Boxing clever

Food scientists are developing increasingly sophisticated packaging materials to extend shelf life of many foods. Nina Notman looks at the delicacies on offer – from spoilage sensors to active antibacterial wrappers

Imagine opening your kitchen fridge to see the sliced ham you bought four weeks ago is still perfectly fresh – its smart colour-changing label confirming it's edible – or pulling a two year old packet of savoury biscuits from the back of the kitchen cupboard and finding them still impeccably crisp. With the help of the latest packaging technology, this could well be the future for food.

Devices like the widget, which brought us 'draught beer in a can', and the sachets of iron filings that keep oxygen away from processed foods, have been around for a while. But so called 'smart packaging' is set to get a whole lot smarter – provided financial, sustainability and legislation hurdles can be overcome.

Smart packaging is an umbrella term used to describe a wide range of packaging and in-package sensors that can extend shelf life or tell you if there is something wrong with the quality of the food, explains Joseph Kerry, a packaging expert based at University College Cork in Ireland.

While much of this work goes on behind the closed (and patented) doors of industrial research and development facilities, the area is also becoming a hot topic in academic and government-funded laboratories. And a substantial part of this research is focusing on ways to monitor the environment inside the sealed food package, such as the humidity and oxygen levels.

'A lot of food products are oxygen sensitive,' says Kerry, 'with processed meats being a particular problem.' Oxygen damages these foods in three ways, he explains: 'It chemically destabilises the fat causing rancidity, can promote the growth of any microorganisms that survive food processing techniques, and combined with supermarket's fluorescent lights can drive pigment oxidation – turning meat brown or grey.'

Kerry and his colleagues have designed a novel type of sensor that can monitor oxygen within food wrappers at levels as low as 0.1 per cent. The sensors are based on a well-known reaction, chemiluminescence, and are easy to add to food packs – as they can be printed onto self-adhesive paper and applied with a labelling gun. 'The device uses porphyrin-based dyes, whose chemiluminescence is affected by the presence of oxygen,' Kerry says. These dyes are read using a fibre optic light in a handheld digital device. 'Your sensor will read 100 per cent chemiluminescence if no oxygen is in the pack, but as oxygen starts to increase, the signal from your chemiluminescence will start to decrease.'

Pointing the finger

It is the food manufacturers who are driving the market for these types of devices, explains Kerry. Oxygen-spoiled food is often returned to the manufacturer by supermarkets expecting a refund, when the damage was actually caused by the retailer storing the food incorrectly.

'The detectors can tell the retailers what levels of oxygen were in the product as they were delivered to the store,' says Kerry. So the manufacturers can point the blame, and therefore the financial loss, at retailers if oxygen enters the package at a later date.

Kerry's sensors are already being used by some food packaging companies on an ad hoc basis to investigate problems with packaging materials suspected to be underperforming. And the researchers are currently talking to some of these companies about putting the sensors into 100 per cent of their food packages.

These sensors cost money to make and, in the highly competitive food industry, manufacturers can not afford to increase the price of their product to cover this loss. But according to Kerry, if the price of the device is low enough – that is, if the costs can be recouped by reducing the number of refunds given to retailers – manufacturers will be keen to use them.

'At the moment each one of our sensors costs around €0.15 (£0.13), and the price needs to come down to about €0.01,' says Kerry. 'Mass production will drive the price down, and we have a project currently where we are looking at less expensive dyes and materials to form the sensors.'

At the VTT Technical Research Centre of Finland, a team led by

In short

- **Smart packaging could prolong shelf life and reduce waste**
- **Antibacterial films and atmospheric sensors can be built into packaging materials**
- **Oxygen-scavenging ketchup bottles have been launched in the US, but legislation is slower in Europe**

A smart temperature monitoring label blinks green inside a wine shipment, confirming that the bottle has been stored correctly

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Maria Smolander is also working towards reducing the costs of sensors for packaging. 'We are interested in indicators that can be printed directly on the packaging material,' says Smolander. 'Price is really a crucial issue when talking about consumer packaging for food,' she adds. And that price can be very low if the sensor is printed directly onto the inside of the package using the same inkjet technology that is used to print the label on the outside of the package.

