9 Active Packaging

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9.1 INTRODUCTION

Active packaging systems have been available since the 1970s but are still not widely used in the food and drink industry. There have been several definitions for active packaging but following the development of the Active and Intelligent Packaging Regulations by the European Commission (EC, 2009), active packaging can be described as packaging intended to extend the shelf life or to maintain or improve the condition of packaged foods, they are designed to intentionally release or absorb substances into or from the food or its surroundings. Typical systems include oxygen and carbon dioxide scavengers or emitters, moisture absorbers, ethylene scavengers, flavour and odour absorbers and ethanol emitters. Active packaging has been used with many food products and is being tested with numerous others. Table 9.1 details some of the different types of active packaging systems available and their potential application. To date most of the research into active packaging has been with modified atmosphere packs to inhibit microbiological and chemical degradation. However, the application could be more widely spread.

The mechanism by which food deteriorates needs to be understood before applying any type of active packaging solution. The shelf life of a food is dependant on numerous factors, such as the intrinsic nature of the food, e.g. acidity (pH), water activity (a_w), nutrient content, occurrence of anti-microbial compounds, redox potential, respiration rate and biological structure; and extrinsic factors, e.g. temperature, relative humidity (RH) and the surrounding gaseous composition. These factors will directly influence the chemical, biochemical, physical and microbiological spoilage mechanisms of individual food products and their achievable shelf lives. By considering these mechanisms it is often possible to apply different active packaging techniques to extend the quality and shelf life of the product.

Active packaging is not synonymous with intelligent or smart packaging, which refers to packaging that senses and informs (Summers, 1992; Day, 2001). The new European Commission Active and Intelligent Packaging Regulations (EC, 2009) describe the following: intelligent packaging monitors the condition of packaged food or the environment surrounding the food. Intelligent packaging can provide assurances of pack integrity tamper evidence, product safety and quality and are being utilised in applications, such as product authenticity, anti-theft and product traceability (Summers, 1992; Day, 2001). They include indicators (time temperature, freshness, ripeness and chemical), gas sensing dyes, physical shock indicators and numerous examples of tamper proof, anti-counterfeiting and anti-theft technologies.

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Table 9.1 Selected examples of active packaging systems.

Active packaging system	Food and beverage application
Oxygen scavenger	Bakery goods – bread, cakes Prepared foods – sandwiches, pizza, ready meals, cured meats and fish, dried foods and beverages
Carbon dioxide scavenger	Coffee, yeast-based goods
Carbon dioxide emitter	Bakery goods, prepared foods
Ethylene scavengers	Fruit, vegetables
Ethanol emitter	Bakery goods – cakes, bread
Moisture absorber	Meat, poultry, fish, fresh fruit and vegetables
Flavour and odour absorber	Fruit juices, meat, poultry, fish

9.2 OXYGEN SCAVENGERS

Oxygen can have a detrimental effect on different food products. It can increase the rate of staling in bakery goods, negatively affect the quality of some fish, e.g. salmon, trout, contribute to discoloration of cooked meats and herbs and also be instrumental in the degradation of vitamins. Oxidative rancidity, resulting in off-flavours and odours, is common with cooked meats, nuts, fried food, cheese and fats. The rate of oxidation is influenced by composition, available oxygen concentration, temperature and the presence of any pro-oxidants, such as light and metal ions. The removal of oxygen can help maintain the quality of the food (Potter *et al*., 2008).

There are a number of methods that can be used to remove oxygen from a pack, including modified atmosphere packing and the inclusion of an oxygen scavenger. Modified atmosphere and vacuum packing can be used with high-barrier films but depending on the efficiency of the equipment not all of the oxygen is removed from the pack. In addition, vacuum packing can only be used with certain food types so as not to damage the structure of the product. Layered foods and those that have been mixed or kneaded will contain trapped oxygen, which will be released into the headspace of the pack during shelf life. Oxygen scavengers can be used alongside these methods or independently.

