Recent Trends in Packaging of Dairy and Food Products

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Packaging is an indispensible vehicle to deliver products to consumers. The definition of packaging says that it is a co-ordinated system of enclosing food to protect it from tampering or contamination from physical, chemical and biological sources. Now a days consumer requires food that are fresh, mildly preserved, convenient and ready to serve. Per capita consumption of packaging material in India is 4.3kg/person/annum and still to be increased. In response to changing consumer lifestyles, large retail groups and food service industries have introduced highly competitive mix of marketing & trading strategies which depends on quality of packaging material and technology employed (Brody *et al*., 2008). Various methodologies of packaging technology for food have developed over the years. New concepts of active packaging, intelligent packaging and nanotechnology offers innovative solutions which plays an important role for improving or monitoring food quality & safety and extending shelf-life (Dobrucka and Cierpiszewski, 2014).

Driving forces for innovation in food packaging technology

Despite the best of barriers, processing technologies and controls, foods are susceptible to biochemical and other forms of deterioration and thus there is need for appropriate packaging technology. Innovation in food packaging material and packaging technology is governed by increase in consumer demand for minimally processed foods, change in retail and distribution practices, new consumer product logistics, new distribution trends (such as internet shopping), automatic handling systems at distribution centers (milk ATMs) and stringent requirements regarding consumer health and safety (Suppakul *et al*., 2003). All of these lead to development of newer packaging technologies such as modified atmospheric packaging, active packaging, intelligent packaging and recently nanopackaging.

Controlled and modified atmosphere packaging

Modified atmosphere packaging (MAP) is the replacement of air in a pack with a single gas or mixture of gases (mainly CO_2, N_2 and O_2) whereas controlled atmosphere storage refers to the constant monitoring and adjustment of gas levels within gas tight stores or containers. It provides an optimum atmosphere for increasing the storage length and quality of food. The MAP technique has proven to be useful in prolonging the shelf life of cheese samples in terms of microbiological and sensorial aspects. Shelf life of ready-to-serve pizza increased up to 45 days by MAP, compared to conventional air pack (15 days) (Preeti *et al*., 2011). Most of controlled atmosphere storage techniques are suitable for bulk storage, but usually not for retail units (Ooraikul and Stiles, 1991).

Active packaging

Active packaging is an innovative packaging technology that incorporate certain additives into packaging film or within packaging containers by which package, product, and environment interact to prolong shelf life or enhance safety or sensory properties as well as maintain the quality of the food product (Priyanka and Anita, 2014). Ahvenainen (2003) has given a broad classification of active packaging techniques (Table 1).

Table 1 - Active packaging techniques

Absorbing System	Releasing System	Other System
Oxygen absorbers Carbon dioxide absorbers Ethylene absorbers Humidity absorbers Absorbers of off flavours Lactose remover Cholesterol remover	Carbon dioxide emitters Ethanol emitters Antimicrobial releasers Antioxidant releasers	Self-heating aluminum or steel cans and containers Self-cooling aluminum or steel cans and containers

Oxygen scavenger (absorber)

Oxygen scavenger removes oxygen from inside of package. Materials such as iron incorporated into package structures that chemically combine and effectively remove oxygen from the inner package environment. The system is based on the oxidation of iron and ferrous salts to form stable oxide (de Abreu *et al.*, 2012). One gram of an iron will react with 300 cc of O_2 (Labuza, 1987). Various other materials can also be used as oxygen scavengers like sulfites, boron, photosensitive dyes and enzymes. Classification of oxygen absorber depends upon activation mechanism (auto activated, water activated and UV activated), scavenger form (sachet, label and extrudable component) and reaction speed (fast, medium and slow effect). Commercially available oxygen scavenger with trade name are Ageless, Fresilizer, Oxyguard, $Zero_2$, Vitalon, PureSeal, Bioka and Sanso-cut are available (in different form of oxygen scavenger and different active substances) (Mohan *et al.*, 2010). Probiotic yoghurt added with glucose oxidase maintain low levels of dissolved O_2 and cell viability of *B. longum* and *L. acidophilus* up to 21st day of storage at refrigerated temperature (Cruz *et al.*, 2012). Study on UHT milk packaged with oxygen scavenging film shown to reduction in dissolved oxygen content (23% -28%) and stale flavor volatiles during storage (Perkins *et al.*, 2007).

