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Active Packaging in keeping the food fresh– A Review

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ABSTRACT

The demand for safe and high quality foods, as well as changes in consumer preferences have led to the development of innovative and novel approaches in food packaging technology. One such development is the smart or intelligent food packaging technology.Packaging is an essential component of the food system, assuring the safe handling and delivery of fresh and processed food products from the point of production to the end user. Technological developments in packaging offer new prospects to reduce losses, maintain quality, add value and extend shelf-life of agricultural produce and consequently secure the food system. The objective of this review is to highlight the contributions of packaging in securing the food system by maintaining quality and reducing food losses. It also discusses some of the emerging packaging technologies that have revolutionized the way we handle and package food to meet the increasing consumer demands for consistent supply of high quality, safe and nutritious products.

Key Words: *Packaging, Shelf-life, Food products, Waste.*

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1. INTRODUCTION.

Packaging can be defined as a method to protect the food with the aim of minimizing the environmental impact on it.In the current market scenario, packaging provides the most important first point of contact by which a company presents its products to consumers.The Packaging Institute International (PII) defines packaging as the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions: containment, protection, preservation, communication, utility and performance. If the device or container performs one or more of these functions, it is considered a package.

Smart,active, intelligent and green are terms used to describe innovative packaging technologies developed to prolong the shelf life, enhance the quality and safety of food and protect the environment [1].

Conventional passive packaging systems protect the food products only from external environmental hazards.Smart packaging systems are used to modify and monitor the internal and external food environment and provide multiple barriers to protect food [2]. Maintaining food quality,improving safety and reducing post-harvest wastes are key objectives of a smart packaging food system. High incidence of post-harvest wastes pose a major problem in the food industry and world at large[3]. An estimated 1.3 billion tonnes of food is wasted annually in production, distribution, and homes.Reports from developed countries such as Britain, Sweden and USA have indicated that almost one third of purchased food is wasted at food service institutions and households [4].

In the early days of agriculture, leaves and animal skin were used as packaging materials to carry food over short distances and to secure them for later use [5].In modern food systems, the principle functions of packaging have widened to include containment, protection, communication and convenience [6]. Paine and Paine (1992) noted that “To ensure delivery, the package must at least provide information as to the address of recipient, describe the product and perhaps describe how to handle the package and use theproduct[7]”.

2. PROCESSING & PACKING

Packaging consists of a diverse array of options(fig.2.1) [8]. Processing and packaging includes under its banner five important stages. It is driven by health and hygiene factors, food safety, high quality, fresh tasting, and balanced vitamins and nutrients. Other important aspects of food processing and packaging are toxin removal, marketing and distribution, maintenance of taste, year-round availability and long shelf-life [9]. Processed foods are preserved for a longer time, protected from dust, moisture, and micro-organisms and are odour free [10]. The advent of machineries, robotics and automation technology has driven down the overall cost of processed food versusoriginal food products [11].

Research areas for the food processing and packaging industry would include

(i) Optimization of equipment and utilities; (ii) Food safety and security; (iii) Supply chain waste reduction; (iv) Development of seasonal infrastructure; and (v) Advanced automation and control methods.

The productivity of a typical food processing plant depends on Pre-preparation; Processing and preservation methods; Packaging materials; Systems for material flow; Automation, instrumentation, and control scheme; Degree of smartness in the sensors; Sophistication in the machineries and mechanisms (including application of robotics); Inspection methods; Printing methods; Security identification; Graphic design and digital work flow; Sanitation and sterilization; and Factory-wide execution management strategy including supply-chain management [12].

Figure2.1:Production & Packaging of cookies.

2.1 Smart Packaging

A smart package is a package that provides the consumer with an additional offering beyond the protection, containment, and communication of the enclosed product. Smart packaging falls into oneof four categories – mechanical, chemical, electrical, or electronic [13].

(i) Mechanical applications are the simplest of the four and can be defined as anything that adds a functional mechanism to the package. Most consumers are already familiar with this type of smart packaging, which includes a pour spout in a milk carton or a straw in a juice box.

(ii) Packages that include a chemical component are most often used in food packaging to produce a visibleresult when a chemical change in the product contained in the package reacts with chemicals built into the package itself. This may manifest as a colour change that signals when the package has been breached or when the product has gone bad.

(iii) Electrical packages contain a small paper battery that can produce a small electrical charge. These are used mainly to show that a package has been opened or tampered with or can be used in the production of re-closable packages.

(iv) Electronic packages, the most advanced type of smart packaging, rely on paper-thin circuitry to produce an effect beyond the simple functionality of the package. They can be used to “power electronic displays, send sound, light, or electronic signals, or provide product/supply chain information”.

