ACTIVE PACKAGING

INDUSTRY LEAFLET

ActInPak

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INTRODUCTION

Traditional packaging materials such as plastics, glass and cardboard are designed to be as inert as possible. Modern packaging strategies however, seek to promote an additional active role to assist in maintaining the product's quality. Such packaging concepts are called *active packaging*.

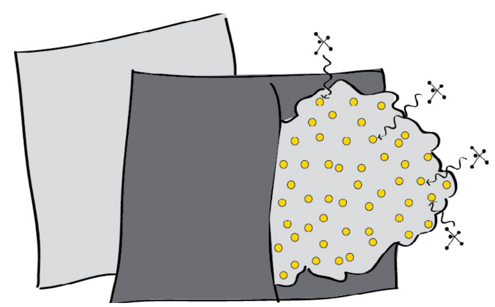
They are deliberately made to contain substances that interact with the atmosphere inside the packaging or the packaged product. In other words, active packaging concepts are used to actively extend the shelf-life of a wide array of products, varying from cosmetics, pharmaceuticals, electronics and construction materials to fresh products such as cut flowers, fruits, vegetables, fish and meat.

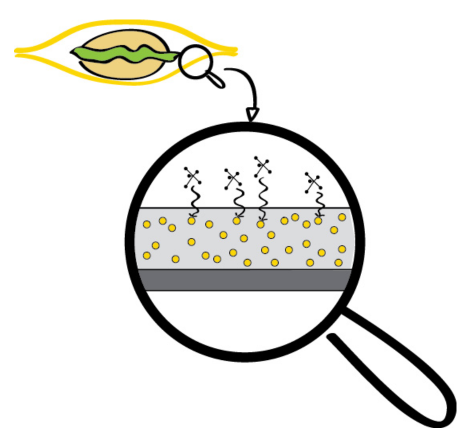
In this leaflet, you will find an overview of active packaging technologies, its uses and benefits as well as the ways in which it can be integrated in packaging.

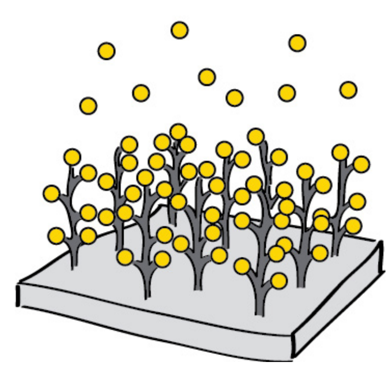
TYPES OF ACTIVE PACKAGING

The term active packaging does not refer to a single technology, but to a wide variety of technologies that tackle various specific challenges in different ways. However, a general distinction can be made between three types of active packaging technologies.

Scavengers, also known as absorbers, are active packaging technologies that absorb substances from the packaging's inner atmosphere or from or the packed product, and are the most commonly used type of active packaging technology. Especially moisture and oxygen scavengers are frequently used, since oxygen and moisture both are often involved in deteriorative reactions and are important causes of quality loss and degradation in (food) products and organic compounds. Common examples are sachets with silica gel. These moisture scavenger sachets are already part of our everyday life, as they are usually found inside boxes of electronic products or bags for clothing items. Most scavengers absorb a specific substance, but some only absorb a substance above a certain threshold; Potassium chloride, for example, absorbs water vapour only above 87% relative humidity. These types of scavengers are also known as *regulators*.

