Recent Advances in Packaging of Fruits and Vegetables

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Packaging is the art, science and technology of enclosing or protecting products for distribution, storage, sale and use.

Aim of Packaging: To control, the environmental contamination, physical damage and micro-organisms in order to ensure the quality and to extend the shelf-life.

Advancements in packaging

1. Active packaging
2. Intelligent packaging
3. Biopolymer based Packaging
4. Nanotechnology based Packaging

1. Active packaging

It is a packaging system that interact with the package environment by absorbing or releasing specific substances to inhibit microbial growth, reduce chemical reactions and extend product shelf life. These substances change the condition of the packaged food to improve food safety or sensory properties, while maintaining the quality of the packaged food.

Modified Atmosphere Packaging

This packaging modified the composition of gas inside a package by lowering the amount of Oxygen level (1-5 %) and increasing the amount of Carbon dioxide (2-15 %) in order to extend shelf-life and improves product quality. So, it can be considered as an active packaging.

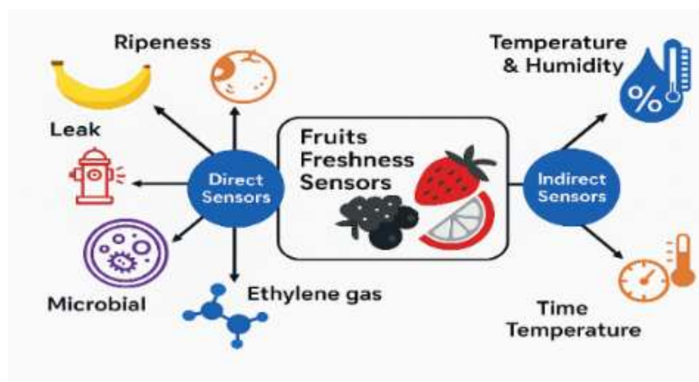
Active packaging includes

- **O_2 Scavengers:** Substances used to remove or absorb residual oxygen from the packaging environment. Ex: Ferrous and Ferric oxide, Ascorbic acid
- **CO_2 absorbers /Emitters:** These remove excess CO_2 or release CO_2 into the package to create a controlled atmosphere to inhibits microbial growth anaerobic fermentation. Ex: Hydrated lime, activated charcoal magnesium oxide.
- **Ethylene absorbers/scrubber:** Compounds that can be used for ethylene absorption within polymeric film packages. Ex: Potassium permanganate ($KMnO_4$) absorbed on celite, vermiculite, silica gel or alumina pellets. Squalene and phenyl methyl silicon can also be held in small sachets within the packages or impregnated in the wrappers or into porous materials like vermiculite.
- **Anti-oxidants:** BHA – Butylated Hydroxyanisole, BHT – Butylated Hydroxytoluene, Ascorbic acid.
- **Flavour/odour absorbers:** Activated carbon, Zeolites, Silica gel with odour-binding agents and Cyclodextrins
- **Moisture absorbers:** Silica gel, Calcium chloride, Clay minerals (e.g., bentonite) and Starch-based desiccants
- **Anti-microbial films:** Made from chitosan, silver based nano particles, essential oils
- **Preservative releasers:** Potassium sorbate, sodium benzoate, Nisin

2. Intelligent packaging

Intelligent packaging systems monitor the condition of packaged foods and provide information about their quality during storage and transportation. These systems use sensors and indicators that detect specific molecules and correlate them with parameters such as freshness, ripeness, leakage, microbial contamination and gases emitted by the produce. Thus, intelligent packaging allows for the use of **real-time monitoring** until the product is delivered to the customer.

Different sensors may be used depending on the type of product being monitored,



Direct freshness sensor: Detects a particular substance directly from the produce as an indicator for fruit/vegetable freshness like ripeness, spoilage, microbial etc.

Spoilage: Can be detected with the help of pH sensor which undergoes colour changes in acid and base. When a fruit spoils, it releases different types of volatile organic compounds that can be detected with pH sensors.

Ripeness: The sensor reacts with the aromas emitted by ripening process. The sensor becomes red (Juicy) and changes to orange (firm) and then finally to yellow (crisp) with increasing ripeness

Indirect freshness sensor: Indirect detection means checking outside conditions like time and temperature to check if the produce is still fresh, without directly sensing the produce itself.

i)**Humidity indicators:** Humidity indicator cards are small labels or strips placed inside packaging that change colour based on the moisture level (humidity).