There is a long history of the use of metals and moisture for removing oxygen from packs. Ferrous sulphate, copper powder, zinc and alkali metal salts have all been used. Work by Isherwood and colleagues in 1943, based on the oxidation of ferrous sulphate (Anon, 1992), led to the development of the oxygen scavenger in a sachet form. Products that benefit from being packed with an oxygen scavenger are beverages, such as juices, tea, coffee and beer, baked goods (cakes and crumpets), cheese, meats and some sauces.

The effectiveness of the oxygen scavenger within a pack depends largely on the equilibrium RH of the food and the diffusion of oxygen through the packaging material. The capacity of an oxygen scavenger depends on its mode of activation, scavenging capacity and rate of oxygen removal. When selecting an oxygen scavenger it is important to consider the desired shelf life of the product, the oxygen content of the pack and the packaging material (Potter *et al*., 2008).

The most well-known oxygen scavengers take the form of small sachets containing various iron-based powders combined with a suitable catalyst. These chemical systems often react with water supplied by the food to produce a reactive hydrated metallic reducing agent that scavenges oxygen within the food package and irreversibly converts it to a stable oxide. The iron powder is separated from the food by keeping it in a small, highly oxygen permeable sachet that should be labelled *Do not eat*. The main advantage of using this type of oxygen scavenger is that it is capable of reducing oxygen levels to less than 0.01%, which is much lower than the typical 0.3–3% residual oxygen levels achievable by modified atmosphere packing. Iron-based oxygen scavengers were first marketed in Japan in 1976 by the Mitsubishi Gas Chemical Co. Ltd under the trade name Ageless^{TM}. The sachets contain fine iron powder are covered with sea salt and a natural zeolites impregnated with NaCl solution. Mitsubishi claims that their scavengers can reduce oxygen levels to below 0.01%.

Non-metallic oxygen scavengers have also been developed to alleviate the potential for metallic taints being imparted to food products. The problem inadvertently setting off on-line metal detectors is also alleviated even though some modern metal detectors can now be tuned to phase out the scavenger signal whilst retaining high sensitivity for ferrous and non-ferrous metallic contaminants (Anon, 1995). Non-metallic scavengers include reducing agents, such as ascorbic acid, photosensitive dyes, enzymic oxygen scavenger systems, which can be incorporated into sachets or immobilised onto the packaging film surface (Hurme, 1996).

Ascorbic acid can be used as a reducing agent and in the presence of a transition metal, such as copper, can remove oxygen. The ascorbic acid is broken down into dehydroascorbic acid with the sulphite element adding one oxygen molecule to create a sulphate (Waite, 2003). The amount of oxygen absorbed will depend on the level of ascorbic acid present. Ascorbic acid scavengers can be in the form of sachets or labels or incorporated into bottle caps. The Pilsbury Company patented a sachet form of this system. It claims to inhibit the growth of aerobic micro-organisms but the level of oxygen absorbed is determined by the level of ascorbic acid within the sachet.

Immobilised enzymes, such as glucose oxidase or ethanol oxidase combined with a catalyst, can be used to reduce the oxygen level within a pack. Here the oxygen and moisture oxidise the glucose to glucono-delta-lactone with the consequent production of hydrogen peroxide. Catalase degrades the hydrogen peroxide to water and oxygen, as residual hydrogen peroxide may lead to the undesirable oxidation of the food. Although the action of the catalase generates oxygen, the combination of both enzymes reduces the overall oxygen concentration of the system (Steven & Hotchkiss, 2003). To achieve 0.1% oxygen within a 500 mL headspace, 0.0043 mole of glucose is required (Brody *et al.*, 2001).

Enzymes are very sensitive to their surroundings, e.g. pH, water activity. Bioka (Bioka Ltd.) is an enzyme-based oxygen scavenger that generates carbon dioxide to replace the oxygen within the pack. The scavenger can be in the form of a sachet or incorporated into a packaging film and can be used with a wide range of products including bakery, snacks, cooked and cured meats and fish, dried goods and ready-to-eat foods.