Consumer focused

Unlike Kerry's oxygen sensor, the range of packaging sensors VTT are working on are designed with the consumer in mind. These sensors visibly change colour, or appearance in some way, to indicate if the food has been stored in an unsuitable environment.

'Lots of people do not want to use food after the best before date, and so lots of food that is safe to eat is discarded,' says Smolander. If consumers were able to use sensors to verify that the food is still ok, there would be less wastage and we would become much more sustainable, she argues.

One such device they are developing is a printable humidity sensor for dry products such as crisps and nuts. The sensor can tell the consumer if there is too much moisture inside the packaging, explains Smolander – so they would know if the product has been stored correctly before they bought it, and then in their homes before they eat it.

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Smart labels could make unpleasant surprises like this a thing of the past

The humidity sensor is based on two water absorbing layers, sequentially printed directly onto the packaging. The first layer is made of polyvinyl alcohol, calcium chloride and a pH-sensitive dye called bromocresol blue – making the layer look blue. Printed onto this layer is a pattern of clear spots, consisting of polyvinyl alcohol and lactic acid. The acid decreases the pH underneath the spots, turning the dye here from blue to yellow, so the sensor looks like a blue square with yellow dots.

'In dry conditions the printed pattern remains unchanged,' Smolander says. But in elevated relative humidity, water is absorbed into the two layers, causing the acid to migrate throughout the sensor. As the concentration of acid at each spot falls, the pH rises above the threshold of the pH-sensitive dye, and the yellow spots disappear to leave a plain blue square.

Killer packaging

Perhaps an even more effective way to avoid food waste is to develop packaging to extend the shelf-life of the food product – and this is an area that a number of researchers internationally, including VTT and Kerry's colleagues at University College Cork, are moving into.

'Nanoparticles, such as silver, can be incorporated into packaging to prevent the growth of spoilage and pathogenic microorganisms,' says Kerry. 'This is seen as a cutting edge area in the field of smart packaging,' he adds. Another top scientist in this field, Mark Morgan from Purdue University in the US, explains the concept: an antimicrobial is immobilised on to the packaging film, and when bacteria come into contact with the antimicrobial they will be either killed or deactivated.

'What my team are trying to do is immobilise bacteriophage – viruses that attack specific bacteria – onto the packaging film,' Morgan says. 'So if there is no bacteria [in the product], the bacteriophage will stay on the film. But if there are listeria, the bacteriophage will capture the listeria – and then inject their DNA into them to create more bacteriophage.' The assumption is that the threat from the bacteria in the food will be removed and it will still be edible – Morgan suggests that the technology might be particularly suitable for ready-to-eat meats.

Morgan is currently working on developing a technique to immobilise the bacteriophage into the packaging in a way that is suitable for mass production. And, in the same way as the VTT team and their humidity sensors, he is looking to incorporate this step in

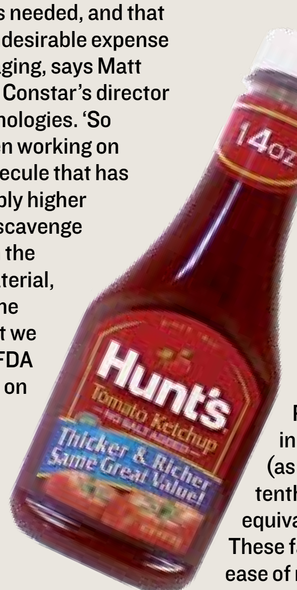
Coming soon to a supermarket near you

On 22 July, a new type of oxygen scavenging material gained regulatory approval in the US. The second generation of food packaging company Constar's DiamondClear packaging material – PET (polyethylene terephthalate) with an embedded oxygen scavenging amide – was given the green light for use in food packaging by the FDA.

The amide-based oxygen scavenger is built into the PET material, says Constar's principle scientist Girish Deshpande. And, when the amide comes into contact with oxygen, a peroxide is formed. 'The peroxide then breaks into two radicals and propagates the oxygen scavenging reaction by generating additional sites [in the polymer] for oxygen to attack,' he explains.

In the first generation of DiamondClear a fairly large amount of the oxidasable material was needed, and that added an undesirable expense to the packaging, says Matt Dauzvardis, Constar's director of new technologies. 'So we have been working on another molecule that has a considerably higher capacity to scavenge oxygen than the previous material, and that is the material that we just gained FDA approval for on 22 July.'