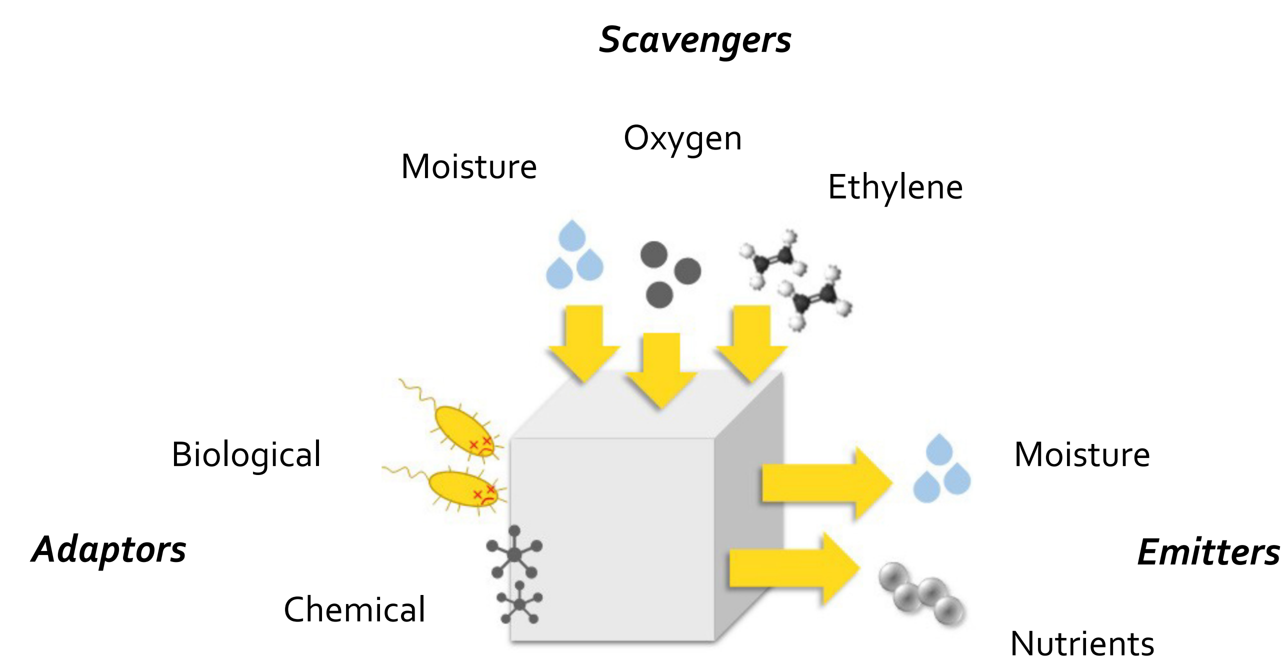






Emitters or releasers are active packaging technologies that release substances (i.e. ethanol, CO_2, moisture, antioxidants, flavours, colouring agents, etc.) into the packaging and can be used for different reasons. An important application is to compensate for the absorption of components into the food or the loss of substances via migration thereof through the packaging material. Release-agents are typically encapsulated in order to achieve a controlled or triggered release of the released substances. Different encapsulation materials can be used. The effects of emitters wear off over time.

Adaptors form a third category of active packaging technologies. These solutions do not absorb or release substances but cause desirable chemical or biological changes in the packed product and/ or in the microbial life present in the packed product or the packaging's inner atmosphere. For example: a packaging material that reduces the growth of micro-organisms through the reactive compounds that are immobilized (fixed) on the material surface. Because the active substances are immobilized, they do not migrate into the atmosphere. This means that they have a long-lasting effect but only function when in contact with the product.



THE RIGHT TECHNOLOGY FOR EACH APPLICATION

All active packaging concepts have one thing in common: they interact with the packaged product and/or the atmosphere inside the packaging in order to prevent quality loss and prolong shelf life. As you already learned in the previous section, different types of active packaging work in different ways and tackle different causes of quality loss. In addition thereto, every technology has its own requirements regarding processing, storage and handling, which means that although a technology might tackle the right cause of quality loss, it might still not deliver the desired results when it is not correctly processed or handled or stored for too long. This means that to find an active packaging technology that works well for your application, it is important to thoroughly understand your product and how it is produced and processed as well as the causes and mechanisms of quality loss for each specific situation.