Oxygen scavengers have been successful in Japan for a variety of reasons, including the acceptance by Japanese customers of innovative packaging and the hot and humid climate in Japan during the summer months, which is conducive to mould spoilage of food products. In contrast to the Japanese market, the acceptance of oxygen scavengers along with other active packaging systems has been slow in other parts of the world, although there are many established suppliers within both North America and Europe and sales have been growing. The disadvantage of using a sachet form of the oxygen scavenger is the accidental ingestion of the contents by the consumer believing it is an additional ingredient within the pack. Therefore, there have been developments of oxygen scavenging labels that can be applied to the inside of the pack or incorporated into the packaging material including trays, films and caps.

The use of oxygen scavenging films was discovered when nylon was laminated to PET and the residual cobalt from the polymerisation catalyst led to a photo-initiated oxidation of the nylon (Potter *et al.*, 2008). Packaging films rely on polymers with double bonds reacting with oxygen. The reaction is catalysed by transition metal salts, such as cobalt. However, straight chain polymers can release low molecular weight aldehydes and other flavour damaging compounds. Further developments have avoided this by basing the double bonds within a cyclic olefin ring incorporating the oxygen into the compound rather than fragmenting it. A photo-initiator is incorporated to prevent the reaction occurring before the pack is exposed to UV light (LeGood & Clarke, 2006).

Oxygen scavengers incorporated into the packaging material are activated when exposed to UV light at a specified wavelength. The photosensitive dye molecules become charged, which in turn excite the oxygen molecules within the pack, which then become trapped and bound within the film. The polymer-based oxygen scavenging film OS2000 (Cryovac Europe) reduces residual oxygen in a pack within a few days of packing to parts per million. It is an oxidisable co-polymer layer laminated to a PVdC outer layer that provides a barrier to external gaseous exchange so the film only scavenges oxygen from inside the pack (Castle, 2004). $ZerO_2^{TM}$ is an oxygen scavenger polymer developed by Food Science Australia and Visy Industries. Photosensitive dyes trap the oxygen in the packaging once the reactive components are activated by means of UV light.

There has been a move away from traditional materials, such as glass and metals, with high oxygen barrier properties to plastic materials with variable barrier properties. Non-carbonated drinks, such as a fruit juice, sports drink and functional beverages and beers, are all sensitive to oxygen. UV light and the presence of oxygen can affect the colour, flavour and vitamin content of beverages. Tests have shown that oxygen enters through the closure, affecting the sensory properties of the beverage. Therefore, to limit the amount of oxygen, oxygen scavengers can be used to remove any residual oxygen. Iron-based oxygen scavengers cannot be used for this application because when wet, their oxygen scavenging capability is rapidly lost. Instead, various non-metallic reagents and organo-metallic compounds that have an affinity for oxygen have been incorporated into bottle closures, crowns and caps or blended into the polymer material so that oxygen is scavenged from the headspace and any ingressing oxygen is also scavenged. Amoco Chemicals have developed a PET bottle with an oxygen scavenger (AMOSORB) incorporated into the inner and outer layer of the PET, providing a barrier to external oxygen. A polyamide and nanoclay matrix (IMPERM) is included as a barrier against oxygen and carbon dioxide. No adhesives are used to bind the IMPERM to the PET enabling the bottle to be recycled (Potter *et al.*, 2008). Constar International has produced a bottle containing an oxygen scavenger that binds the oxygen molecules and retain them within the container.

9.3 CARBON DIOXIDE SCAVENGER AND EMITTERS

There are many commercial sachets and label devices that can be used to either scavenge or emit carbon dioxide. Applications of carbon dioxide scavengers include coffee, battered goods, and cheese as well as fresh and dehydrated meat and poultry products. Fresh roasted or ground coffee cannot be left unpackaged because it will absorb moisture and oxygen and lose desirable volatile aromas and flavours. Fresh coffee produces high levels of carbon dioxide due to reactions that occur during the roasting process, most is removed during the grinding but some remains trapped and is slowly released once packed. If the coffee is hermetically sealed in packs directly after roasting, the carbon dioxide released will build up within the packs and eventually cause them to burst (Subramaniam, 1998). To prevent this problem, a one-way valve can be incorporated into the packaging that will allow excess carbon dioxide to be released from the pack. Alternatively, a carbon dioxide scavenger or a dual action oxygen and carbon dioxide scavenger can be used to remove the carbon dioxide.

