FLAVOUR - PACKAGING INTERACTIONS

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Abstract

The packaging refer to the changes of mass and energy between the packing product, the packing material and the environment. Even though it's very clear that there are interactions between the package and the flavor this phenomena does not influence at a large extent the products' qualities so it could cause irreversible problems in practical situations. More over, in some cases the interactions between the package and the flavour can help to the maintaining of the desired quality of foods.
Keywords: *packaging,, interactions, flavor.*

Introduction

Interactions within a package system refer to the exchange of mass and energy between the packaged food, the packaging material and the external environment. Food-packaging interactions can be defined as an interplay between food, packaging, and the environment, which produces an effect on the food, and/or package.

Mass transfer processes in packaging systems are normally referred to as permeation, migration and absorption.

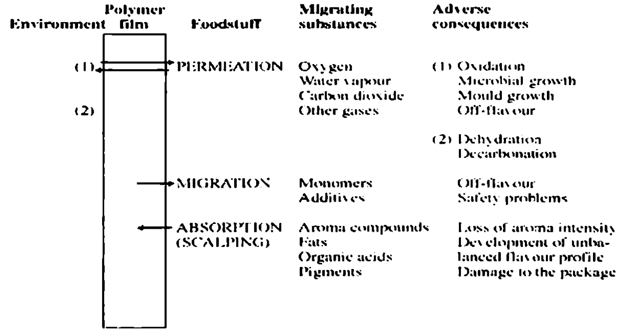

Fig. 1: Possible interactions between foodstuff, polymer film and the environment, together with the adverse consequences

Permeation is the process resulting from two basic mechanisms: diffusion of molecules across the package wall, and absorption/desorption from/into the internal/external atmospheres. Migration is the release of compounds from the plastic packaging material into the product. The migration of compounds from polymer packaging materials to foods was the first type of interaction to be investigated due to the concern that human health might be endangered by the leaching of residues from the polymerisation (e.g., monomers, oligomers, solvents), additives (e.g., plasticisers, colourants, UV-stabilisers, antioxidants) and printing inks. Later, absorption or scalping of components originally contained in the product by the packaging material attracted attention. Product components may penetrate the structure of the packaging material, causing loss of aroma, or changing barrier and/or mechanical properties, resulting in a reduced perception of quality.

The fundamental driving force in the transfer of components through a package system is the tendency to equilibrate the chemical potential. Mass transport through polymeric materials can be described as a multistep process. First, molecules collide with the polymer surface. Mass transport through polymeric materials can be described as a multistep process. First, molecules collide with the polymer surface. Then they adsorb and dissolve into the polymer mass. In the polymer film, the molecules 'hop' or diffuse randomly as their own kinetic energy keeps them moving from vacancy to vacancy as the polymer chains move. The movement of the molecules depends on the availability of vacancies or 'holes' in the polymer film. These 'holes' are formed as large chain segments of the polymer slide over each other due to thermal agitation. The random diffusion yields a net movement from the side of the polymer film that is in contact with a high concentration or partial pressure of permeant to the side that is in contact with a low concentration of permeant. The last step involves desorption and evaporation of the molecules from the surface of the film on the downstream side. Absorption involves the first two steps of this process, i.e. adsorption and diffusion, whereas permeation involves all three steps.

Experimental

There are several factors that affect the flavour absorption. As polymer packaging is more and more widely used for direct contact with foods, product compatibility with the packaging material must be considered. Flavour scalping, or the absorption of flavour compounds, is one of the most important compatibility problems. The properties of a plastic packaging material are the foremost important parameters that control the amount of flavour absorption. The properties of a polymer result from its chemical nature, morphology, formulation (compounding with additives), processing, and even storage and conditions of use. Important parameters derived from the chemical structure, such as glass transition temperature, crystallinity and free volume that have an effect on flavour absorption are essentially determined upon the selection of a particular polymer.