According to S.Rangarajan [14],smart packaging has seen rapid growth in recent years and looks to be on the rise, due in large part to the proliferation of printed electronics as a viable method for mass-producing cheap,functional electronic products. This will purportedly cut production costs by 99% and as a result the smart packaging industry is expected to grow to “$1.45 billion from $7.5 million in 10 years” as of 2010.

2.2 ActivePackaging

It is categorized into active scavenging systems (absorbers) and active releasing systems (emitters) [15].

Under scavenging packaging system, unwanted compounds such as oxygen, excessive moisture and ethylene which accelerate the spoilage process in foods are removed from the product [16]. For instance, oxygen may cause off- flavours, nutrient loss (through oxidation) and colour changes; hence the usage of oxygen scavengers to maintain quality and extend shelf life of some food products [17]. The moisture content of packed horticultural products should be controlled because high moisture content favours microbial growth [18]. The softening of dry crispy food products such as biscuits and caking of coffee result from unregulated moisture content. Moisture controlling systems are often used to scavenge excess moisture that contributes to product quality loss. Excessmoisture loss might impose lipid peroxidation and desiccation of packed products. It is therefore imperative to have a good understanding of product physiology, structure and composition when designing the packaging as food stability is closely linked to water activity [19].

Active releasing packaging system is another aspect of active packaging and this involves the addition of beneficial agents to the package to preserve the quality of the content. Releasing packaging system favours the addition of compounds such as carbon dioxide, moisture, preservatives and antioxidants into the package(fig. 2.2). Carbon dioxide releasing systems are also used to retard respiration of horticultural crops and subsequently prolong shelf-life [20]. The main objective of active packaging, with both scavenging and releasing systems, is ensuring exceptional food quality and extended shelf-life [21].

Figure 2.2 :Active packaging with oxygen absorber in polyethylene tray packed meat

2.3 Intelligent Packaging

It monitors the condition of packed food or the environment surrounding the food. **"Intelligent packaging"** is an emerging technology that uses the communicationfunction of the package, whereas **"active packaging"** focuses on protection and aims to extend the shelf life to maintain and improve the quality and acceptability of packaged food [22]. Intelligent packaging refers to the use of packaging as an intelligent messenger to monitor the condition and provide quality information of packed foods to the consumers(fig . 2.3) [23]. Indicators such as temperature, microbial growth, product authenticity, and pack integrity are used in intelligent packaging. At the moment, freshness and leakage indicators are commercially available for monitoring food [24].

Figure 2.3:Intelligent packaging with freshness indicator.

3. INTELLIGENT PACKAGING SYSTEM

3.1 Temperature Regulation

A combination of low temperatures and appropriate packaging can be used toextend the shelf life of perishable products [25]. Different products need different storagetemperatures [26]. For example, certain whole tropical fruits are susceptible to chilling injury when exposed totemperatures in the range 0-10°C. Chilling injury causes loss of quality through poor ripening, pitting of theskin and rotting [27].

Some Time–temperature indicators or integrators (TTIs) can also be used. TTIs are defined as simple, cost-effective and user-friendly devices to monitor, record, and cumulatively indicate the overall influence of temperature history on the food product quality from the point of manufacture up to the consumer . Temperature indicators show whether products have been heated above or cooled below a criticaltemperature[28].

Wanihsuksombat et al. (2010),characterized a prototype of a lactic acid- based time temperature indicator for monitoring food product quality. Four lactic acid-based TTIs were made in different substrate concentrations. Colour changes associated with the diffusion of lactic acid were monitored [29]. In the vapor diffusion of lactic acid, an irreversible colour change of a chemical chromatic indicator (from green to red) clearly and progressively occurred due to pH reduction. The temperature dependence of these TTIs kinetics was characterized isothermally in the range of 4–45°C, yielding activation energy (Ea) of, approximately, 50 kJ/mol. Figure 3.1 depicts colour changes of TTI at 4,18and 37°C. Lactic acid is monoprotic, having a hydrogen atom which may dissociate from the parent molecule, forming hydrogen ions (H+) and lactate ions (CH3CH(OH)COO-) with pKa of 3.85 at 25°C [30].

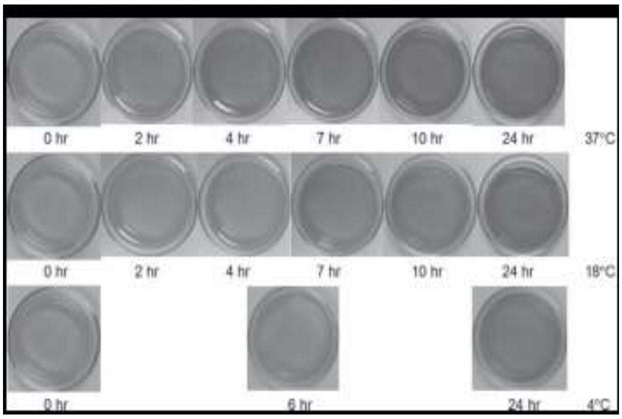

Figure 3.1: Colour changes of a lactic acid-based TTI indicator at different temperaturesexperiment done by Wanihsuksombat et al. in 2010.