Carbon dioxide scavengers are made from calcium hydroxide, sodium hydroxide or potassium hydroxide, calcium oxide or silica gel (Potter *et al.*, 2008). The carbon dioxide reacts with the hydroxides to produce carbonates.

During respiration of fresh fruit and vegetables carbon dioxide is generated. Due to their different rates of respiration the level of carbon dioxide within a pack can increase substantially. High levels of carbon dioxide can cause tissue damage, discoloration and pack collapse in addition to off-flavours and odours and the growth of anaerobic micro-organisms. The permeability of the packaging material can be matched to the respiration rate of the product, unless a number of products are being packed with different respiration rates. A carbon dioxide scavenger may be incorporated into the pack to remove excess carbon dioxide. EMCO Packaging Systems Ltd has developed OxyFresh, which is a combined oxygen emitter and carbon dioxide scavenger for fresh produce. The OxyFresh complements the respiration of the produce by replenishing the oxygen and removing the carbon dioxide that is produced.

Pack collapse or the development of a partial vacuum can also be a problem for food packed in a modified atmosphere. Carbon dioxide is highly soluble in fats and moisture within the product and this can cause the pack to collapse. Therefore, there is a need to generate carbon dioxide within a pack to optimise shelf life. Carbon dioxide emitters in the form of sachets or labels usually contain ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate. Sodium bicarbonate when combined with citric acid and moisture produces carbon dioxide. Ascorbic acid absorbs oxygen and releases the equivalent amount of carbon dioxide when used in conjunction with sodium hydrogen carbonate (Waite, 2003). Dual carbon dioxide emitters and oxygen scavengers can be used with bakery goods, nuts and crisps. Mitsubishi Gas Chemical Co. has developed a dual carbon dioxide emitter/oxygen scavenger comprised of a non-iron formula. They are used in Japan with rice cakes, nuts and dried fish. Freshpax®M (Multisorb Technologies) is also a dual action oxygen scavenger and carbon dioxide emitter that is available as a sachet or label.

9.4 ETHYLENE SCAVENGERS

Ethylene (C_2H_4) is a plant growth regulator that accelerates the respiration rate and subsequent senescence of horticultural products, such as fruit, vegetables and flowers. Many of the effects of ethylene are necessary, e.g. induction of flowering in pineapples, colour development in citrus fruit, bananas and tomatoes, stimulation of root production in baby carrots and development of bitter flavours in bulk delivered cucumbers. In most horticultural situations, it is desirable to remove ethylene or to suppress its negative effects, which may include softening and deterioration of the produce and can also induce a number of physiological disorders in the produce. Consequently, much research has been undertaken to incorporate ethylene scavengers into fresh produce packaging and storage areas. Effective systems utilise potassium permanganate ($KMnO_4$) immobilised on an inert mineral substrate, such as alumina or silica gel, so providing a large surface area. $KMnO_4$ oxidises ethylene to acetate ethanol and in the process, changes colour from purple to brown, and hence indicates its remaining ethylene scavenging capacity. Films can be impregnated with powdered pumice stone, which acts as the ethylene scavenger trapping it when released by the fruit. Zeolite also adsorbs ethylene, water vapour and odours from the pack. EverFresh bags, (EverFresh USA) are impregnated with a natural mineral called oya, which absorbs ethylene gas from fresh produce.

Activated carbon-based scavengers with various metal catalysts can also effectively remove ethylene. The ethylene is absorbed by the carbon and broken down. They have been used to scavenge ethylene from produce warehouses, incorporated into sachets for inclusion into produce packs or embedded into paper bags or corrugated cardboard boxes for produce storage. Tests have shown that charcoal can reduce softening in some fruits such as kiwi and bananas (Waite, 2003). Stayfresh longer bags slow down the natural ageing process of produce and stop moisture and bacteria forming. Biofresh (Grofit Plastics) absorbs a number of gases including ethylene, ammonia and hydrogen sulphide, which are known to contribute to the ripening of fruits.