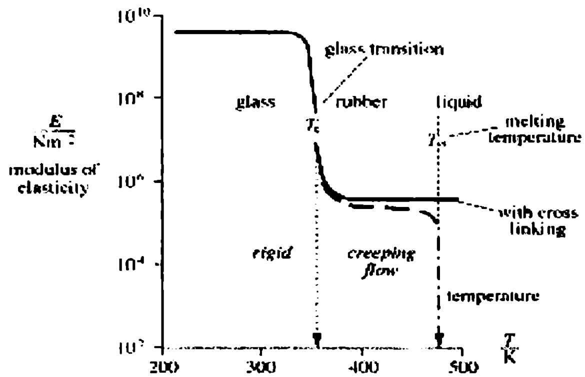

Fig. 2: Modulus of elasticity against temperature, showing the glass transition and Melting temperatures

Figure 2 shows the behaviour of one of the many properties of an amorphous and semicrystalline polymer: the modulus of elasticity. There are two sharp breaks indicating phase transitions. At low temperatures the polymer is rigid and brittle: it forms a 'glass'. At the glass transition temperature *Tg* the modulus of elasticity drops dramatically. Many of the properties of the polymer change a little at this temperature. Above *Tg* the polymer becomes soft and elastic; it forms a '*rubber*'. At high temperatures, the polymer may melt, to form a viscous liquid.

The polymers that we know as glassy polymers, such as the polyesters polyethylene terephthalate (PET), polycarbonate (PC) and polyethylene nafthalate (PEN), have a *Tg* above ambient temperature. At room temperature, glassy polymers will have very stiff chains and very low diffusion coefficients for flavour molecules at low concentrations. Rubbery polymers, such as the polyolefins polyethylene (PE) and polypropylene (PP), have a *Tg* below ambient temperature. Rubbery polymers have high diffusion coefficients for flavour compounds and steady-state permeation is established quickly in such structures. Stiff-chained polymers that have a high glass transition temperature generally have low permeability, unless they also have a high free volume.

The free volume of a polymer is the molecular 'void' volume that is trapped in the solid state. The permeating molecule finds an easy path in these voids. Generally, a polymer with poor symmetry in the structure, or bulky side chains, will have a high free volume and a high permeability.

The importance of crystallinity to absorption has been recognised for many years. All polymers are at least partly amorphous; in the amorphous regions the polymer chains show little ordering. However, polymers often contain substantial 'crystalline' parts, where the polymer chains are more or less aligned. The crystalline areas are typically a tenth denser than the amorphous parts; for many permeants they are practically impermeable. So, diffusion occurs mainly in the amorphous regions in a polymer, where small vibrational movements occur along the polymer chains. These micro Brownian motions can result in 'hole' formation as parts of the polymer chains move away from each other. It is through such 'holes' that permeant molecules can diffuse through a polymer. Therefore, the higher degree of crystallinity in a polymer, the lower the absorption.

There are relatively few reports relating flavour absorption to the relative concentrations of the sorbants in a liquid or vapour. Low sorbant concentrations will affect the polymer only to a very limited extent and the amount of absorbed compounds will be directly proportional to the concentration of the sorbants. Higher concentrations, however, the absorption of compounds into a polymer material may alter the polymer matrix by swelling. Consequently, to avoid overestimation of the amounts of absorbed compounds or swelling of the polymer, it is advisable to use a mixture of compounds in the concentration range that can be expected to be found in a food application. However, to generate reliable and reproducible analytical data, experimental procedures are usually carried out with enhanced concentrations. Interactions between different flavour compounds may also affect the absorption of low molecular weight compounds into polymer food packaging materials. Some flavour compounds exhibit a lower absorption rate in mixtures compared to systems containing the individual flavour compounds. This may be due to a competition for free sites in the polymer and/or alteration of the partitioning between the solution and the polymer due to an altered solubility of the compounds in the solution.

Therefore, the use of single compound model solutions may cause an overestimation of the amount absorbed in an actual food packaging application.

The polarities of a flavour compound and polymer film are an important factor in the absorption process. The absorption behaviour of different classes of flavour compounds depends to a great extent on their polarity. Different plastic materials have different polarities; hence their affinities toward flavour compounds may differ from each other. Flavour compounds are absorbed more easily in a polymeric film if their polarities are similar. Polyolefins are highly lipophilic and may be inconvenient for packaging products with non-polar substances such as fats, oils, aromas etc., since they can be absorbed and retained by the package. The polyesters, however, are more polar than the polyolefins and will therefore show less affinity for non-polar substances.

The size of the penetrant molecule is another factor. Smaller molecules are absorbed more rapidly and in higher quantities than larger molecules. Very large molecules plasticise the polymer, causing increased absorption into the newly available absorption sites. Generally, the absorption of a series of compounds with the same functional group increases with an increasing number of carbon atoms in the molecular chain, up to a certain limit. It was reported that compounds with eight or more carbon atoms were absorbed while shorter molecules remained in the product. It was also observed that highly branched molecules were absorbed to a greater extent than linear molecules.

