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Food packaging technology: Functions, materials and intelligent innovations

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Abstract
Food packaging is important in today's society as it surrounds, enhances and protects the goods we buy, from the moment they are processed and manufactured through storage and retailing to the final consumer. With the advancement of science, various packaging materials came into existence. With the growing concern for environment in recent times, factors such as eco-friendliness and chemical composition started playing equally important role in the selection of packaging materials. The continued quest for innovation in food and beverage packaging is mostly driven by consumer needs and demands influenced by changing global trends, such as increased life expectancy, fewer organisations investing in food production and distribution. This paper focuses on the functions, materials and intelligent innovations in food packaging technology.

Keywords: Food packaging, packaging functions, intelligent packaging

Introduction
Packaging is essential and pervasive in today's society as it surrounds, enhances and protects the goods we buy, from the moment they are processed and manufactured through storage and retailing to the final consumer (Robertson, 2009) [12]. Packaging plays a vital role in the conservation, preservation and transportation of food products. Packaged products create confidence in the consumer with respect to quality, quantity, safety and protection.

Packaging may be defined in terms of its protective role as 'means of achieving safe delivery of products in sound condition to the final user at a minimum cost' (Fellows, 2005) [7]. Cateora and Graham (2002) [4] described packaging as an integral part of the 'product' component of the 4 P's of marketing: product, price, place and promotion. Packaging has been described as a tool that protects and contains goods with the aim of minimizing the environmental impact on our consumption (Alam *et. al*, 2003; Alam, 2006) [2, 1].

Food packaging development started with human kind's earliest beginnings. Early forms ranged from gourds to sea shells to animal skins. Later, pottery, cloth and wooden containers were introduced. Food packaging has evolved from simply a container to hold food to something today that can play an active role in food quality. Many packages are still simply containers, but they have properties that have been developed to protect the food like barriers to oxygen, moisture, and flavours. Packaging has allowed access to many foods year-round that otherwise could not be preserved (Risch, 2009) [11]. Modern food packaging is believed to have begun in the 19th Century with the invention of canning by Nicholas Appert (Brody *et al.*, 2008) [3].

The sophistication in marketing strategy and the demand for ready-to-consume and ready-to-eat packaged foods which are convenient is constantly rising. Utilizing modern technology, today's society has created an overwhelming number of new packages containing a multitude of food production. The food industry utilizes four basic packaging materials – metal, plant matter (paper and wood), glass and plastic.

Functions of packaging
a) Containment – to hold the contents and keep them secure until they are used
b) Protection – against mechanical and environmental hazards encountered during distribution and use

c) Preservation – prevention or inhibition of chemical changes, biochemical changes and microbiological spoilage
d) Communication – to identify the contents and assist in selling the product. Any special handling or storage instructions and method of opening and/or using the contents is also mentioned on packages
e) Machinability – to have good performance on production lines for high speed filling, closing and collating, without too many stoppages
f) Convenience – throughout the production, storage and distribution system, including easy opening, dispensing and/or after-use retail containers for consumers
g) Economy – for example, efficiency in distribution, production and storage
h) Environmental responsibility – in manufacture, use, reuse, or recycling and final disposal (Coles, 2003; Fellows, 2005) [5, 7].

Packaging materials

With the advancement of science, various packaging materials came into existence. In the past, their selection was governed by two factors wiz performance and cost. With the growing concern for environment in recent times, other factors such as eco-friendliness and chemical composition started playing equally important role in the selection of packaging materials.

Package design and construction play a significant role in determining the shelf life of a food product. The right selection of packaging materials and technologies maintains product quality and freshness during distribution and storage. Materials that have traditionally been used in food packaging include glass, metals (aluminium, foils and laminates, tinplate, and tin-free steel), paper and paperboards, and plastics. Moreover, a wider variety of plastics have been introduced in both rigid and flexible forms. Today's food packages often combine several materials to exploit each material's functional or aesthetic properties (Marsh and Bugusu, 2007) [10].

During the last 50 years, flexible packaging materials and rigid plastic containers have made inroads into packaging of processed foods replacing conventional glass and metallic containers. Flexible packages are not in general hermetic in nature, although there are excellent barriers against microorganisms and dirt. Flexible material such as paper, plastic film and thin metal have different properties for water vapour transmission, oxygen permeability, light transmission, burst strength, etc. therefore multilayer or laminates of these materials which combine the best features of each are used (Khader, 2001) [9]. The merits and demerits of some packaging material with special emphasis have been discussed here under.

Polyolefins: Polyolefin is a collective term for polyethylene and polypropylene, the two most widely used plastics in food packaging, and other less popular olefin polymers. Polyethylene and polypropylene both possess a successful combination of properties, including flexibility, strength, lightness, stability, moisture and chemical resistance, and easy process-ability, and are well suited for recycling and reuse.