9.5 ETHANOL EMITTERS

Ethanol is widely recognised as a germicidal agent. It is particularly effective against mould but can also inhibit the growth of yeasts and bacteria. Ethanol can be sprayed directly onto food products just prior to packaging. Several reports have demonstrated that the mould-free shelf life of bakery products can be significantly extended after spraying with 95% ethanol to give concentrations of 0.5–1.5% (w/w) in the products. However, a more practical and safer method of generating ethanol is through the use of ethanol emitting films and sachets (Rooney, 1995). The advantage of this is that the ethanol does not have to be sprayed directly onto the product but can be slowly released from the sachet into the pack. The use of ethanol has been found to be beneficial as an anti-fungal and anti-bacterial agent for fish and cheese but is mainly used in bakery applications. A number of different studies have found that ethanol is effective in controlling the growth of moulds, including *Aspergillus* and *Penicillium* and bacteria, such as *Salmonella*, *Staphlococcus* and *Esherichia coli* (Potter *et al.*, 2008). There is a conflicting information that ethanol emitters can also inhibit the growth of yeasts.

Many applications of ethanol emitting films and sachets have been patented primarily by Japanese manufacturers. These include Ethicap^{TM}, Antimould 102^{TM} and Negamold^{TM} (Freund Industrial Co.), Oitech^{TM} (Nippon Kayaku Co. Ltd.), ET Pack^{TM} (Ueno Seiyaku Co. Ltd.) and Ageless type SE (Mitsubishi Gas Chemical Co. Ltd). All of these films and sachets contain absorbed or encapsulated ethanol in a carrier material that allows the controlled release of ethanol vapour. Ethanol and water are adsorbed onto silicon powder within a sachet. Moisture from the product activates the emitter and ethanol is released into the headspace or the pack. For example, Ethicap, which is the most commercially popular ethanol emitter in Japan, consists of food grade alcohol (55%) and water (10%) adsorbed onto silicon dioxide powder (35%) and contained in a sachet made of paper and ethyl vinyl acetate (EVA) copolymer laminate. To mask the odour of alcohol, some sachets contain traces of vanilla or other flavours. Dual action ethanol emitter and oxygen scavenger sachets are available.

The size and capacity of the ethanol emitter used will depend on the weight and water activity of the food and the shelf life required. When the food is packed with an ethanol emitting sachet, moisture is absorbed by the food and ethanol vapour is released and diffuses into the package headspace. Research has also shown that bakery products packed with ethanol had reduced staling as the ethanol acts as a plasticiser in the protein network of the bread.

9.6 MOISTURE ABSORBERS

Excess moisture is a major cause of food spoilage. Soaking up moisture by various absorbers or desiccants is very effective in maintaining food quality and extending shelf life by inhibiting microbial growth and moisture-related degradation of texture and flavour. Several companies manufacture moisture absorbers in the form of sachets, pads, sheets or blankets. Condensation within food packaging is a particular problem with fruits and vegetables; it can also lead to excess drip from meat, poultry and fish products. During respiration of fresh produce, water vapour is produced and builds up inside the packaging material. If the packaging does not have the correct permeability properties, this build-up of moisture within the pack causes the product to degrade more quickly. Moisture ingress into the pack can also be detrimental to bakery and dried goods, causing spoilage and affecting the quality of these products. Excess moisture from drip by meat and fish looks unappealing, affects the quality of the product and causes spoilage. A moisture absorber can reduce the levels of moisture within the pack.

The absorption material may include desiccants, such as silica gel, calcium oxide and activated clays and minerals. Silica gel remains dry and free flowing even when saturated and can absorb moisture at high temperatures and humidity. Colour changing silica gel can indicate the level of saturation. Molecular sieves are composed of sodium, potassium or calcium silicates and are excellent absorbers with a greater capacity compared to silica gel and clays. Molecular sieves are also capable of absorbing odours. Clay is a natural mineral capable of absorbing moisture. It is non-swelling and does not deteriorate as it absorbs moisture. Activated carbon can also remove both moisture and odour from a pack.

