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# Active and intelligent packaging: A boon to food packaging

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**Abstract**
Packaging is a socio- scientific discipline that manages to provide best goods to consumers for their use. Active packaging is defined as deliberate addition of some component(s) in or on packaging material or packaging headspace to intensify properties of the packaging system. Active packaging systems are categorised as- active compounds that are stuffed into sachets or pads and then added in the package and active compounds are added directly into the package or on the packaging material. Intelligent packaging includes indicators giving information about quality and safety of the product; history of package, atmosphere inside and outside the package etc. It gives information to the producer, retailer and consumer about quality and surrounding environment. Now a day's there is a huge increase in production of active and intelligent packages and their use in commercial products may act as a boon for packaging industry.

**Keywords:** active packaging, intelligent packaging, shelf life, etc.

## 1. Introduction
Packaging is a socio- scientific discipline that manages to provide best goods to consumers for their use [1, 2]. Various functions of packaging are - Prevention of product from environment, mode of communication between producers and consumers, reduces amount of waste produced, promotion of product, maintains quality and safety of the product, tamper proofing, material reduction etc[3,4]. Food packaging technology is developing gradually overcoming various demands of the urbanized society [5, 6]. Major challenges faced by faced by food packaging are- increased shelf life, global market, convenience, safe food, food waste, etc [5]. Food waste is the main global concern which can be reduced by new techniques of producing small packages of required amount of the product, use of better packaging technology to improve shelf life and maintain the organoleptic properties of the food [5].

## 2. Active Packaging
Active packaging is defined as deliberate addition of some component(s) in or on packaging material or packaging headspace to intensify properties of the packaging system [7]. Active packaging is beyond conventional method in which the package, product and its environment combine to increase shelf life, improve food safety or organoleptic quality and simultaneously preserves the overall quality of food [8, 9]. It prevents various physiological, chemical and microbiological processes inside the package like respiration of fruits and vegetables, lipid oxidation, spoilage from micro- organisms, etc [8]. Objectives of active packaging are

- To remove unwanted compounds
- To add desired component(s)
- Prevention from micro-organisms
- Change physical conditions inside the package
- Change permeability of film
- Less use of preservatives
- To reduce losses

Some examples of active packaging systems are tabulated in Table 1.

**Table 1**: Some active packaging systems

| Active Packaging System | Mechanisms | Food Applications |
|---|---|---|
| Oxygen absorbers | Iron-based, metal/acid, metal (e.g., platinum) catalyst, ascorbate/metallic salts, enzyme-based and nylon MXD6 | Bread, cakes, cooked rice, biscuits, pizza, pasta, cheese, cured meats and fish, coffee, snack foods, dried foods and beverages |
| Carbon dioxide absorbers/ Emitters | Iron oxide/calcium hydroxide, ferrous carbonate/metal halide, calcium oxide/ activated charcoal and ascorbate/sodium bicarbonate | Coffee, fresh meats and fish, nuts and other snack foods and sponge cakes |
| Ethylene absorbers | Potassium permanganate, activated carbon and activated clays/zeolites | Fruits and vegetables |
| AM packaging | Organic acids, silver zeolite, spice and herb extracts, BHA/BHT antioxidants, vitamin E antioxidant, chlorine dioxide and sulphur dioxide | Cereals, meats, fish, bread, cheese, snack foods, fruits and vegetables |
| Ethanol emitters | Encapsulated ethanol | Pizza crusts, cakes, bread, biscuits, fish and bakery products |

| | | |
|---|---|---|
| Moisture absorbers | Poly(vinyl acetate) blanket, activated clays and minerals and silica gel | Fish, meats, poultry, snack foods, cereals, dried foods, sandwiches, fruits and vegetables |
| Flavor/odor adsorbers | Cellulose triacetate, acetylated paper, citric acid, ferrous salt/ascorbate and activated carbon/clays/zeolites | Fruit juices, fried snack foods, fish, cereals, poultry, dairy products and fruits |
| Self-heating and self-cooling | Quicklime/water, ammonium nitrate/water and calcium chloride/ water | Ready meals and beverages |
| Changing gas permeability | Side chain crystallizable polymers | Fruits and vegetables |

***Source*:** [7]

**3. Active Packaging Systems**

Active packaging consists of oxygen scavengers, carbon dioxide adsorbers and emitters, moisture control agents and anti-microbial packaging technologies [10, 11]. Active packaging systems are categorised as-

1. Active compounds are stuffed into sachets or pads and then added in the package
2. Active compounds are added directly into the package or on the packaging material

**Sachets and Pads**

They pose to be an effective form of active packaging but cannot be used in liquid foods. Sachets and pads should be attached with the package otherwise the film can take the sachet to a place where it cannot perform its function. Absorbent pads may absorb liquid or gases and infused with silver, copper or copper oxide nano particles [12, 13].

