchers wanted to know why. Using a scanning electron microscope, they found that the structure of the lauric acid film looked strikingly different from the others. Other films contained large, irregular pores, but the lauric acid-chitosan film was hole-free and consisted of regularly spaced layers.

Next they modeled the arrangement of the film's molecules. Computer simulations showed that flat chitosan molecules become spirals when combined with fatty acid. The water-repelling parts of a fatty acid molecule stick into the center of these spirals, closing any gaps through which water molecules might sneak through. However, fatty acids with more than 12 carbons do not fit as well. Some parts of those longer fatty acids stick out, forcing wider spacing between chitosan strands and making the film more porous, Pavlath explains.

"Now that we know this, we can take a look at other possibilities of how we can make the holes even smaller," he says. The USDA group has now strung together three-carbon lactic acid molecules for testing in films.

Slowing or stopping the flow of water and gas is only a first step, especially if one hopes to make edible containers. "We're not talking about making a plastic bag out of an edible film," Labuza emphasizes. "[Edible films] are very fragile as stand-alone films, and they don't heat seal."

Furthermore, most of the edible films developed so far work only in fairly dry environments. "They do not have very good barrier properties when the humidity goes up," Labuza says. When the air around them gets sticky, the films absorb moisture and swell, opening up microscopic pathways for moisture and oxygen to reach the food inside.

Nor do scientists know how to apply these films yet. Pavlath and his colleagues hand-dip each piece of fruit. "Obviously, that's not something that could be done at 10,000 pounds per hour," he says.

Getting an even coat has also proved difficult. Labuza has coated celery and raisins by dipping them into vats of liquid film or spraying them. In another technique, he puts the raisins on a tray full of tiny holes and blows air up from beneath the tray so that the raisins bounce around. He then sprays the coat onto the dancing raisins. Put on too thick a coat, he says, "and you can tell it's there."

And when all is said and done, the academic research means little if companies don't make use of it.

"We've made a lot of progress on the scientific aspects," says Wisconsin's Fennema. "But I can't say there's been much progress on the part of commercial organizations in using these films."

So edible-film researchers do not expect to see many of the fruits of their labors on the market in the near future. "It may take another five years before we see these in widespread use," Labuza says. □