3.2Protection From Oxygen

The presence of oxygen in a package can accelerate oxidative reactions that result in food deterioration [31].Oxygen facilitates the growth of aerobicmicrobes and molds. Oxidative reactions result in adverse qualities such as off-odors, off-flavors, undesirable colour changes, and reduced nutritional quality [32].

Therefore, oxygen scavengers are used,which removes oxygen, thereby retarding oxidative reactions, and they come in various forms: sachets in headspace, labels, or direct incorporation into package material and closures [33]. Oxygen scavenging compounds are mostly agents that react with oxygen to reduce its concentration(fig. 3.2). Ferrous oxide is the most commonly used scavenger.Others include ascorbic acid, sulfites, catechol, some nylons, photosensitive dyes, unsaturated hydrocarbons, ligands, and enzymes such as glucose oxidase.

To prevent scavengers from acting prematurely, specialized mechanisms can trigger the scavenging reaction. For example, photosensitive dyes irradiated with ultraviolet light activate oxygen removal. Oxygen scavenging technologies have been successfully used in the meat industry [34].

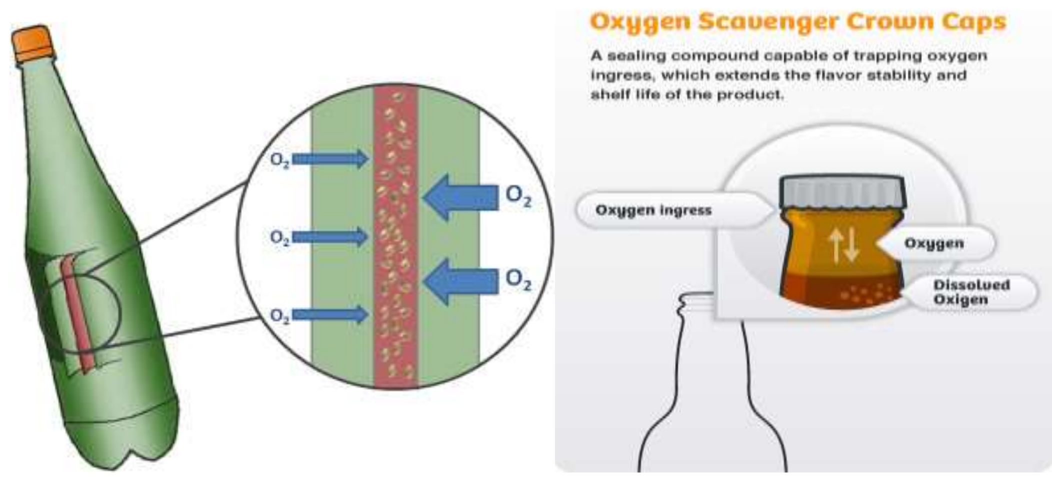

Figure 3.2: Oxygen Scavangers

3.3 Moisture Control Agent

For moisture-sensitive foods, excess moisture in packages can have detrimental results: forexample, caking in powdered products, softening of crispy products such as chips, andmoistening of hygroscopic products such as sweets and candy. Conversely, too much moisture loss from food may result in product desiccation [35].

Moisture control agents help control water activity, thus reducing microbial growth; remove melting water from frozen products and blood or fluids from meat products; prevent condensation from fresh produce; and keep the rate of lipid oxidation in check [36]. Desiccants such as silica gels, natural clays and calcium oxide are used with dry foods while internal humidity controllers are used for high moisture foods (for example, meat, poultry, fruits, and vegetables) (Table 3.1).

Desiccants usually take the form of internal porous sachets or perforated water-vapor barrier, plastic cartridges, etc (fig. 3.3) [37]. Humidity controllers help to maintain an optimum in-package relative humidity (about 85% for cut fruits and vegetables), reduce moisture loss, and retard excess moisture in headspace and interstices where microorganismscan grow. Pure absorbers remove liquid squeezed or leaking from fresh products and can be enhanced by other active additives such as oxygen scavengers, antimicrobials and pH reducers [38].

Figure 3.3: Silica Desiccant

Table 3.1: Moisture levels of different food items.