To start with the product and its reasons and mechanisms of quality loss, it is important to know what determines the shelf-life of the product. The shelf-life of a product depends on the various intrinsic properties of the product, which include pH, nutritive value, the natural presence or absence of antimicrobial agents, breathability and biological structure, and of external factors such as the length of the supply chain and storage conditions such as temperature, relative humidity and the air composition. These factors will determine the chemical, biochemical, physical and microbiological spoilage of products, and thus also the shelf-life of the product. Depending on the spoilage mechanism(s) of the product, a specific type of active packaging technology can be selected that will be beneficial to the specific product.

In addition thereto, one should also consider the strength of the effect of the specific active packaging technology. This is important because in some cases, when the active technology absorbs or releases too much of a certain substance, the active technology can actually have adverse effects on the lifespan of the packaged product. For example, absorbing too much moisture from bread packaging can make the bread dry out too fast, and removal of too high quantities of gases can cause the packaging to deform or tear due to pressure differences. Therefore, it is important to know exactly how much of a substance should be absorbed or released in which timeframe, in order to determine the type and quantity of the active packaging technology that is suitable for the specific application.

Knowledge of the value chain of the product is also important. Especially the processing and handling of the packaging material and the length of the value chain are of relevance. Some active materials are volatile, and are thus not suitable to be exposed to high temperatures. Using such active packaging technologies for (food) products that are heated for e.g. preservation reasons would thus not make sense. The length of the intended lifespan of the product is also important, as the duration of packaging activity should be adapted to that.

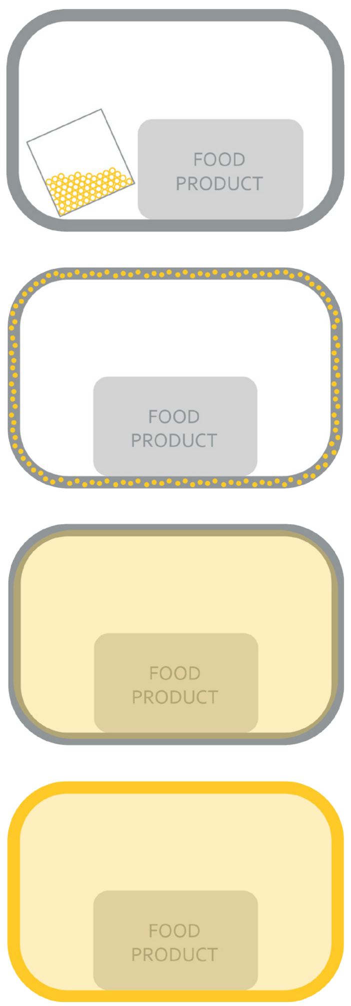
The table on the following pages provides an extensive overview of various active packaging technologies, their technical composition, action mode and application areas.