Polyethylene: Polyethylene is a crystalline polymer with density varying between 0.915 and 0.970 g/ ml. Ethylene, a reactive olefin monomer is the basic food stock for LDPE and HDPE. Permeability to water vapour and gas decreases as density goes up. All polyethylene films are excellent water barriers and fairly poor barriers to N_2, O_2 and CO_2. At room temperature, polyethylene is a fairly soft and flexible material. It maintains its flexibility well under cold conditions, so is applicable in frozen food packaging. Polyethylenes are readily heat sealable.

LDPE (low density polyethylene) is heat sealable, inert, odour free and shrinks when heated. It is a good moisture barrier but has relatively high gas permeability, sensitivity to oils and poor odour resistance. It is less expensive than most films and is therefore widely used.

HDPE (high density polyethylene) is stronger, thicker, less flexible and more brittle than LDPE and has low permeability to gases and moisture. It has higher softening temperature (121˚C) and can therefore be heat sterilized. Sacks made from 0.03 – 0.15 mm HDPE have high tear strength, penetrating resistance and seal strength. They are proof and chemically resistant and are used instead of paper sacks.

Polypropylene (PP): Polypropylene or Oriented Polypropylene (OPP) is a clear glossy film with good optical properties, high tensile strength and puncture resistance. It has low permeability to moisture, gases and odours, which is not affected by changes in humidity. It is thermoplastic thus stretches, although, less than polythene.

Aluminium packaging: Commonly used to make cans, foil, and laminated paper or plastic packaging, aluminium is a lightweight, silvery white metal derived from bauxite ore, where it exists in combination with oxygen as alumina. Magnesium and manganese are often added to aluminium to improve its strength properties. Unlike many metals, aluminium is highly resistant to most forms of corrosion; its natural coating of aluminium oxide provides a highly effective barrier to the effects of air, temperature, moisture, and chemical attack. Aluminium is also used extensively for the preparation of food and beverages as it conducts heat extremely well, making it very energy efficient for preparing and serving both hot and cold food. Aluminium packages are secure, temper-proof, hygienic, easy to open and recyclable. It is easy to sterilize for food and medical applications.

Aluminium foil: Aluminium can be rolled into ultra-thin foils of thickness less than 0.0006 inch. Aluminium foil is an excellent barrier to liquids, UV light, water vapour, gases, odours and bacteria. Below the thickness of 0.0015 inch, the foil may sometimes contain imperfections created during rolling called pinholes. These imperfections increase as the foil gets thinner. The mechanism of moisture or gas transmission is through orifices, the pinholes. Lamination of foil to other substrate, particularly extrusions lamination with polythene seals any pinholes present, thus reducing the permeability.

Laminates: Since in most cases, it is not possible to provide the ultimate package requirements using only one of the components, a combination of films, foils, papers, resins and coatings are constructed depending upon the ingredients to be packaged. The combination of materials is termed as lamination. There are two general processes for lamination–adhesive lamination and extrusion lamination. Lamination of two or more films improves the appearance, barrier properties and mechanical strength of a package. A less expensive alternative to laminated packaging is metalized film. Metalized films are plastics containing a thin layer of aluminium metal. These films have improved barrier

properties to moisture, oils, air, and odours, and the highly reflective surface of the aluminium is attractive to consumers.
Besides packaging materials, packaging techniques/ methods also plays significant role in extending shelf life and maintaining the quality of the product. Vacuum packaging and modified atmospheric packaging (filling with various inert gases) are techniques to improve the shelf-life of perishable foods. Shrink wrap packaging is a system where heat shrinkable thermoplastic film is wrapped around an article or a group of articles and made to shrink around it by application of heat to achieve a skin light package.

Heat sealing: Heat sealing is the process of enclosing an object in a thin clear thermo-plastic sheet, which is bonded/ sealed by heat and pressure to form a closure against air or tampering. A heat sealer machine is used to seal products, packaging, and other thermo-plastic materials using heat. This is done with uniform thermo-plastic monolayers or with materials having several layers, at least one being thermo-plastic. A hot bar sealers has heated tooling kept at a constant temperature. There are one or two heated bars which contact the material to heat the interface and form a bond. The bars have various configurations and can be covered with a release layer (Anon., 2011) [13].