The first generation of this technology is used by a well-known US ketchup supplier, ConAgra Foods, in their Hunt's tomato ketchup bottle. And Constar are currently looking for manufacturers to use their latest version, according to Dauzvardis.



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While the new scavenger does still add direct cost to the PET, Dauzvardis says that the manufacturers recoup the money through needing to use less material (as DiamondClear PET is very thin) and in lower transport costs (as the material is only one tenth of the weight of an equivalent glass container). These factors, coupled with the ease of recycling PET, makes this technology a sustainable packaging option, he adds.

the printing process: 'We are trying to use the same process that is used for printing the ink on the outside of the packaging, the energy curable inks, to put the active elements on the inside.'

Morgan's thoughts have also turned towards legislation, another obstacle often blamed for delaying the entry of these types of material into the food packaging market. Morgan says that most of the materials his team are using are US Food and Drug Administration (FDA) approved – except for the chemicals they were using to trigger the immobilisation–polymerisation step. To avoid this, he has developed a process that uses an electron beam to provide the energy needed to start the polymerisation process without a photoinitiator. 'We think this process looks promising for getting approval,' he adds.

Boxed in

Another Purdue-based food packaging scientist hoping legislation won't block the path of his innovative microbe-killing procedure is Kevin Keener, whose concept is to use the gaseous environment surrounding the food – rather than the wrapping itself – to control any bacteria left in packaged food.

Keener's idea is to generate reactive gases within the food package after it has been sealed, targeting any bacteria remaining inside the package. The process runs two gas ionisation plates across the outside of packages as they pass along the conveyer belt in the factory, straight after the food and 'modified gas atmosphere' (which many vegetables are packed in as standard) have been sealed in. The plates ionise the gases inside the package and Keener says that 'reactive oxygen species are primarily what we are targeting, things like nitric oxide, peroxide, ozone'. The reactive species convert back to harmless gases before the foods reach the supermarket shelves.

'We have been able to show conceptually that [gas] ionisation can occur inside a package,' Keener explains, and the reactive species produced have been demonstrated to significantly reduce microbe levels in the packaged food. However, the process requires a delicate balance in the amount of reactive gases generated – enough to kill the microbes, but not so much that it degrades the food, for example by bleaching it. But Keener thinks the team are on track. 'In the lab we have achieved a five-fold reduction in salmonella in tomatoes, with no visual changes to the fruit,' he announces proudly.

This process is very low energy: 'To ionise a package containing a kilogram of food only uses 30–40 watts of energy, and we think we can get this down,' he says. 'So the actual cost will only be related to the equipment, and I would estimate that would be in the range of $15 000–20 000 [£9000–12 500] per unit – which is not a significant cost for food manufacturers.'

In terms of legislation, Keener is hopeful that the FDA will look favourably on his procedure, as the ionisation process is already well established for food use. However, he admits that 'there are questions from the regulatory concerned about the interaction of the ozone with the package, and documented research is needed to show the ionisation process isn't having a harmful effect on the package.

'Assuming all goes favourably, we are probably looking at 18 months before we have an industrial prototype and then it could be available for food companies in two years and shortly after that you would see products on the market.'

'In 20 years time people will laugh and wonder how nanoparticles were never in all packaging materials'

While Morgan and Keener are confident they will gain regulatory approval to use their concepts in food packaging, not all researchers in Europe view the situation so favourably. Ulphard Thoden van Velzen, from Wageningen University in the Netherlands, believes that 'consumers are afraid of technology in Europe, but in Japan and other countries – such as Australia – technology is viewed as the way forward.' He claims that this has caused many European academic and industrial research and development efforts in this field to fail.

Kerry agrees that 'the Europeans seem to be more effected by worry than anyone else and that this generally tends to hold up technological development.' But adds that he does think people are right to ask questions.

Kerry also points to the new EU legislation announced on 1 June, introducing an authorisation scheme for substances used in smart packaging, saying positively: 'I don't see any of the legislation that is there at present stopping the development of any of this in the long term.'

'We've been told that in 20 years time people will laugh and wonder how nanoparticles were never in all packaging materials.'

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Active antibacterial wrappers could keep foods fresh for longer

Further reading

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