TECHNOLOGY		TECHNICAL COMPOSITION	ACTION MODE	APPLICATION AREAS
SCAVENGERS (absorbing technologies)	Oxygen scavengers	Oxygen absorbers can be based on oxidation of iron, ascorbic acid, photosensitive oxidation, enzymatic oxidation (i.e. glucose oxidation), unsaturated fatty acids, rice extract or yeast immobilized on a solid substrate.	Oxygen absorbers reduce the oxygen level in the packaging, thereby preventing oxidation reactions and growth of aerobe bacteria and fungi. Also prevents discoloration of fresh meat and keeps out pests in for example museum environments.	Cheese, bread, bakery goods, nuts, milk powder, coffee, tea, beans, grains, pasta, meat, fish, drinks, ready-made meals, spices, soups & sauces, products containing vitamins A, C and/or E, artwork conservation (musea)
	CO_2 scavengers	CO_2 absorbers can be based on calcium hydroxide and sodium hydroxide or potassium hydroxide, calcium oxide and silica gel.	Removal of CO_2 from the packaging prevents rupturing of the packaging during storage due to CO_2 build-up.	Meat, fish, poultry, beer, cheese, coffee, dough, flowers
	Moisture scavengers	Moisture absorbers can be based on glycerol, clay, silicon oxide, propylene glycol, polyacrylates and cellulose nanofibers. The most commonly used moisture absorbers are those based on silica gel.	Reduction of moisture level in the packaging reduces the growth of bacteria and fungi and prevents weakening of paper-based packaging materials due to water uptake.	Absorbing trays for meat, fish, poultry, bread, ready-made meals, cut fruits and vegetables, blisters for powdered pharmaceutical products, hardware products, metal goods, clothing items, electronics, artwork conservation (musea)
	Ethylene scavengers	Ethylene absorbers can be based on aluminium oxide and potassium permanganate, carbon or zeolite.	Reduction of ethylene levels in the packaging slows down the natural ripening process of fresh fruits, vegetables and flowers.	Import and export of fresh fruits and vegetables (especially apples, apricots, bananas, mangoes, cucumbers, tomatoes, avocados, carrots, potatoes) but also cut vegetables, cut flowers
EMITTERS (releasing technologies)	Ethanol emitters	Ethanol is encapsulated in silicon dioxide to achieve a slow-release of ethanol vapour.	Slow down the growth of fungi and bacteria, thereby extending the products' shelf-life.	Bread, dried fish products
	Sulphur dioxide emitters	The mechanism of sulfur dioxide release can be based on either the chemical reaction between sodium metabisulfite (active materials) and water (external), or on the reaction of an organic acid with calcium sulphite (both in the packaging).	Sulphur dioxide reacts with active substances such as calcium sulphite with water, or functions through the hydrolysis of metabisulphite. These emitters are used as a bleaching agent to prevent discoloration of (white) food products, as an anti-oxidant and for its antimicrobial properties.	Dehydrated white vegetables, various heat-treated foods, various processed foods, unprocessed foods such as fresh fruits, vegetables, cut flowers, meat and fish products, cosmetics, pharmaceuticals
	CO_2 emitters	CO_2 emitters can be based on ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate.	CO_2 emitters are most commonly used in combination with oxygen absorbers. For example: ascorbic acid-based sachets are both oxygen absorbers and CO_2 emitters at the same time.	Meat products, MAP-packed products
	Antimicrobial emitters	Examples of antimicrobial agents used in release systems include acid anhydride, alcohol, bacteriocins, chelators, enzymes, antioxidants, organic acids, (components of) essential oils and polysaccharides.	Antimicrobials are typically encapsulated and are released once a trigger, such as a certain (high) humidity level, is present in the packaging. Antimicrobials are used as preservatives.	Meat & fish products, fruits, vegetables, cut flowers, schoes and leather goods, archives
	Aroma and flavour emitters	Flavours and aromas are released slowly and evenly in the packaged product during its shelf life or release can be controlled to occur during opening the package or food preparation.	Addition of aromas and/or flavours can improve the aroma of fresh products or enhance the flavour of food once the package is opened. Gradual release of aroma's and/or flavours can offset the natural loss of taste or smell of products with long shelf lives.	Bread, meat and other applications, fun-element in packaging for detergents, perfumes, air fresheners, etc.
	Antioxidant emitters	Examples of anti-oxidants in food products are vitamin C, vitamin E (tocopherol), resveratrol and citric acid. Next to that, certain minerals such as selenium, chromium and zinc are important because they are part of enzymes that function as antioxidants. In the body, uric acid also functions as an antioxidant.	Antioxidants neutralize harmful free radicals, thereby preventing oxidation and extending the product's shelf-life.	Dehydrated foods and fat-containing foods
ADAPTORS	Contact-based antimicrobials	Examples of antimicrobial agents used for contact systems include titanium dioxide, silver, zinc, calcium or natural preservatives such as nisin, and vegetable oils at nanoscale.	Contact-based antimicrobials and antioxidants are immobilized (fixed) on the matrix of the packaging material. Because they do not migrate into the atmosphere, they have a long-lasting effect but only function when in contact with the product. Antimicrobials are used as preservatives.	Meat & fish products, fruits, vegetables, cut flowers, cosmetics, medicines, medical equipment

INTEGRATION OF ACTIVE TECHNOLOGIES

Active packaging technologies can be integrated in the packaging material in several ways. One widely used method is the insertion of a separate entity, which contains the active material (e.g. silica gel), inside the packaging, just before sealing.