Temperature is probably the most important environmental variable affecting transport processes. The permeability of gases and liquids in polymers increases with increasing temperature according to the Arrhenius relationship. Possible reasons for increased flavour absorption at higher temperatures are (Gremli, 1996):

- increased mobility of the flavour molecules;
- change in polymer configuration, such as swelling or decrease of crystallinity;
- change in the volatile solubility in the aqueous phase.

For some polymers, exposure to moisture has a strong influence on their barrier properties. The presence of water vapour often accelerates the diffusion of gases and vapours in polymers with an affinity for water. The water diffuses into the film and acts like a plasticiser. Generally, the plasticising effect of water on a hydrophilic film, such as ethylene-vinyl alcohol (EVOH) and most polyamides, would increase the permeability by increasing the diffusivity because of the higher mobility acquired by the polymer network. Absorbed water does not affect the permeabilities of polyolefins and a few polymers, such as PET and amorphous nylon, show a slight decrease in oxygen permeability with increasing humidity. Since humidity is inescapable in many packaging situations, this effect cannot be overlooked.

Results and Discussion

The importance of packaging–flavour interactions depends on the extent they can affect the quality of the packed food. The food matrix is one of the main aspects which determine how important packaging–flavour interactions are. Food products containing fat or oil are able to keep the flavour compounds in the food itself and the loss caused by flavour scalping will be diminished. Some proteins are able to bind some flavour compounds that are no longer available for absorption into a plastic polymer. Aqueous food products have less ability to bind flavour compounds in the food matrix and therefore these foods are more susceptible to losing flavour compounds in the packaging polymer, which can result in quality defects. Many flavour compounds have a lipophilic character and therefore a good affinity to apolar polymers such as PE and PP. The highest amounts of absorbed flavour compounds are found in these types of polymers.

Polyesters, such as PET, PC and PEN, have a more polar character and therefore they show less affinity to the common flavour compounds. This means that polyesters absorb fewer flavour compounds and these polymers are therefore better packaging materials in the context of loss of flavour compounds due to flavour scalping. On the other hand, generally, there is less evidence that flavour scalping influences the taste and odour of a product. Although flavour compounds can be absorbed in substantial amounts, sensory defects are rarely found. Another factor is the way the polymer properties are affected. There is evidence that oxygen permeation can be enhanced due to absorption of flavour compounds.This means that as a secondary aspect, food quality can be affecte due to oxidative chemical reactions, e.g., lipid oxidation can influence the quality of the product.

A second parameter of importance is the mechanical properties of a polymer. Some rare research work could be found dealing with the way flavour absorption affects the mechanical strength of a polymer. On the other hand packaging and flavour interactions may act in a possitive way. We are now entering the field of active packaging applications. Polymer packaging material can be used to remove selectively undesirable compounds, causing off flavours, from the packed food. In certain orange varieties a bitter compound, limonin, is developed during the extraction and pasteurization process of the juice. Inclusion of an absorbent might remove such a compound selectively. Also an active packaging concept has been described for reducing bitterness of grapefruit juices, caused by the presence of naringin. A thin cellulose acetate layer is applied to the inside of the packaging as an absorbent. Such a layer contains the enzyme naringinase, which hydrolyses naringin to non-bitter compounds.

Other types of compounds responsible for off flavours are amines and aldehydes. Such compounds could also be removed by applying active packaging. Amines are formed from protein breakdown in fish muscle and include strongly alkaline compounds. A Japanese patent for example claimed the removal of amines from food by interaction between acids incorporated in the polymer and the off-flavour compounds. ANICO Company Ltd (Japan) introduced another approach to remove amine odours. Bags made from a polymer containing ferrous salt and an organic acid claimed to oxidise the odours as they are absorbed by the polymer. Aldehydes are formed in the lipid autoxidation reaction and they can reduce the quality of food products considerably.

Conclusion

In conclusion, although it is very clear that packaging and flavour interactions exist, this phenomenon does not influence the food quality to the extent that it causes insuperable problems in practical situations. Moreover, in some cases packaging and flavour interactions can help to maintain the desired quality of food products.

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