When selecting a moisture absorber, there are a number of factors that should be considered in order to select the correct absorber and absorption capacity. These include the following:

- the size and weight of the product
- the desired shelf life of the product
- the different temperatures and humidity the product will be exposed to
- the water vapour transmission rates of the packaging material
- the initial water activity (Aw) of the product
- the sensitivity of the product to moisture

It is important to determine the required absorption capacity of the moisture absorber to ensure that it can maintain the moisture levels of the product so as not to affect the organoleptic qualities. It should also be considered that the product may be packed in an environment with a low/high temperature/humidity but transported to a country with an alternate environment. A moisture absorber requires a greater capacity to absorb at higher temperatures. The water vapour transmission rates of a packaging material will also change, depending on the environmental temperature.

There have been some developments with moisture absorbers. Dri Fresh Resolve (Sirane Ltd.) is an absorbent meat pad with a breathable surface. During storage, cut red meat can become brown on the base where it is in contact with the moisture absorber because of the lack of oxygen. The Dri Fresh Resolve allows oxygen to circulate and have contact with the base of the meat thus maintaining the desirable red colour of the meat. The pad is also produced without using any adhesives or bonding materials. It is composed of corn starch and a cellulosic absorber, making it fully compostable (Potter *et al.*, 2008). EverDri (EverFresh USA) is an acid-free moisture absorber that is incorporated into a bag allowing the moisture to penetrate to the inside of the bag and not allowing the water to come back out again. The moisture is absorbed by capillary condensation in diatomaceous micropores. This is different to standard silica gel absorbers that tend to use the formation of a Si-OH bond to absorb the moisture (Potter *et al*., 2008).

In addition to moisture absorbers, sachets for humidity control in packaged dried foods are available. Humidipak (Humidipak Inc.) uses a saturated solution of substances to maintain the desired humidity within the pack. It works by absorbing and releasing moisture in response to the surrounding environment.

9.7 FLAVOUR/ODOUR ABSORBERS

The interaction of packaging with food flavours and aromas has long been recognised, especially through the undesirable flavour scalping of desirable food components. For example, the scalping of a considerable proportion of limonene has been demonstrated after only two weeks storage in aseptic packs of orange juice (Rooney, 1995).

Odour and flavour absorbers can be used to remove unwanted odours and flavours produced during the oxidative and biochemical reactions that occur during the deterioration of a product. When the package is opened, these compounds are released and detected by the consumer. Commercially, there are very few of these types of scavengers available and they are currently not permitted in the EU. Odour is one of the main detection methods used by consumers to determine whether a product is still safe to consume (Vermeiren *et al*., 2003). There are concerns that if the odour were removed, the consumer may consume food that is unfit for consumption.

However, there are opportunities for this type of product with the debittering of pasteurised citrus juices. Some varieties of orange, such as Navel, are particularly prone to bitter flavours caused by limonin, a tetraterpenoid, which is liberated into the juice after orange pressing and subsequent pasteurisation. Processes have been developed for debittering such juices by passing them through columns of cellulose triacetate or nylon beads (Rooney, 1995). The bitterness in grapefruit and lemon juices is caused by the flavanone glycoside naringin. To remove these compounds, adsorbers such as cellulose triacetate or acetylated paper can be incorporated into the packaging material of the orange juice. The acetate layer contains the enzyme naringinase consisting of α-rhamnosidase and β-glucosidase, which hydrolyses naringin to pruning. Low density polyethylene (LDPE) can also be used in conjunction with cellulose acetate to reduce limonene (Waite, 2003).

Two types of taints amenable to removal by active packaging are amines, which are formed during the breakdown of fish muscle proteins and aldehydes that are formed from the auto-oxidation of fats and oils. Food acids, such as citric acid, can be used to scavenge amines. Anico bags (Anico Co.) consist of a film containing a ferrous salt and an organic acid (citric or ascorbic acid), which oxidise the amines as they are absorbed by the polymer, creating harmless salts (Sivertsvik, 2003). Sodium sulphate and other organic sulphates have been shown to remove aldehydes. Tocopherols, such as vitamin E, also help to absorb aldehydes.