Alternatively, the packaging material itself can be active by nature, or be made active by blending the active components into the bulk of the material or adding it to the surface of the material via coating or lamination processes.



Active materials can be integrated in the packaging by means of a ***separate element***.

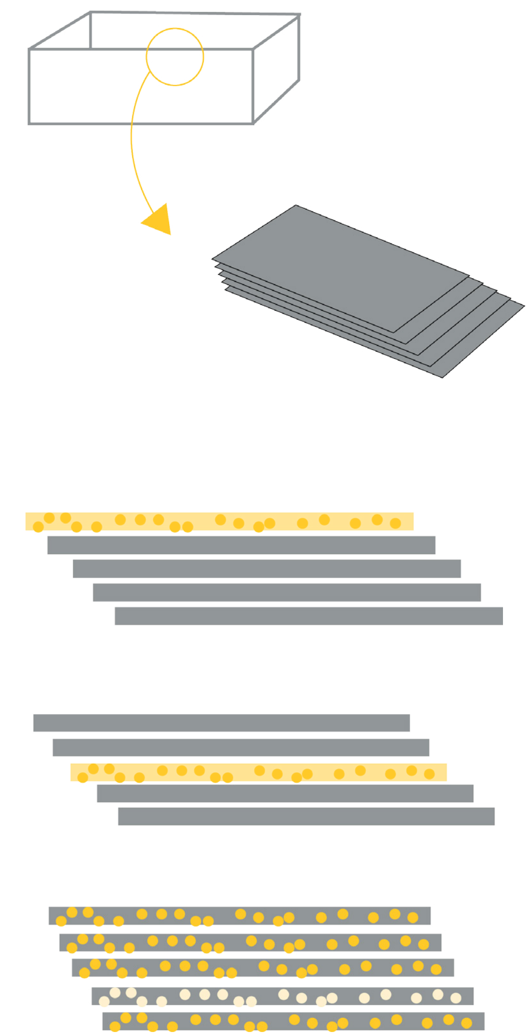
Active agent can be integrated ***into*** the packaging material.

Active agent can be integrated ***onto*** the packaging material.

Active agent can ***be*** the packaging material.

Schemes are taken after reference [1].

In packaging materials that consist of multiple layers, the so-called multilayer-materials, there are even more possible ways of incorporating one or more active functionalities in the material structure.



Schemes are taken after reference [2].

As a top layer, the active components can be added by means of lamination, coating or – in case of paper and board – via surface sizing. Depending on the materials and processes used, this can be done either during the production of the material itself, or during conversion.

As a core layer, the active component can also be sandwiched between two or more non-active layers. When the envisioned material is a type of folding boxboard or solidboard, it is possible to incorporate the materials directly during board production. In this situation, the active components will be blended into the paper pulp that is used to produce the middle layer(s) before pressing the layers together. Alternatively, the active material layer can also be combined with the other layers through lamination in a conversion step.

Different active properties in each layer is also possible when working with multilayer structures. By blending different active components in each layer of the final structure it is possible to achieve a multilayer material with various active functionalities. Again, for folding boxboard or solidboard this can be done during board production. For all other materials, lamination is the easiest way to achieve such materials.

Each of the methods described in this section have their advantages and drawbacks, in the sense that not all options are available for all materials and active technologies. For example, volatile release substances won't be suitable for being added in the bulk of paper or plastics because they would be damaged by the heat that is typical in the production processes of these materials. In other cases, a certain way of integrating the components in the material simply doesn't make sense for practical reasons; adding active technologies that require contact with the packaged product in the bulk of a thick paperboard, for example, does not make the material more effective than adding a thin layer of the active material to the surface of the board.

