„ACTIVE PACKAGING CONCEPTS – ARE THEY ABLE TO REDUCE FOOD WASTE?"

Kajetan Müller[1]

[1] *University for Applied Science Kempten, Bahnhofstraße 61, D - 87435 Kempten and Fraunhofer Institute for Process Engineering and Packaging, Giggenhauserstraße 35, D-85354 Freising, Germany; Contact; e-mail: kajetan.müller@ivv.fraunhofer.de; phone: +49 (0) 8161 491 509*

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Abstract

Kajetan Müller; Fraunhofer IVV; Freising

Abstract:

The article concentrates on the three most promising active packaging concepts, namely antimicrobial packaging, humidity regulating systems, oxygen scavengers and on time temperature and freshness indicators. The active principles, potential food applications, pros and cons of the active packaging concepts are shown. Several shortcomings in the field of active and intelligent packaging could be identified und thus active packaging is still in the focus of various research projects dealing with packaging.

Sustainability of packaging

About 30 % of all produced food worldwide deteriorates while agricultural production, storage, food production, logistics, in trade or due to the consumer behaviour. In developed countries the waste is in large part caused by distribution and by the consumer.

Thus, in the last 5 years, sustainability has become an important issue for food and packaging industry. It is however difficult to get a concise definition what "sustainable packaging" really means. There is one dominating function of the packaging which determines its performance: Its ability to preserve the quality of the packed product since the majority of the environmental loads as generated by a packed product is created by the food production, the refrigeration and preparation sequence. The primary packaging is – depending on the food type, logistic aspects and consumer behaviour – only responsible for approximately 10 % of the environmental loads of the whole food chain.

There are different options to reduce the environmental loads of packaging material. One is the reduction of the usage of material, commonly called light weighting or down gauging. This method is very promising if the functionality of the packaging is maintained. Another strategy is to apply recycling methods that allow for high grade applications of the recycled materials. This is recently done for bottles and containers, especially from PET. Finally, a frequently discussed option is to use materials from natural, renewable resources – often called biopolymers. However, the most important functionality of the packaging which determines its performance is its ability to preserve the quality of the packed product since the majority of the environmental load is generated by a packed product, by the food production, the refrigeration and preparation.

Therefore it is obvious to use additional packaging functionalities like active or intelligent principles if these functionalities are able to extent the shelf life and the quality and safety of food. The major impact of the packaging material on the environment is given by perishable food products like meat, sausage, dairy products, fruits and vegetables. Therefore the research activities in the area of active and intelligent packaging should focus on these products.

Active packaging

By "active packaging" or "active packing" we generally mean a packaging technology that has an active and sustained influence on packaging properties. The first active packaging components were introduced in Japan in 1977 and added to the packaging in the form of small cushions, so-called sachets. These cushions still consist of a permeable membrane containing O_2 absorbers. O_2 absorbers, however, are not the only cases of application for "active packaging". The packaging atmosphere can also be influenced by moisture absorbers and regulators as well as by CO_2 or ethylene absorbers and/or CO_2 or ethanol detectors. A further interesting area of use is the addition of antimicrobial materials. Of the numerous active systems developed in recent years, only a few are commercially significant: These include oxygen scavengers (oxygen absorbers), moisture absorbers and anti-microbial effective plastics.

A special type of active packing is so-called intelligent packaging where an internal or external indicator documents product qlity or the life history of the contents from bottler to customer. Examples are, moisture, CO_2, O_2, time-temperature and freshness indicators.

Oxygen scavengers:

Sachets are often used (mainly in Asia), they are very effective O_2 scavengers and have high O_2 absorption capacity, but also have the disadvantage of being unsuitable for direct contact with fluids. Nor are they accepted by the European consumers. The active material is thus preferably incorporated in the polymer matrix of the packaging material. The reaction speed of scavengers bound in the polymer matrix is generally slower than that of the iron-based materials found in sachets. The O_2 absorbent can be either a polymer (polyamide based or polyolefin based) or a reagent (iron or sulphite) dissolved or dispersed in the polymer.

