# Packaging that packs a punch: a look at rapidly developing technologies

Packaging, especially using plastic based materials, is all around us and nowhere is this truer than in the food and meat industries where shelf-life extension, appearance, freshness and quality are king.

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The potential advantages are huge – one product had its shelf-life extended by 800% simply by changing the packaging material – and quality was boosted as well.

Technologies in this area have developed very rapidly over the last few years – first MAP, then designer packaging materials, then anti-microbial packaging and then a whole host more. You could almost be forgiven for ignoring the rapid pace of technological change and sticking with tried and tested existing solutions. But is there something that is easy and possibly much better?

Much of it boils down to one, essentially simple, thing. It is called 'vapour permeability' and most product and shelf-life-extensions depend, absolutely critically, upon it. All that permeability really means is keeping some gases in, keeping some gases out, and controlling the flow of a few things as well. And as for 'vapour' that just means gas – as in the oxygen you breathe. Simple.

Now that the hard part is done let me add just a little basic knowledge and you will be able to apply these techniques to your specific products. Your products may need very individual solutions, but it is not as complicated as it sounds.

## Tried and tested techniques

As far back as the late (neolithic) stone age farmers managed to preserve their seeds in good condition over several years simply by burying them in a well-sealed hole. Today we know that the first few seeds would have germinated and used up all of the oxygen, replacing it with $CO_2$. All they knew was that it stopped their seeds rotting and some have been preserved right up to the present day.

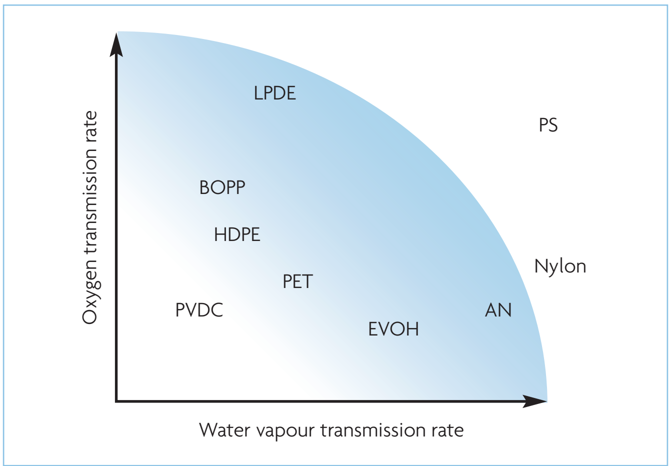
Next, in 12th Century China, fruit farmers discovered that coating their oranges and lemons with something waxy kept them tasty, juicy, fresh and un-rotted for much longer.

We do basically the same thing today – we just call it packaging. We may have replaced the clay seal and the wax with several thousand formulations, usually involving some form of plastic, but the way it works is just the same. It is vapour permeability that controls the flow of some gases and prevents the in or out flow of others. And that is all there is to it – building barriers to vapours that some foods want to keep in (like water vapour in the case of the fruit farmers), keep out (as oxygen in the case of grain) and controlling the flow of others – such as ethylene in the case of ripening fruit and vegetables, nitrogen or argon in the case of MAP and both oxygen and water vapour in the case of keeping meat red and preventing freezer burn.

If you get this balance right it will extend shelf life, it can improve appearance, enhance freshness and quality and both delay or speed ripening. Get it wrong, for example keeping oxygen away from a cheese, and you can do exactly the opposite and reduce shelf-life and quality.


**MAP permeability and life extension.**

**Fig. 1. Barrier material comparisons (adapted from Santos, TAPPI 2010).**




## Measuring flow of vapour

The next step is to outline how we measure the flow of vapours through a barrier such as a plastic film or the waxed skin of a lemon, as this will explain how vapours actually flow through solid barriers. This is very different from the way the same things keep liquids (normally water) in or out.

Something that is a very good barrier to water as a liquid, can be virtually useless at preventing water as a vapour from flowing through it.

Liquids flow through (often microscopic) gaps in solids, but gases permeate molecule by molecule between the molecular make-up of the barrier material. This can be reduced but can never be prevented.

As an example: packaging that includes materials such as silicone, cellulose, EVOH or PVOH, despite the fact that they are good barriers against liquid water, can be virtually useless in applications where water as a vapour is present, it can flow through these materials almost as if they were not there. Other materials perform just as poorly for other vapours such as oxygen, $CO_2$, nitrogen, ethylene and other gases.

To use a modern vapour permeability meter to test the permeability of flat barrier material, including the edible films in a pastry and pizza to keep the crust or base dry, you use the barrier to separate two sides of a chamber, one side is exposed to the vapour you want to test, and on the other side you slowly pump though a dry gas (normally nitrogen).

The vapour under test that passes molecule-by-molecule through the barrier is swept off to a sensor and measured with extreme accuracy (parts per million to parts per billion accuracies are common).

If it is not a flat sample, such as a film, that is being tested, the principle remains the same but the

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configuration varies. For example with a 'closed container' such as frozen packed meat, fast-food meals or products in tubs, jars or tins, there are two main test options. In the first you part-fill the container with, for example, water, seal it on the production line and then place it in a special chamber and measure anything that escapes from the tin to the test chamber.

The second method involves placing the container in a special humidity and temperature-controlled chamber and then passing the dry gas through the container itself.

While this offers a measure of the water vapour entering the container, as opposed to leaving it, careful sealing is required. In most cases, the vapour permeation rates from the two methods are similar so the easier method is used.

Any part of a package can be tested for permeability – either by using a specially manufactured jug to hold just that component in the testing environment, or by sealing off the other parts of the container using a non-permeable material.