**Functions of Sachets and Pads**

**a) Oxygen absorbers/ Oxygen scavengers** [7]

Oxygen causes many various deteriorating changes in food product. Presence of high oxygen decreases shelf life and nutritional quality of the food [14]. Evacuation of oxygen decreases deteriorating reactions such as oxidative rancidity, enzymatic discolouration etc. Powdered iron or ascorbic acid is used as oxygen absorber. Most commonly powdered iron is used; it gives large surface area for reaction. Overall reaction is as follows:

$$Fe+\frac{3}{4}O_2+\frac{3}{2}H_2O \rightarrow Fe(OH)_3$$

Absorbers can decrease the oxygen concentration in the headspace of the package by 0.01%. There are different size variations of oxygen scavengers that utilize 20-2000mL of oxygen. Various factors that are responsible for selection of type and size of absorbent include size, weight and shape of the product; water activity of the product; amount of oxygen dissolved in the product; required shelf-life of the product; oxygen permeability of the packaging material; initial oxygen level in package headspace. Various applications are- sliced, cooked, cured meat products, cured fish, bakery goods, dried products, milk, dried- eggs, spices, herbs and confectionery.

**b) Carbon dioxide absorbers and emitters** [7]

There are fewer sachets which absorb carbon dioxide. Carbon dioxide absorbers can be of two types

1) Containing physical absorbent (zeolite)
2) Containing chemical absorbent (Calcium hydroxide)

**c) Ethylene absorbers and emitters**

Ethylene is a plant hormone formed during ripening of fruits and vegetables [15]. Most of the ethylene absorbers are potassium permanganate based. Reaction of functioning of ethylene absorber is as follow:

$$3C_2H_4 + 12KMnO_4 \rightarrow 12Mno_2 + 12KOH + 6CO_2$$

Other ethylene absorbers are activated charcoal, bentonite and alumino silicates i.e. zeolites [16].

**d) Moisture absorber**

Moisture is collected in the package due to change in temperature, drip loss etc. Water is also produced during breakdown of fats and carbohydrates [17]. The accumulated water can cause growth of spoilage micro-organisms. The excessive water can be removed by use of food package that is highly impermeable to water vapours [18]. Common absorbing systems include a super absorbent polymer present between two layers of microporous or non-woven polymer. Some of the moisture absorbents are polyacrylate salts, carboxy methyl cellulose (CMC) and graft copolymers of starch.

**e) Odour removers**

Undesirable odours and flavours are removed by elimination of amines, aldehydes and fatty acids produced during primary and secondary oxidation of fatty acids. Bitter compounds (limonin) are also removed from fruit juices. Some unpleasant odours can be sensed by consumers on opening of the package even when the food is safe to be consumed [20]. Plastic processing like moulding, extrusion can lead to off flavours. Antioxidants can also be used to decrease unpleasant odours [16, 20, and 21].

**f) Antimicrobial agents**

Meat and meat products are more susceptible to microbial spoilage. The main aim is to reduce, inhibit or retard the growth of micro- organisms [22]. Antimicrobial agent increases the lag phase and decreases the growth phase of microbial growth curve and ultimately reduces the growth of micro- organisms [5]. Ethanol emitters can be used to increase shelf life of bread, dried and semi- dried fish products and staling of bread [23]. Other antimicrobial agents are silver-based compounds like Ag-zeolites, organic acids, bacteriocins like nisin and pediocin, hexamethylene tetramine, enzymes like lysozyme, fungicides, and organic compounds like triclosan [22, 16, 24, 21].

**4. Intelligent Packaging**

Intelligent packaging includes indicators giving information about quality and safety of the product; history of package, atmosphere inside and outside the package etc [7, 25]. It gives information to the producer, retailer and consumer about quality and surrounding environment [11]. Various examples of internal and external indicators are tabulated in Table 2. It is a better

approach to regulate quality and safety of the food product [26].