The table below provides an overview of the different integration methods and their advantages and drawbacks in terms of applicability. It compares between different ways of integrating active technologies in paper and board packaging.

Whether or not a specific active packaging technology is able to deliver certain effects or opportunities is dependent on many factors, including the composition of the active material and the product it is used on. Therefore, we recommend to always contact the producer of the active material to learn whether or not it is suitable for your application and which effects can be achieved.

	SACHETS	TOP LAYER IN LAMINATE OR SURFACE TREATMENT	CORE LAYER IN LAMINATE	IN BULK
Suitable for contact-based active components	N	Y	N	Y*
Requires active component to be heat-resistant	N	Y/N**	Y/N*	Y
Multiple active functions possible	Y	N	Y/N***	Y
Accidental ingestion possible	Y	N	N	N
Easy consumer apprehension	N	Y	Y	Y
May affect processing methods/ equipment	N	Y	Y	Y

* less suitable for thick materials; ** depends on processing method;
*** depends on total amount of layers in laminate

MARKET IMPLEMENTATION

Successful market introduction depends on more than technological viability of a new technology; costs have to correspond with the gained benefit, legislative and regulatory issues must be addressed, and broad consumer acceptance is required. More on these challenges is written in the roadmap of WG2 (Working Group 2).
In this section, we present to you the opportunities and challenges active packaging has to offer. Legislation on the topic is briefly explained.

OPPORTUNITIES

The introduction of active packaging has been regarded as a response to continuous changes in market trends and consumer demands [3]. Active packaging concepts (materials and methods) are a promising development, because they can deliver several benefits to producers, brand-owners and retailers in all sectors in terms of economics, logistics and sustainability. For example, as active packaging concepts are able to maintain the quality and extend the shelf-life of a wide variety of products throughout the value chain, the most apparent benefit is a reduction in food waste, loss of products and economical value. Food waste is an environmental, social and economic challenge – approximately 1.3 billion tonnes or one third of the produced food for human consumption is wasted [4]. Preservation of food is an efficient method for saving food, obtain optimal shelf life and preventing from being wasted. Quality preservation results in a higher market value for all types of products and increases competitive value, but also makes the value chain as a whole more efficient, as less arable land, water, fertilizer, raw materials, fuel, etc. is required to supply the same amount of consumers. Another advantage is that by using active packaging technologies, the need for chemical preservatives inside foodstuffs, textiles, etc. becomes redundant. This way, products are more natural but still the quality is maintained and safety guaranteed (lower risk on food poisoning, allergies, etc.).

Active packaging technologies can also deliver new logistic opportunities. For example, a longer shelf-life for products enables producers of fresh produce such as cut flowers, fruits and vegetables increased flexibility in production, and to store their products longer, which is especially beneficial from an economic viewpoint during the peak season, when market prices are often low due to overproduction. Storing products for just a few more days can increase profitability, thus supporting the economic health of especially agricultural and horticultural businesses. For local production, increased shelf-life is not always needed (or wanted due to freshness perspective). However, active packaging can contribute to inhibit or reduce the deteriorative processes. Thus, the quality of fresh product after selected end of storage may be higher/improved compared to concepts without active packaging. This could result in potential increased profitability. Another potentially interesting logistic benefit of extended shelf-life is that new transportation routes or methods become feasible. From this viewpoint, it will become possible to import products from farther away, or choose to follow the cheaper route of transporting overseas instead of airfreighting.

Further down the value chain, active packaging can also bring other, less obvious benefits. In packaging processes, for example, active packaging allows packages to be filled faster and/or for thinner packaging films to be used, as scavenging and emitting technologies can compensate for the lower amounts of gases added to MAP packages during filling and for the lower barrier properties of thinner films. Each of these possibilities deliver new business opportunities that can increase economic health and competitiveness of companies. And there's more to come!