Application: Beverage Packaging

Cap manufacturers currently offer various crown caps and plastic screw-on caps with O_2 scavengers. However, what is important for practical use is the possibility of closing the bottles in conventional closing machines, as well as for caps that are not too expensive. That is why systems with the scavenger integrated into the sealing cap are used almost exclusively by commercial applications. Their rate of O_2 consumption depends on scavenger reactivity and concentration, as well as the permeability and surface of the compound. Mostly sulphate-based scavengers are used for caps. Depending on the scavenger formula, the oxygen permeability of plastics screw-on caps can be lowered to values of <0.001 to 0.01 cm^3 (STP)/(closure day bar). Caps with only passive barriers exhibit values of 0.01 to 0.05 cm^3 (STP)/(closure day bar).

PET bottles are being used more and more often for oxygen sensitive beverages such as beer and fruit juices. Monolayer PET bottles have proven unsuitable for bottling oxygen sensitive beverages. Assuming, for example, a bottle weight of 35 g to 45 g for a 1 l juice bottle, the oxygen permeability of a monolayer PET bottle is on the order of approx. 0.3 to 0.4 cm^3 (STP) /(bottle day bar). Given a shelf life of nine months, oxygen permeation through the bottle wall would add up to around 24 to 32 mg/l (ppm). By using active or passive barrier materials permeability can be reduced by approximately one order of magnitude. When MXD6 is used for a blend with PET in combination with a cobalt catalyst, the achievable barrier value is nearly comparable to a glass bottle.

Application Case: Food Covers

When ready to eat meals are sterilized in plastic packaging (with ethylene vinyl alcohol copolymer (EVOH) as the barrier layer), sterilization (typically for a few minutes at 121°C) temporarily weakens the oxygen barrier. This behaviour, known as retort shock, has an unfavourable effect on product shelf life. The solution may lie in integrating oxygen scavengers in the packaging material to protect the packaged food against oxygen: The sterilized packaging absorbs approx. 1.5 mg oxygen during the first 14 days after sterilization. In unsterilized packaging, the amount is only 0.015 mg, or a hundred times less. This is where the oxygen scavenger steps in. The oxygen-base scavenger typically used is activated by damp heat and provides precisely the oxygen barrier required in the post-sterilization phase while the EVOH is still wet.

Application Case: Flexible Packaging

Whereas the clear advantage of longer shelf life has been proven for oxygen scavengers in the above mentioned cases, i.e., for beverage packaging and sterilizable food covers, they have been applied only to a very small extent in the area of flexible packaging, even though there may be meaningful areas of application. Potential applications include packaging for oxygen-sensitive sausages, nuts or convenience products. E.g. sausages packed in transparent materials are subject to photosensitized oxidation processes in consequence of which they gray due to the combined influence of light and oxygen. This graying can be avoided if any influence from either light or oxygen can be entirely eliminated. The oxygen influence is the one to be avoided, since the customer would like to look at the packaged goods in the store, i.e., the exclusion of light would not be understood. Several approaches have been tried for protecting sausages with oxygen scavengers, however, previously available commercial scavengers have failed to provide the necessary reaction kinetics. Oxygen scavengers with increased reaction kinetics are currently in the development phase.

Moisture absorption and regulation:

We have to differentiate between moisture absorption and moisture regulation: Moisture absorbers bind water vapour or liquid water, thereby preventing the (food) product from absorbing water. Moisture absorbers are often used in form of sachets or pads. They are capable of absorbing 20 to 30 mass.-% water. In order to manufacture moisture absorbers drying agents like molecular sieves, calcium oxide or silicone gel can be incorporated into a polymeric matrix. Until now the main field of application is pharmaceuticals such as packaging for inhalation powder. An example of a commercially utilized moisture absorbent film is Alcan Packaging's "Formpack" for tablet blisters.

Moisture regulation allows the adjustment of desired oxygen content. The approach being adopted is to use deliquescent salts in packaging materials in order to control the RH. These salts have the ability to absorb large amounts of water vapour when the RH exceeds a certain value. The salts dissolve in the absorbed water to form solutions, namely they deliquesce. If the RH subsequently decreases, the absorbed water is released again. This mechanism allows the RH to be adjusted to a desired value, namely regulated. The value of the RH depends on what salt is chosen. The absorption behaviour of a salt is described by its sorption isotherm which shows the equilibrium moisture absorption as a function of the RH. Different salts have differing absorption properties, and hence the optimum humidity for storing products can be set by careful selection of the salt. For fruits and vegetables the preferred RH is between 85 % and 95 %. For example, potassium chloride, which is used as a food additive, absorbs water vapour above 87 % RH and is therefore suitable in combination with tomatoes.