Objectives of Intelligent Packaging

- Indicator of quality of food
- Indicator of ripeness or maturity of the product
- Shelf life information
- Indication of temperature of the food product

**Table 2:** Some commonly used internal and external indicators

| Indicator | Principle/ Reagents | Information given | Application |
|---|---|---|---|
| Time- temperature indicators (External) | Mechanical<br>Chemical<br>Enzymatic | Storage Conditions | Foods stored under chilled and frozen conditions |
| Oxygen- Indicators (Internal) | Redox dyes<br>pH dyes<br>Enzymes | Storage Conditions<br>Package Leak | Foods stored in packages with reduced oxygen concentration |
| Carbon dioxide- Indicators (Internal) | Chemical | Storage Conditions<br>Package Leak | Modified or controlled atmospher food packaging |
| Microbial growth Indicators (Internal External) or Freshness Indicators | pH dyes<br>All dyes reacting with certain metabolites (volatiles or non- volatiles) | Spoilage (Microbial quality of food) | Perishable foods such as meat, fis and poultry |
| Pathogen Indicators (Internal) | Various chemical and immunochemica methods reacting with toxins | Specific pathogenic bacteria suc as *Escherichia coli* 0157 | Perishable foods such as meat, fis and poultry |

***Source*:** [9]

**5. Classification of Intelligent Packaging System**

A) Product quality indicators- TTI, Gas indicators, Freshness indicators
B) Product protection- Tampering, theft etc.
C) Increases convenience- During preparation and cooking of food

**i) Product quality indicators**

Quality and freshness of the product gives an indication of The acceptability of the product throughout its journey from packaging to consumption.

Quality indicators generally show colour changes which are permanent and easy to interpret by the consumers [7]. TTI (Time-Temperature indicators are classified as full history indicators (respond continuously) and half history indicators (respond at some fixed temperature).

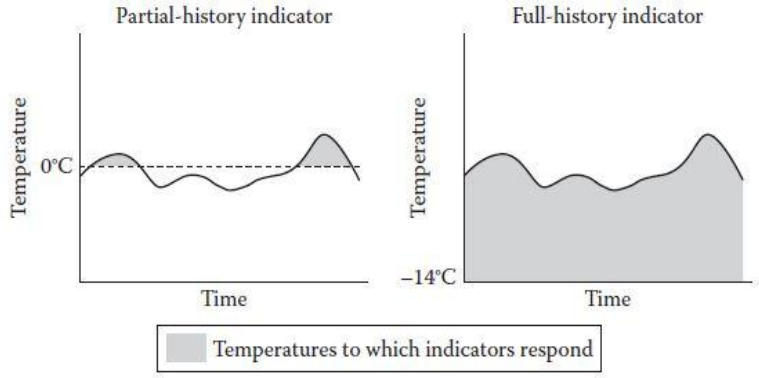


**Fig 1**: Two major categories of TTI [7]

Gas concentration indicators are useful for modified atmospheric packaging. They are also used as indicator of leakage or to check efficiency of active packaging systems [27]. An ideal oxygen gas indicator should be inexpensive, have long shelf life under normal conditions, easily integrated in the food package and easily printable [28]. Oxygen indicators are redox-dyes and enzyme based systems [29]. RFID (Radio frequency identification) tags provide information regarding history and details of the product making traceability of the product easier [30]. Microbial contamination detection is another important aspect. Biosensors are devices which detect record and transmit information of biological deterioration reactions in the product. It contains a bio receptor and a transducer. Bio receptor is specific for an analyte and transducer converts biological signals to electrical signals. The bio receptor can be an enzyme, antigen, hormone, nucleic acid. Transducer may vary according to parameter to be observed. Use of impedance biosensors for detecting foodborne pathogens was observed [31].

**ii) Product Protection**

Theft is not a problem for food products; it is basically in high value commodities like electronics and clothes. To decrease theft cases holograms, special inks and dyes, laser labels and electronic tags have been introduced, but their use in food packaging is less as it increases cost of the product. Tampering is main concern in food industry. Tampering indicators change colour or show words like open or stop if the package is damaged or seal is broken.

**iii) Provides Convenience**

Intelligent packaging which increases convenience of the package and provides an advantage for the consumer's are-

**a) Thermo chromic Inks**

Used in containers or packages which are needed to be heated or cooled before consumption. They can be printed on the labels or the containers. They provide us hidden messages such as drink me or too hot by changing their colour. Thermo chromic ink technology was first utilized in wine labelling.

**b) Microwave Doneness Indicators**

They indicate doneness of the product heated in the microwave oven. There are various drawbacks of these indicators- False indications due to non- uniform heating, difficulty in observing the colour change without opening the oven etc.

## 6. Conclusion

In today's era of convenience based food products, a need for an overall packaging system is highly felt. Therefore, active and intelligent packaging are a useful technique to increase shelf life, keep a track of the product, to get information regarding internal and external surrounding of the food product, etc. Now a day's there is a huge increase in production of active and intelligent packages and their use in commercial products. This has the potential to be one of the greatest achievements fields of food science and technology as this system can work efficiently to reduce the waste and shortage of the food supply.

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