One of the biggest problems is that you can not simply use the published permeability values of these products – thickness, processing, and especially building multi-layer designer barrier materials, means you are required to test the resultant materials. Although adding the values of different barriers together sound right it does not give you the right answer!

Also for historical reasons, varying standards, different methods of measuring (which produce results that vary by over 100% ) complicate the matter still further.

The only solution is testing. Beware: many permeability meters only measure water vapour, and if oxygen, nitrogen, ethylene or other vapours are important to your product you must use a meter that measures these (such as a mass spectrometer-based test instrument).

| Product | Comment | Typical packaging material |
|---|---|---|
| Fruits and vegetables | These products respire and so the precise $O_2$ and $CO_2$ permeability of the packaging material is vital if equilibrium of gases is to be maintained (ie EMAP). The level of $O_2$ needs to be depressed and $CO_2$ raised. Unfortunately, levels of $CO_2$ higher than 10% produce phytotoxic (poisonous to plants) conditions, so nitrogen is used as a filler gas as it neither encourages nor discourages bacterial growth. | Materials such as polyolefin plastomers and certain grades of cellophane are suited for these applications. |
| Red meat | A high rate of oxygen transmission is required to maintain the bright red colour of meat. A low water vapour transmission is also needed to avoid drying the meat while providing high oxygen transmission to maintain the colour. | Special grades of cellophane, polyethylenes and nitriles. |
| Non-vegetable packaged food, such as crisps and dried food. | These products are packed in an inert gas atmosphere (99.9% nitrogen). Under normal conditions temperature and pressure has little effect. | Materials are based on a metallised foil bonded over a strong substrate polymer. |
| Bakery, convenience food items | These products require transparent, resistant, but flexible packaging. A small amount of monomers is an absolute requirement, because of the special nature of the processing and its use in contact with food. | Oriented polystyrene (OPS). |
| Fish and some cheeses | These need very low gas permeability films so that the gas-mixture will stay largely unaltered within the package. Raised $CO_2$ is a bacterial and fungal growth inhibitor. | Polyamides are often used for boil-in-the-bag products. |

**Table 2. Packaging requirements for different products.**

Also be warned that many products either need or are stored in areas of relatively high humidity – so you need to check them under these conditions. Most meters do not like high water vapour humidity as it destroys many types of sensor – so be sure to check!

## Different requirements for each product

Now you need to know that virtually every food product, and sometimes the same product during different parts of the food chain, requires different conditions. In some you need to exclude oxygen, but some will be ruined without it. And it is the same for every single vapour that is relevant to your product.

For example, strawberries act in a completely different way to carrots or greens or meat or cheese, which is why it takes a little thought to choose the best packaging characteristics for your product.

What's worse is that the gases diffuse both inwards and outwards, and at different rates. A film's permeability of oxygen bears little relationship to its permeability to water vapour or other gases. A barrier that is good for one can be useless for another – and most products need a balance across several gases.

To make it still more complicated, some products respire and change the dynamic balance of $O_2$ and $CO_2$ still further. Water vapour is also of critical interest, preserving the dynamic moisture stability of the produce, influencing the growth of pathogens and, in excess, causing unsightly condensation in the pack.

**Table 1. Water vapour of widely used packaging materials.**

| Material | Permeability (m1m-2 MPa-1 per day) | | | |
|---|---|---|---|---|
| | $N_2$ | $O_2$ | $CO_2$ | $H_2O$ |
| PE (0.922) | 120 | 300 | 2,300 | 5,300 |
| PE (0.954-0.960) | 18 | 71 | 230 | 860 |
| PP (0.910) | – | 150 | 610 | 4,500 |
| PVC | 2.7 | 8.0 | 67 | 10,000 |
| PVdC | 0.07 | 0.35 | 1.90 | 94 |
| PS | 19 | 73 | 590 | 80,000 |
| PA (Nylon 6) | 0.67 | 2.50 | 10 | 47,000 |
| PET (MylarM) | 0.33 | 1.47 | 10 | 8,700 |

## Designer packaging

This is where designer packaging comes in – multi-layer films with each layer effectively having a different permeability for each gas.

So you might build up a film with one layer for mechanical strength and one to prohibit the flow of water vapour, and yet another to control oxygen, nitrogen or ethylene, or even an antibacterial film.

Of course one film may cause problems for another – and this is where you need someone with a good understanding of the different materials and processes available so you can create a barrier that is right for your specific product.

It gets a little complicated when you get to this level but if you can double or treble the shelf life of your product, improve its ongoing appearance and enhance freshness then it is usually worth it.

Table 1 shows many of the widely used packaging materials and their water vapour (often the main concern) and other, food-critical, vapours.

There are a whole new set of rules for foods that need to be chilled or frozen. As an example, although there are several myths about the source of 'freezer burn', it is actually caused by water vapour leaving the product (turning meat and other products brown or giving them greyish white spots and a bloom) – even when the packaging is a complete barrier to liquid water and ice.

Packaging with an 'appropriate' resistance to water vapour (permeability, or permittivity) can virtually eliminate freezer burn – as well as preventing a series of undesirable chemical reactions, biological decays and changes to the physical structure of the ingredients.

So, as a summary there are great gains that can be made but they do require a basic understanding of what it is that the packaging does.

The role of vapour permeability is absolutely critical and the central factor in the whole process. You need to match or build the available materials to the individual needs of your specific food or meat products.

You need to understand the role of each of the main gases for your product and use packaging materials that control them in the ways that you want. ■