Aldehydes can also be formed several weeks after heat processing with products, such as UHT milk. Nylon MXD6, D-sorbitol and cyclodextrin were blended with PET to produce an aldehyde scavenging film in a trial carried out by Suloff *et al*. (2003). The results showed that the total amount of aldehydes removed from the pack was two to ten times higher with the blended scavenging film compared to standard PET films. The aldehyde scavenging film also demonstrated selective scalping, preferring smaller molecular weight aldehydes compared to larger molecular weight aldehydes. EKA Nobel in cooperation with Akzo has developed a range of synthetic aluminosilicate zeolites that, they claim, adsorb odorous gases within their highly porous state. Their BMH™ powder can be incorporated into packaging materials, especially those that are paper-based, and apparently odorous aldehydes are absorbed in the porous interstices of the powder (Goddard, 1995). Multisorb Technologies offer two different products, Minipax and Strippax, which are capable of absorbing mercaptans and hydrogen sulphide. Dupont Polymers also have a film, Bynel IXP 101, which has been used to remove the hydrogen sulphide from packs of cured poultry.

Recent developments have seen flavour and odour release outside of the pack to attract consumers to purchase the product. A controlled release of aroma occurs on the supermarket shelf and then a further aroma release happens when the consumer opens the pack. By using these systems, desired flavour and odours can be developed during storage as the natural properties deplete during shelf life. ScentSational Technologies, LLC, has developed Encapsulated Aroma Release™ whereby flavours and aromas can be released into the package head space to enhance the product. They can also aromatise the packaging material and attract the potential customer. This technology can be applied to existing manufacturing methods, e.g. blow moulding and thermoforming with no additional tooling required.

9.8 LACTOSE AND CHOLESTEROL REMOVERS

In a society with a growing trend of health consciousness, it has become desirable to remove particular components from foods including lactose and cholesterol. Potentially, lactase could be incorporated into the wall of the packaging material to hydrolyse the lactose in milk or milk-based products. Cholesterol reductase converts cholesterol to coprosterol, which cannot be absorbed by the intestine and therefore leaves the body undigested and reducing the amount of cholesterol absorbed.

9.9 ANTI-OXIDANT RELEASE

Oxygen can be detrimental to food products causing off-flavours and odours and colour changes to the product. Products high in fats and oils are particularly prone to oxidation including nuts, crisps and processed meats. Anti-oxidants can be incorporated into the packaging to reduce the degree of oxidation. Butylated hydroxytolune (BHT) and butylated hydroxyanisole (BHA) have been incorporated into the lining of the packaging material from which they are released during storage by diffusion. Alpha-tocopherol can also be extruded onto HDPE as an anti-oxidant. It has a slower release rate compared to BHT. A large proportion of the anti-oxidant is lost during release but the remainder is absorbed by the food, offering some protection. Trials have found that the rate of release is influenced by the food within the package. The fat content, alcohol and acid level all affect the rate of release (Koontz, 2006).

9.10 TEMPERATURE-CONTROLLED PACKAGING

Temperature-controlled active packaging includes the use of innovative insulating materials, self-heating and self-cooling cans. For added convenience, self-heating and cooling packs for food and beverages allow the consumer to eat or drink whilst working or travelling.

The basic principle with self-heating packs is that a button of the can/pouch is pushed releasing a small amount of water that, when mixed with a salt, usually calcium oxide, causes an exothermic reaction that heats the product. Self-heating packs have been used for a number of hot beverages including coffee, chocolate and soup.

Development of this type of container is not easy with complaints that range from the product being too hot or not heating at all. OnTech™ currently commercialises self-heated coffee, cocoa, tea and soups in the United States and Australia under the brand name Hillside. Food Brand Ltd. manufactures self-heating cups called Rocketfuel containing a blend of coffee and guarana and Nuova Bit S.r.l., produces self-heating coffee, tea and chocolate products distributed under the brand name CaldoCaldo (Potter *et al*., 2008).