CO_2 scavenger

The CO_2 scavenging sachet absorb the occluded CO_2 which otherwise cause the package to burst if not removed during storage (Dobrucka and Cierpiszewski, 2014). Carbon dioxide absorbers contain material such as calcium hydroxide, sodium hydroxide, potassium hydroxide, calcium oxide and silica gel. The mechanism is as given below:

$CaO + H_2O \rightarrow Ca(OH)_2$

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

It has applications in coffee, battered goods and cheese (Kerry *et al.*, 2006).

Ethylene absorber

Ethylene is a growth stimulating hormone that accelerates ripening and reduces the shelf life of fruits and vegetables, thus control of ethylene plays an important role in prolonging the postharvest life of many types of fresh produce during storage. Ethylene scavengers are useful for preserving ethylene sensitive fruits and vegetables such as apples, bananas, mangoes, tomatoes, onions and carrots. Potassium permanganate can be used as Ethylene absorber which oxidizes ethylene to carbon dioxide and water. Use of Activated carbon for ethylene adsorption and subsequent breakdown by metal catalyst (pelladium) can also be done. Inclusion of finely dispersed material such as zeolite can also absorb ethylene in their fine pores and thus used as a ethylene absorbers (Terry *et al.*, 2007). Active packaging using $KMnO_4$ as ethylene absorber for banana extend the shelf life to 36 days at 13 ± 1°C (Chauhan *et al.*, 2006).

Moisture absorber

In moisture sensitive foods, excess moisture in packages can have detrimental effects like caking in powdered products, softening of crispy products (crackers) and moistening of hygroscopic products (sweets and candy) (Brody *et al.*, 2008). Silica gel, molecular sieves, natural clay, calcium oxide, calcium chloride and modified starch can act as moisture absorber (Suppakul *et al.*, 2003). Placing humectants between two layers of a plastic film which is highly permeable to water vapour can be done to control excess water. Controlling relative humidity (RH) using deliquescent salts (such as $CaCl_2$, $MgCl_2$) in packaging materials can regulate moisture (Mohan *et al*., 2010).

Release or absorption of flavours and odours

Undesirable odours and flavours are produced as the food material is broken down. Inclusion of cellulose triacetate, acetylated paper, citric acid, ferrous salt, activated carbon, clays and zeolites in to packaging material absorbs off flavours and odours (Almenar *et al.*, 2009). They are also incorporated to improve the organoleptic quality of the product. Activated carbon sachet when placed in package containing tomatoes it showed slowed ripening changes and improved sensory attributes (Bailen *et al*., 2006).

Lactose and cholesterol removal

Beta-galactosidase (lactase) can be covalently attached to surface-functionalized low-density polyethylene films which act as active packaging materials. It is used for people suffering from lactose intolerance and thus used in milk and other dairy products (Goddard *et al*., 2007). Immobilized cholesterol reductase can be incorporate in to the packaging material to reduce cholesterol and (Ahvenainen, 2003).

Antimicrobial releasing system

Antimicrobial packaging is done to control or even prevent the growth of undesired or spoilage microorganisms by releasing antimicrobial substances. Practices like adding a sachet containing antimicrobial substance into the package, dispersing bioactive agents in the packaging film, coating bioactive agents on the surface of the packaging material comes under this system. It works by extending the lag phase and reducing the growth phase of microorganisms. Class of antimicrobial compounds includes acid anhydride, antibiotic, bacteriocin, organic acid, polysaccharide etc (Han, 2000). Chitosan coating films have been tested against *Pseudomonas* in emmental cheese showed reduction by more than 2 log units and thus improvement in storage life can be possible. Aantimicrobial materials with trade name are AgION™ (AgION Technologies LLC, USA), MicroFree™ (DuPont, USA), Sanitized® (Sanitized AG / Clariant, Switzerland), Zeomic® (Shinanen New Ceramics Co., Japan), MicroGard™ (Rhone-Poulenc,USA) are commercially available (Coma, 2008).