As the technical developments in the field of active packaging are ongoing, it is expected that active packaging technologies such as oxygen scavengers will be improved further in the coming years, leading to even greater impacts with lower dosages of active materials.

CHALLENGES

Like with any other technology, active packaging technologies also have some challenges that should be considered. Probably the main challenge of active packaging is that there is no 'one size fits all'-solution. Because there are almost as many different technologies as there are applications, it always require some thinking, developing and testing before one reaches the point of actually implementing an active packaging technology. Adaptation of the technology to a specific application is almost always required to achieve the best effects, as improper use of active packaging technologies, such as adding too much absorbing capacity, may have adverse effects. Therefore, the decision to implement such technologies is often one that is not taken lightly by most brand-owners. In addition thereto, communication of the benefits towards the consumers and value chain stakeholders is often considered to be as challenging as it is important. Earning the trust of consumers and making sure they understand the effects is not always easy, especially when it comes to finding components in their food that are unknown and thus might be considered unsafe or undesired.

Thirdly, there is a challenge related to availability of active packaging technologies. As is quite typical for novel technologies, the market for most active packaging technologies is not very mature yet, in the sense that there are only a few producers of active packaging materials, which can be considered risky by especially larger brand-owners who are considering using such technologies. In addition thereto, suppliers often demand a minimum order size that is too high for most brand-owners that are interested in testing the use of active packaging technologies.

LEGISLATION

Materials that are intended to get in contact with food is regulated under the EU Framework Regulation EC 1935/2004. Article 3 in the Framework Regulation states that no food contact materials shall transfer constituents into food levels that endanger human health (Art.3 EC/1935/2004). Specific requirements for different food contact materials are also allowed in the regulation. However, under European community law, specific regulations have not been adopted for paper and board packaging materials. Specific requirements are present for active and intelligent packaging. According to the framework regulation, packaging materials may only release substances into the food that are regulated as food additives or food flavorings. Additional safety requirements for active and intelligent packaging is set in Regulation EC 450/2009. The use of active and intelligent packaging for product marketed by companies has to be accompanied be a declaration of compliance including consumer information at the retail stage.

For non-food products, these regulations do not apply, which means it is simpler to implement active packaging technologies for non-food applications. However, this does not mean there is no legislation to keep in mind.

More information can be found in the ActInPak Legislation leaflet [5].

ACTIVE PACKAGING LEAFLETS

A series of short-text leaflets on the topic of active packaging has been published.

On the right, there are clickable links to web versions of the ActInPak's Active packaging leaflets in various languages named after their country of origin.

English

Bulgaria

Czech Republic

Greece

Italy

Latvia

Netherland

Norway

Poland

Portugal

Romania

Serbia

Slovakia

Slovenia

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[4] United Nations Environment Programme (2013). Quickfacts. Web: http://www.unep.org/wed/2013/quickfacts/

[5] COST FP1405 ActInPak (2018). Legislation on AIP. Web: https://legislation.actinpak.eu

More information on this topic can also be found in the book:

Cerqueira, M.A., Lagaron, J.M., Pastrana, L.M., Martins De Oliveira Soares Vicente, A.A. (2018). Nanomaterials for Food Packaging: materials, processing technologies and safety issues. Micro & Nano Technology Books. Elsevier. Web: https://www.elsevier.com/books/nanomaterials-for-food-packaging/cerqueira/978-0-323-51271-8

COST FP1405 ActInPak aims to identify and overcome the key technical, social, economic and legislative barriers to a successful deployment of renewable fibre-based functional packaging solutions such as active and intelligent packaging. Currently, 43 countries are involved in the network, with participants representing 209 academic institutions, 35 technical centers, and 83 industrial partners.

For more information, please visit the ActInPak website:

www.actinpak.eu

COST (European Cooperation in Science and Technology) is a funding agency for research and innovation networks. Our Actions help connect research initiatives across Europe and enable scientists to grow their ideas by sharing them with their peers. This boosts their research, career and innovation.

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