Vacuum packaging: Vacuum packaging is a method of packaging that removes atmospheric air from a flexible impermeable package prior to sealing, thus providing anaerobic conditions to the product. It can involve both rigid and flexible types of packaging. The intent is usually to remove oxygen from the container to extend the shelf life of foods and, with flexible package forms, to reduce the volume of the contents and package (Garg, 2003; Saroka, 2008) [15, 16].
Vacuum packaging is recommended for increasing shelf life of perishable items where presence of oxygen is detrimental to the longevity of product freshness. Vacuum packaging reduces product shrinkage as there is no moisture loss or evaporation in a sealed vacuum bag. Garg (2000) [14] stated that vacuum packaged products have better flavour retention. Vacuum packaging techniques are useful for enhancing shelf life of packaged products, such as dates, cashew, cheese, vegetables, meat, poultry, fish, dairy products, and dry products, such as biscuits, chips, *khakhra*, etc.
The sustainability of using vacuum sealing techniques for convenience foods has been described by Triwedi, (2008) [17] where the researcher reported lower moisture pick up by products during storage in vacuum sealed HDPE bags was due to vacuumization. It also showed its superiority in maintaining the lower moisture content, a major shelf life defining factor. It was concluded that moisture content of the processed QCC products increased with the advancement of storage time, however the magnitude of rise was found to be higher in ordinary heat sealed samples than those observed for vacuum sealed ones, which provides excellent barrier against water vapour transmission.

Smart packaging – active and intelligent packaging
Smart packaging can roughly be divided into two categories: active packaging, that provides functionality such as moisture and oxygen control, and intelligent packaging, that can communicate product changes and other information.

Active packaging: demand is being driven by the desire to keep food fresher for longer, to reduce food waste and to promote more convenient packaging for consumers. Although it is more mature and has slower growth predictions compared to intelligent packaging, there are substantial development opportunities for active packaging technologies in niche markets. Active packaging is a group of technologies in which the package is involved with the food products or interacts with the internal atmosphere to extend the shelf life, provides physical barrier to external spoilage, contamination and physical abuse in storage and distribution. Active package contributes to product development, controls maturation and ripening, helps in achieving the proper colour development in meats. For fresh and minimally processed foods, it provides moisture or oxygen barrier to control loss of moisture and enzymatic oxidative browning in fresh cut fruits and vegetables, and to provide controlled permeability rates matched to respiration rate of the fruit.

Intelligent packaging: on the other hand, is at a developmental stage of the product life cycle. Intelligent packaging is a dynamic and potentially high-growth market with developments in printed electronics, microsensors, authentication platforms, and the Internet of Things (IoT) driving the adoption of new technologies.
Intelligent Packaging is packaging which senses and informs various aspects like safety and disposal instructions, e.g. Cox Technologies has developed a colour indicating tag that is attached as a small adhesive label to the outside of packaging, which monitors the freshness of sea food products. A barb on the back side of the tag penetrates the packaging film and allows the passage of volatile amines, generated by spoilage of the sea food which will progressively turn the fresh tag colour into pink as the sea food ages (John P.J., 2010) [8]. Self-heating packages for soup and coffee, self-cooling containers for beer and soft drink are some of the other examples.
Intelligent packaging can be defined as packaging systems that are capable of carrying out intelligent functions (such as detecting, sensing, recording, tracing, communicating, and applying scientific logic) to facilitate decision making to extend shelf life, enhance safety, improve quality, provide information and warn about possible problems.

Companies offering commercially available intelligent packaging technologies in 2018: based on four criteria; barcodes/QR codes; sensors/printed electronics; Augmented Reality (AR); smart indicators/pigments and inks (Eagle J, 2018) [6].

- **Amcor MaXQ:** a digital packaging system featuring barcodes, print and QR codes to grow consumer engagement and loyalty. People can use their smartphones to interact with brands, discover special offers or learn new information. When consumers scan a MaXQ code printed on the product packaging, they can discover product features, nutritional information and whether the product is legitimate. The advantage of this technology for companies and brands, was that the codes establish trust with shoppers and prevent counterfeit products in the supply chain hotspots, since each MaXQ code is unique and comes as a proof of purchase when it is scanned. MaXQ digital system means consumers can directly interact with a brand's consumer care team to gain real-time product feedback, customer satisfaction and other measurable marketing insights. The system also delivers loyalty rewards, promotional and targeted messages to the consumers' smartphones as soon as they scan the code.
- **Everything:** is an Internet of Things (IoT) company

connecting consumer products to the Web and managing real-time data to drive applications and analytics throughout the product lifecycle. EVRYTHNG transforms packaging into intelligent digital identities creating consumer engagement opportunities. Brands can track their products at all stages of the logistics and distribution channel, gain personalized marketing insights and post-purchase service experience for consumers. Customers include Mondelēz, Coca-Cola, Unilever, LVMH and Diageo. It has three products in smart packaging that operate under the IoT platform: Halo, an anti-counterfeit and brand protection platform and analytics for luxury brands and their protection. Amplify, which digitizes products, making them smart, for direct consumer engagement and Activate, a large-scale product management suite that can create product information and identities for supply chain and B2C applications.

