Nanoreactors for food quality control
Prof. Cornelia Gabriela Palivan
Chemistry Department, University of Basel

Reducing food waste through smart packaging

A lot of food is withdrawn from sale or thrown away by consumers because it has exceeded its best-before date. However, these products would often still have been perfectly edible. NRP 69 researchers have developed various nanotechnology processes that indicate the quality of food on its packaging. They have designed active surfaces that react to changes in acidity and other signs of product deterioration. Such active surfaces operate as reactive labels that either indicate the freshness of the food or even extend its shelf life, thereby helping to reduce food losses.

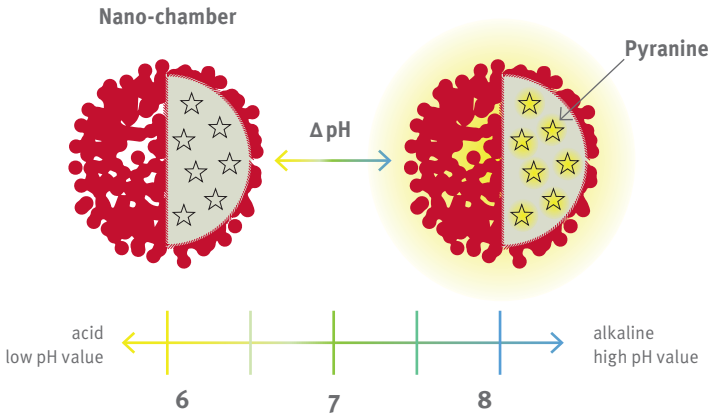
On almost all food packaging, a best-before date indicates how long the products can be kept. But many of these packaged foodstuffs can be enjoyed well beyond this deadline without any risk to health or loss of taste. Nevertheless, many consumers throw food away once it has passed its best-before date, resulting in unnecessary food waste. As part of the NRP 69 programme, researchers at the University of Basel have developed smart labels for packages that can provide information on the quality of the packaged food.

To indicate through the labels on packages whether the product is still edible, the chemists designed active surfaces onto which small nanotechnology compartments acting as nanoreactors are attached. These react if there are changes in their environment that can be associated with changes in the quality of the packaged food. The most important and very reliable indicator of changes in quality is the acidity level (measured as the pH value). But the nanoreactors developed in this study can also be modified to react to the appearance of free radicals, specific molecules or gases in the packaging that indicate a deterioration in the food. The researchers customised the nanoreactors to these deterioration phenomena. They assessed two different methods of creating such smart labels that can be attached on the surface of the packaging.

The first method monitors changes in the pH value of the food. To do this, the researchers used nano-compartments containing the fluorescent dye pyranine. This substance changes its fluorescence intensity with even small fluctuations

Nano-compartments indicate changes in acidity

Nano-compartments containing the fluorescent substance pyranine are attached to the surface of the labels. Even small changes in acidity levels in its vicinity induce a change in the intensity of the fluorescence of the substance. If the pH value increases, then the pyranine becomes brighter. Since changes of the pH value can indicate the decline of a product's freshness, this mechanism can be used to create labels that provide information about the quality of food.



in the pH value. Pyranine is therefore ideally suited to indicating the freshness of foodstuffs. The chemists encapsulated the pyranine into nano-compartments and, in tests on lactic acid and ethylenediamine – substances that appear when food decays – confirmed its sensitivity to pH fluctuations. The fluorescence intensity of the pyranine declines in an acidic environment, whereas it increases in an alkaline environment. Changes of the pH value can indicate the decline of a product's freshness.

The researchers then developed two different processes for attaching these nanoreactors to the active surfaces, which will serve as smart labels once placed on the packaging. One procedure is based on a reductive amination reaction, and the other is based on a thiol-ene click reaction. Both fixing processes were tested on glass surfaces. The thiol-ene click reaction was the most stable. It also enabled the nanoreactors to be densely arranged on the surface, making the smart labels more effective and more reliable. Various tests showed that the integrity of the nanoreactors was preserved; in dark, dry conditions, they remained stable and reactive for up to eleven months.

The second method is based on the recognition of specific molecules that occur during food decay. To achieve this, the researchers created functional polymer membranes. Both single and double-layer membranes were tested during the project, with the double-layer membranes proving to be the most stable. The chemists incorporated specific enzymes into these membranes (laccase and tyrosinase). Both enzymes were effective and maintained their bioactivity for a prolonged period of time. These membrane-bound enzymes are suitable for producing small labels that can measure free radicals and decay phenomena in the vicinity of food.

Further information:
www.nrp69.ch

A gateway system can freshen up products

Researchers see huge development potential for nanoreactors containing enzymes that can keep food fresher and therefore edible for longer. The concept is based on a nano-level gateway system: if the freshness of the food diminishes, compounds in the nano-compartments are released, restoring the quality of the product. This is possible due to the enzymes incorporated into the nano-compartments, which produce substances needed for preserving food. In the membranes of the nano-compartments, proteins take on the role of gatekeeper: if the pH value changes they release the products manufactured by the encapsulated enzymes, thus "freshening up" the food. This system is very complex and might primarily be suited for expensive and luxury foods. This technology also has potentially interesting applications in the pharmaceutical industry.

Application

Smart labels indicate food deterioration

Both of the nanotechnology methods investigated in the project open up a variety of possible applications for intelligent food packaging. The easiest to implement are smart labels, which indicate the quality status of the packaged food. The procedure tested in NPR 69 using labels on which nano-compartments containing a dye are attached to the surface of the packaging is very promising in this respect since the dye reacts to small changes in pH value. Besides, there is no direct physical contact between the label and the food, so the system's safety is guaranteed. One possible application is coloured labels on packaging that indicate the condition of the food. Such intelligent labels acting as traffic lights could supersede rigid best-before dates and help reduce the amount of food removed from sale or thrown away by consumers even though it is still perfectly edible. Smart labels are therefore a promising way of reducing food waste.