Antioxidant release

Antioxidant compounds scavenge radicals by inhibiting initiation and breaking chain propagation or suppressing formation of free radicals by binding to the metal ions, reducing hydrogen peroxide, and quenching superoxide and singlet oxygen. Compounds such as herbs and aromatic plants, natural vitamins (vitamin C and vitamin E) and polyphenol are used for this purpose (Murthy *et al*., 2002). BHA and BHT can also be incorporated into polyolefin films for Dry Products (Brody, 2001). Whole milk powder with multilayer active packaging film containing α-tocopherol showed delayed lipid oxidation (Restrepo *et al*., 2009). Enzymatic browning of apple can be reduced by incorporation of anti-oxidant agents (cysteine and sulphite) in packaging film (de Oliveira *et al*., 2008).

Carbon dioxide emitter

In certain food products (fish and shellfish) high CO_2 levels (10-80%) are helps in reducing microbial growth and extending shelf life (Kerry *et al*., 2006). Such systems are based on either ferrous carbonate or a mixture of ascorbic acid and sodium bicarbonate (Rooney, 1995). Commercially available CO_2 emitters are Ageless and FreshPax® by Mitsubishi Gas Chemical Co., Japan (de Abreu *et al*., 2012).

Ethanol emitter

Ethanol denatures the proteins of molds and yeasts at high concentration and it exhibits antimicrobial effects even at low levels. Ethanol vapor also exert an antistaling effect in addition to its antimold properties. A sachet called Ethicap® generates ethanol vapor and can be used for cakes and breads (Arvanitoyannis and Oikonomou, 2012). Shelf life of sliced wheat bread kept at 20°C increased up to 24 days with ethanol emitter (Latou *et al.*, 2010).

Self heating and self cooling

Self heating employs calcium or magnesium oxide and water to generate an exothermic reaction. When the bottom of can is pushed the salt reacts with water and heat is produced during the exothermic reaction that heats the product. It has been used for plastic coffee cans, military rations, and on-the-go meal platters. Self cooling involves the evaporation of an external compound that removes heat from contents To cool the drink the lower part is twisted, breaking the seal, leading to expantion of liquid and its evaporation which reduces the temperature of beverage to 16°C (Brody *et al*., 2008).

Edible coating

Edible coatings are consumable films which provide supporting structures and protective layers to food. These films and coatings guarantee the fresh appearance, firmness and shine, thus adding value to the product (Lin and Zhao, 2007). Various substances suitable for the development of edible coatings are hydrocolloids based on proteins of animal or plant sources (e.g. whey, soy, corn, legumes) or polysaccharides (e.g. cellulose derivates, alginates or starches), lipids (e.g. waxes, shellac, fatty acids) or even synthetic polymers (e.g. polyvinyl acetate) (Cargi *et al*., 2004). It can be used to enhance the nutritional value of fruits and vegetables by carrying basic nutrients that lack or are present in low amounts. Edible coating as carriers of antimicrobial compounds is another potential alternative to enhance the safety of fresh-cut produce. Active coating of sodium alginate with MAP (50% CO_2 and 50% N_2) is done to prevent excessive dehydration from the mozzarella cheese surface and to increase shelf life up to 160 days at 4°C (Mastromatteo *et al.*, 2014).

Intelligent packaging

Intelligent packaging systems give information on product quality directly (freshness indicators), about package and its headspace gases (leak indicators), and the storage conditions of the package (time temperature indicator) (Arvanitoyannis and Oikonomou, 2012). Intelligent packaging could be defined as a packaging system that is capable of carrying out intelligent functions (sensing, detecting, tracing, recording and communicating) to facilitate decision making to extend shelf life, improve quality, enhance safety, provide information and warn about possible problems (Otles and Yalcin, 2008).