- **Scan Trust IoT:** By combining QR and 2D barcodes and an IoT platform, Scan Trust's codes contain an identity verification that cannot be replicated. Authentication is made with a smartphone. The QR codes are directly printed on existing products, packaging, labels, cartons or documents. Its IoT-based program gives supply chain transparency by enabling full control of the logistics and distribution chain and its Scan Trust suite can identify counterfeit spots in the distribution channel. This protects brands supply chain, monitors distributors and prevents inventory duplication.
- **Smart glyph:** works across pharmaceuticals, FMCG, retail logistics, financial services, film/media and gaming. It provides smarter barcodes, smart login and smarter adherence. The Smarter Barcodes are changing the ways of how products and customers will be communicating in the future. It is allowing more interaction between a products' brand and customers. This patented technology, applicable to all barcodes and for all packaging, requires the use of a mobile phone with a camera to facilitate scanning of the barcodes on the products' packaging.
- **Magic Add:** makes the internet of packaging possible by using intelligent back-end technology to manage FMCG products along the entire supply chain. Information about a particular product is updated in the cloud during its lifecycle; meaning it is possible to track the product at any time among the supply chain. The platform uses block chain to update and store code information securely on to the cloud. Companies get notified when and if packages within a shipment get misplaced/lost during the shipping journey. Each product has a machine-readable identity due to its adaptation to multiple coding systems: QR, RFID, NFC, and data matrix. Different information can be presented to different users by the same product identifier.
- **Blippar:** is a technology company that specializes in augmented reality (AR) and the mobile apps that it develops. It allows shoppers to check the quality and origins of their food by scanning an item with the Blippar app. The Blippar app is a basic enabling technology that uses image recognition to activate the specific interactive and digital experience on any mobile phone or tablet device. Blippar has already created various "blipps" for consumer packaged goods companies, such as General Mills, Pepsi and Heinz Ketchup. Customers can track down important information such as: quality certificates; nutritional information; location details and images of farms.
- **Thin film:** is a Norwegian provider of near field communication (NFC) for mobiles featuring label and packaging integration services and CNECT cloud-based software platform. The technology allows customers to tap a particular product with their smartphone and receive personalized content of the product, including brand story, product news, ingredient information, video tutorials and interactive content. Its Open Sense Technology is a dual-ID tag integrated with a sensor that detects the sealed or opened status of a product for personalized content and it allows product authentication, refill fraud protection and pre- and post-sale engagement via a smartphone or tablet. Its NFC Speed Tap Tags is a single-ID NFC tag that can be integrated into product labels and bottle caps. Tapping the tag with a smartphone enables instant consumer engagement as well as brand protection.
- **Water. IO:** platform allows any package to become smart by connecting it to an Internet of Packaging (IoP) platform that can be accessed through their brand analytics dashboard via an app. Their unique patented technology enables special sensors embedded into any package to retrieve information regarding the product without interfering with original packaging.
- **Timestrip:** is a technology business that designs and manufactures time and temperature indicators for packaging, supply chain and consumer behaviour. Timestrip designs patented low-cost smart indicators that monitor elapsed time and/or temperature changes. The indicators monitor processes in food service, pharmaceutical and consumer products supply chain and logistics to reduce wastage, monitor component lifetimes, deliver quality assurances, improve sales and build brand share. The time and temperature indicators are patented, single-use strips that can be attached directly on a product or device. Each indicator measures a product's shelf life by acting as a visual reminder to replace an expired product. Indicators can range from 30 minutes up to 12 months and can be customized. The technology is protected by two patents: Time indicator and method of manufacturing same and Elapsed time indicator device.
- **Insignia Technologies:** uses patented intelligent pigments and inks that change colour in response to changes in temperature or CO levels. A colour change is observed when exposed to gases or UV light. It offers food fresh indicators and CO indicator pigments that remind users about how long items have been in their fridge and warn when food is past its best via a colour change.

The future of active & intelligent packaging to 2023

It is estimated that both active and intelligent packaging present compelling commercial opportunities for the next five years.

- The increased emphasis on consumer safety and minimising food waste is spurring demand for new technology in modified atmosphere and other active packaging systems.
- The digital revolution and the prospect of greater consumer interaction will help intelligent packaging offer multiple new value-adding options across 2018-2023.
- The Future of Active & Intelligent Packaging to 2023 tracks how value of these packaging components worldwide will rise from $5.68 billion to $7.60 billion at an annual average rate of 5.9% across 2018-2023.

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