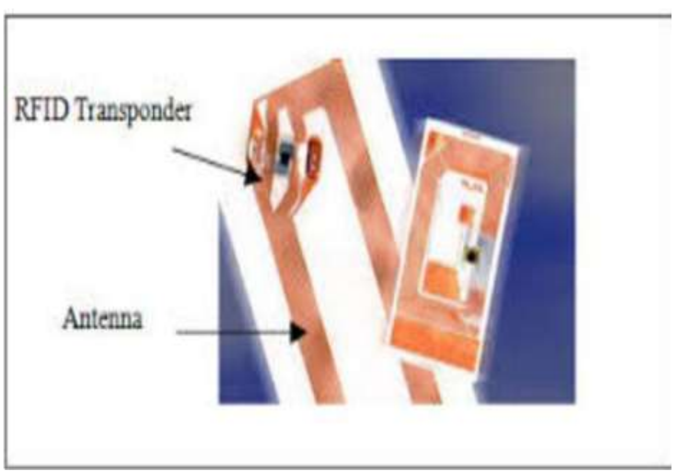
The card has special chemical dots which shows humidity increases, the colour of the dot changes if it shows blue, safe and low humidity and if the card shows pink, high humidity and risk.

ii) **Time-temperature indicators:** TTIs are smart labels that show a visual colour change when the product is exposed to temperatures beyond the safe limit for too long.

- Fresh-check: chemical indicator which check freshness by change visual colour change
- Time strip: Some Time–Temperature Indicators (TTIs) use a special-coloured dye (like blue colour) that is inside a small chamber. When the temperature stays normal, the dye stays in one place no colour change. But when the temperature becomes higher than safe, the dye melts (like butter melts when it gets hot). After melting, it moves through a sponge-like membrane (called a porous membrane). As it spreads, can see a colour line or spot grow this shows that the product has been exposed to too much heat.
- Monitor mark: A blue-coloured oily substance melts at high temperature and spreads through a strip, this spreading shows how long the produce was exposed to unsafe heat.
- Check point: An enzyme-based TTI that changes its colour due to enzymatic reaction means if it shows pink don't use it symbolizes.

iii) RFID tags: RFID-based sensor system. Intelligent packaging can also make use of Radio Frequency Identification Device (RFID) technology to identify and track the product quality during storage and transport in containers/ package.

RFID utilize radio waves and possess tag and bar code for communicate data to a network. When scanned, the RFID tag relays information about the package through the antenna to the reader, which has a receiver that transforms the radio waves emitted by the tag into the appropriate data format.



RFID tags

Bar codes

Thermochromic inks

Thermochromic inks are temperature- sensitive**.** The inks will change color at specific temperature and if appropriate colors are chosen, hidden messages such as "drinks now" or "too hot" become visible**.** Thermochromic technology for beverages first became popular with wine labeling and has been adopted mainly for special occasions and promotions.

3. Biodegradable Packaging Materials: Biodegradable packaging is made from natural substances like polysaccharides, proteins, phospholipids or natural nanoparticles derived from living organisms. These materials break down safely in the environment.

Biopolymers from Natural Sources

- Starch-Based Films: Cassava, Corn and potato starch
- Cellulose-Based Materials: Plant based cellulose
- Chitosan: Obtained from shrimp/crab cells
- Protein-Based Films: Milk protein and soy protein

Bioplastics (Biodegradable Polymers)

- PLA (Polylactic Acid): Cassava and corn starch
- PHA (Polyhydroxyalkanoates): Obtained from bacterial fermentation of sugars/oils.
- Biodegradable films used to wrap or line packaging boxes to reduce moisture loss and microbial spoilage.

PLA trays used for fruits

Chitosan-coated wraps

4. Nano technology: Nanotechnology or nano science uses materials and structures in the nano scale range, (usually 100 nm or 10^{-9} m). Nano technology in packaging: Improves strength and barrier, acts anti-microbial film, maintains the freshness and can incorporated with active and intelligent packaging. It includes,

Nano emulsion: Acts as carrier of active agents can deliver antimicrobial, antioxidant or flavor compounds into packaging films or coatings.

Nano cellulose: Type of nanomaterial derived from cellulose, the main structural component of plant cell walls. It consists of ultra-fine cellulose fibres that have dimensions in the nanometre scale.

Synthetic nano particles: Zinc Oxide and Titanium Oxide

Natural based nano particles: Clay nano particles, Chitosan, Strach and Lignin based nano particles

e-nose and e-tongue

The electronic nose and electronic tongue are functionally in similar ways as in human sense smell and taste. The smell of volatile and taste of non-volatile component actually gives information about quality and shelf-life of produce.

Near Field Communication (NFC)

NFC technology is included in packaging in the form of a small chip. This chip is a wireless link that can be activated by another chip, such as smartphone (Bluetooth). Tiny amounts of data are then transferred between the two devices, giving information of the product with the special NFC chip.

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