Time temperature indicators (TTIs)

Product safety and quality is affected by variation in temperature and thus its monitoring is needed during storage. TTIs are devices that show an irreversible change in a physical characteristic, usually color or shape, in response to change in preset temperature (Pavelkova, 2013). They continuously monitor, record and indicate the overall influence of temperature history on the product. The response is made to chemical, enzymatic or microbiological changes (Taoukis, 2008). Depending upon response mechanism they can be available as partial history and full history indicator. Commercially available TTIs are MonitorMark™ by 3M™ (diffusion based indicator label), Timestrip® by Timestrip (monitor elapsed time on perishable products), Fresh-Check® by LifeLines (polymer based), Checkpoint® by Vitsab (based on enzymatic system).

Radio frequency identification tags

Radio frequency identification (RFID) is a system that uses radio waves to track items wirelessly and give information regarding quality of product. RFID makes use of tags or transponders (data carriers), readers (receivers), and computer systems (software, hardware, networking, and database) (Brody *et al.*, 2008).

Oxygen indicator

These indicators indicate rise or fall in oxygen level based on colour change as a result of a chemical or enzymatic reaction (Dobrucka, 2013). They are of three types

1) Luminescence-based oxygen indicators

2) Colorimetric indicators based on oxygen-binding Complexes

3) Colorimetric redox dye (such as methylene blue) based indicators

Freshness indicator

It give indication of the deterioration or loss of freshness of packaged goods by volatile metabolites, such as diacetyl, amines, carbon dioxide, ammonia and hydrogen sulfide. Indicators based on color changes due to changes in pH are of great potential use as indicators (Nopwinyuwong *et al*., 2010). Freshness and fermentation in *kimchi* (fermented vegetable foods in korea) can be monitored by using printing ink consisting of bromocresol purple or methyl red. Fermentation is assessed by change in titratable acidity by change in colour of indicator (Hong, 2000).

Bio Sensor

They are compact analytical devices that detect, record and transmit information pertaining to biological reactions. It consist of bioreceptors (such as enzymes, antigens, microbes, hormones and nucleic acids) and transducers (electrochemical, optical, calorimetric). There are two biosensor systems commercially available: (1) Toxin Guard by Toxin Alert, Canada (antibody based and capable of detecting particular pathogen), (2) Food Sentinel System (based on immunological reactions and detects contamination) by SIRA Technologies, California, USA (Yam *et al*., 2005).

Nanotechnology

Nanotechnology is defined as 'control or manipulation of matter at the atomic, molecular, or macromolecular level, which affects functional behavior.' Nanocomposites are main and major invention of nanotechnology in which nanomaterials were used to improve the barrier properties of plastic wrapping for foods and dairy products. Detection of chemicals, pathogens, and toxins in foods can also be done by nanosensors. Nanovesicles have been developed to simultaneously detect *E. coli* 0157:H7, *Salmonella* spp., and *Listeria monocytogenes*. Nanocoating, which is an aqueous-based nanocomposite barrier coating, that provides an oxygen barrier with a 1–2 micron coating for food packaging use (Brody *et al.*, 2008).

Eco-friendly packaging

Eco-friendly packaging can play a key role in food waste avoidance to protect human health, environment and in preserving natural resources. The ideal packaging material should not possess any environmental issues and should have recycling potential. Research in the production of biodegradable packaging material lead to development of eco-friendly packaging materials. Essential qualities for eco friendly material includes reduce, recycle, renew, reuse and repurpose. They can be material derived from natural resources like starches (such as cellulose, chitin), proteins (such as gluten, soy protein, whey protein) etc. Polylactic acid plastic (PLA) biodegradable thermoplastic derived from lactic acid is currently entering the marketplace. New eco-friendly *AJI-NO-MOTO®* jar made made from sugarcane is also available (Kumar and Gupta, 2012).

Conclusion

The concept of 'package' as a simple instrument for the marketing of food is changing to match the needs of consumers and the food industry. New types of active packaging systems (oxygen scavengers, ethylene scavengers, liquid and moisture absorbers, flavor and odor absorbers or releasers, antimicrobials, etc.) and intelligent packaging systems (time-temperature indicators, gas detectors, and freshness and/or ripening indicators) are developed to cater to special needs. Recognition of the benefits of these technologies by the food industry and increased consumer acceptance is necessary for commercial realization of these packaging technologies. Eco-friendly packaging materials are costlier but offer alternative for management of environmental issues. Coming days are sure to witness new trends & innovation in packaging technology.

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