Self-cooling systems are mainly intended for soft drinks and beers in cans. Tempra Technologies and Crown Holdings launched a self-cooling can (I.C.Can™). The refrigeration of the beverage is achieved without using any cooling gas or pressurised system. The can has two parts. In the upper section, 300 mL of the beverage is kept surrounded by a compartment containing a water gel. In the lower part, a desiccant is kept in a vacuum. To cool the drink, the lower part is twisted, breaking the seal, leading to an expansion of the liquid and its evaporation. The evaporation step reduces the temperature of the beverage by up to 16°C (Potter *et al*., 2008).

Different types of beer keg with self-cooling systems can be found on the market. Coolkeg® is a self-cooling keg produced by Coolsystem Keg GmbH. The cooling system is based on a technology called Zeolite/Water-vacuum developed by Zeo-Tech GmbH. The water absorption properties of zeolites allow the kegs to be returned to the manufacturer in the original state to be refilled and reused. An alternative approach has been taken by the Coca Cola Company; a self-cooling bottle that after opening cools the product by creating ice within it (Potter *et al*., 2008).

9.11 REGULATORY ISSUES, CONSUMER ACCEPTABILITY AND EQUIPMENT CONSIDERATIONS

Originally, packaging was deemed a method for protecting food from contamination, from spoilage and enabling transportation. The regulations related to food contact of packaging detailed that packaging should be inert and not release substances into food that pose a risk to human health; it should not release substances into food that change the taste, odour and composition of the food. However, active packaging can release substances into the food, so in 2004, the food contact materials legislation was revised to include active and intelligent packaging. Active packaging may release substances into food but only under certain specified conditions. The substance released has to be a substance that is authorised in the context of food legislation, e.g. food additive/flavouring, and can only be released into food and in authorised quantities, (Schafer, 2009).

The European Commission has adopted a regulation on active and intelligent materials and articles intended to come into contact with food (EC, 2009). The safety of substances used, labelling and a declaration of compliance are detailed within the regulation. An authorisation scheme will evaluate the substances and approve their uses. The manufacturer is required to issue a declaration of compliance so that adequate information is passed along the supply chain about the materials and devices. The manufacturer is also required to provide the food manufacturer with information on the substances used within the device and the levels released. The food packer then has the responsibility to label their package with the released substance within the ingredients declaration. Any non-edible components of the device are also required to be labelled with the appropriate 'do not eat' symbol and text.

The consumer's perception of active packaging needs further investigation. Knowledge and education about the benefits seem to be lacking with consumers. However, as more manufacturers and retailers use active devices providing information about why they are present, the more the consumer will become used to and accept them.

Incorporating active and/or intelligent packaging into a package will have an impact on the packing line. Most equipment will require adjustment, upgrading or replacement. This can prove to be quite expensive. Adding scavengers and desiccants into a pack requires specialist equipment, such as insertion equipment. Equipment manufacturers are looking to the needs of the future and building equipment that can be easily adapted to accommodate any changes required. Other factors also need to be considered, such as a reduction in production and throughput.

9.12 CONCLUSION

Active packaging is an emerging and exciting area of food technology that can confer many preservation benefits on a wide range of food products. Active packaging is a technology developing a new trust because of recent advances in packaging, material science, biotechnology and new consumer demands.The objective of this technology is to maintain sensory quality and extend the shelf life of foods whilst at the same time maintaining nutritional quality and ensuring microbial safety.

Advances in the last decade have seen active systems incorporated into the main packaging of the product rather than as separate or loose components in the pack. These systems will become more efficient and multifunctional and can be used with a wider range of foods to improve quality and extend shelf life.

Further developments and users of active and intelligent packaging will depend heavily on changes and clarification of the new legislation.

The use of active packaging is becoming increasingly popular and many new opportunities in the food and drink industries will open up for utilising this technology in the future.

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