Antimicrobial Substances:

Antimicrobial agents can be incorporated into packaging materials. The objective of these agents is to control or to inhibit the growth of non-desirable micro-organisms on the food surface. These particles are often transported (migration) from the package to the food surface and are already used as coatings on different polymeric materials or in the mass of the polymer. The activity of these antimicrobial agents is carried out either by contact of micro-organisms onto the internal surface of the packaging material, either directly in the food by emission or slow diffusion of the antimicrobial agent from the packaging material to the food.

Indicators:

a)Time-temperature indicator (TTI): We know the time-temperature indicator (TTI) as a small measuring device attached to the package surface that exploits a change in a physical or physiochemical property to produce irreversible evidence of exceeding a predetermined temperature threshold or record the cumulative time-temperature history. TTIs are working by physical, enzymatic or chemical reactions and are increasingly used to track both chilled and frozen foods.

b) Freshness indicators: Freshness indicators are attached inside the packaging and since they are dependent on any inference from temperature history, they signal directly product quality of the packed food. They detect volatile or non-volatile compounds or changes in the product itself. Used methods are visible indicator tags in contact with package headspace, labels and optical detectors. Freshness indicators detect the presence of microbiological metabolites.

Effectiveness of active packaging in reducing food waste:

The question if active packaging concepts are able to reduce food waste cannot be answered with 'Yes' or 'No':

- Oxygen scavengers have mainly been used previously to improve the barriers in plastic bottles and caps for oxygen-sensitive beverages as well as to avoid so-called retort shock in sterilizable packaging. There are additional, meaningful approaches that would use them to protect food packaged in flexible packing materials. However, their wide-scale commercial use has been delayed and their use is up to now limited to long duration products that are less sensitive against microbial deterioration and more sensitive to bio-chemical deterioration. In contrast: In order to avoid anaerobic conditions, oxygen scavengers should not be used for food that is sensitive to pathogen anaerobic microorganisms.

- Antimicrobial packaging: In Japan, antimicrobial packaging is used since the 1980s with nano silver as antimicrobial agent. However in Europe, the consumers and the food industry have concerns about environmental pollution and food safety, when using nano silver. An ideal solution for the concern of the food industry about environmental pollution and food safety would be the development of antimicrobial films by incorporating food-approved preservatives and natural antimicrobials. These natural antimicrobials would be beneficial especially for products with short shelf life that suffer from microbial deterioration.
- Moisture Regulation: Possible fields of applications for moisture regulating films are fresh fruits, fresh vegetables, minimally processed food and ready-to-eat meals that are sensitive to microbial deterioration. The moisture regulating films could help to prevent food waste. However, further research will be necessary to develop these films.
- Indicators: TTIs are provided in different versions, with different activation temperatures and flow times. Depending on their type, they should be appropriate for specific product categories with defined temperature sensitivity. A crucial factor is a homogeneous initial quality and the ability of the indicator to react on cyclic temperature gradients, which occur during storage and transportation of food. When TTIs are attached to the lid film the core temperature of the food doesn't correspond with temperature of the packaging surface, when the storage conditions changes. The main advantage of TTI's is their ability to indicate the conditions in the cold chain. In contrast to TTIs the freshness indicators directly detect the presence of microbiological metabolites. A potential risk of freshness indicators, however, is a "declared freshness", though the product is already deteriorated. Nevertheless, an effective freshness indicator could help to reduce waste und thus further research is recommended.

Additionally all the developments in the field of new active packaging materials are limited by regulatory issues, since all active packaging must comply with the Commission Regulation (EC) No 450/2009 on active and intelligent materials and articles intended to come into contact with food and additionally with Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food. Anyway, active packaging is and will be in the focus of many research projects in the packaging sector.

Conclusion:

The whole food chain has to be adapted to the requirement of biochemical and microbial sensitive food: Beside harvesting, processing and temperature control the right packaging concept is an essential hurdle against deterioration. Active packaging can help to extent the shelf life of food products and consequently have a share in reducing food waste. Whereas oxygen scavengers should be used for improving the biochemical quality of long duration products, the targeted application of antimicrobial packaging and humidity controlling systems are fresh food products that are sensitive mainly against microbial deterioration.