Food	Moisture level to be maintained
Vegetables	78-92 %
Flours	12-14 %
Dried dates	26-30 %
Dried fruit	15-25 %
Dried mango: - Sugared mango - Natural mango	 7-10 % 12-18 %
Dehydrated foods	2-5 %

3.4 AntimicrobialFood Packaging

The post-processing contamination is one of the major causes of foodborne illness. Antimicrobial packaging is a promising form of active packaging to improve safety and shelf-life of food products [39]. In this, agents may be coated, incorporated, immobilized, or surface modified onto packaging materials (fig. 3.4) [40].Many compounds such as organic acids, bacteriocins, enzymes and polysaccharides have been tried in antimicrobial packaging with varying degree of success [41]. The three basic categories of antimicrobial packaging systems include (i) Incorporation of antimicrobial substances into a sachet connected to the package from which the volatile bioactive substance is released during further storage; (ii) Direct incorporation of antimicrobial agent into the packaging film; (iii) Coating of packaging with a matrix that acts as a carrier for the antimicrobial agent [42].

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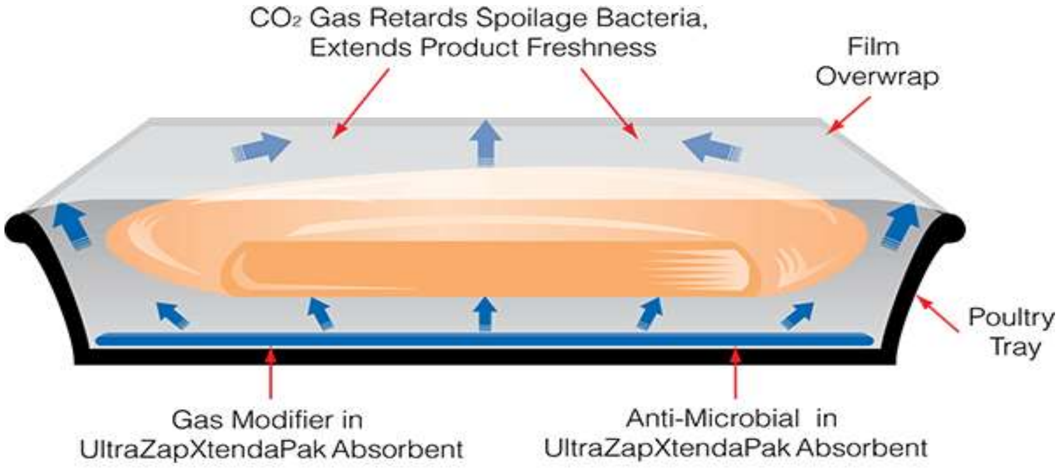

Figure 3.4:Antimicrobial agent used for food preservation.

3.5Heavy Metal Limits

The Heavy Metal limits refer to the sum of concentration levels of cadmium, mercury, lead and hexavalent chromium [43]. The content of the specified heavy metals in packaging or any of its components must not exceed the following limits-

- 600 ppm by weight on or after 30 June 1998
- 250 ppm by weight on or after 30 June 1999
- 100 ppm by weight on or after 30 June 2001 [44]

A packaging component is defined as any part of the packaging that can be separated by hand or by simple mechanical means. An example would be a bottle top [45]. This does not include permanent coatings or pigments which would be regarded as a constituent of the packaging (or of the packaging component) and would thus be part of any calculation, but not required to meet the heavy metal limits independently. As an example, if a steel drum was coated in lead chromate based paint, it would only exceed the limit if the lead chromate was greater than the limit in relation to the mass of the drum and the paint taken together [46]

3.6Nanotechnology in food packaging

Nanotechnology may revolutionize the food industry by providing stronger, high-barrier packagingmaterials, more potent antimicrobial agents, and a host of sensors which can detect trace contaminants, gasses or microbes in packaged foods (fig. 3.5).It enables designers to alter the structure of packaging materials on the molecular scale, in order to give the material the desired properties.By adding nanoparticles, one can achieve packages with more resistance to light and fire, better mechanical and thermal performance, and less gas absorption.

Figure 3.5 :Nanosensors in Packaging

4. ROLE OF PACKAGING IN REDUCING FOOD LOSSES & WASTE

Roughly 30 to 40% of food produced in both developed and developing countries are lost or wasted. The lack of proper post-harvest technologies and cold-chain infrastructure are often cited as the principle factors aggravating food losses and waste in developing countries. The use of cost-effective and resource-efficient packaging technologies can contribute to reducing foodlosses and waste during postharvest handling [47]. Almost one-third of rice grain produce in Asia may be lost due to pests and spoilage related to poor packaging equipment [48].

Several researchers (Table.4.1) have reported the potential of applying appropriate packaging to reduce post-harvest losses and waste in a wide range of products [49].

Table.4.1: Examples of the effects of packaging on food product losses & waste.

Products	**Packaging**	**Effect on quality attributes**
Sweet corn	Cardboard trays (Polyolefin film) versus Cardboard trays (PVC film)	Decay of polyolefin film wrapped cobs was 1.5% compared to 51.4% decay for PCV film
Blueberries	Polylactide containers versus clamshell containers	Berries packed on clamshell containers were unmarketable after 3 days of storage at 10°C unlike Polylactide packed fruit that was still marketable after 18 days of storage
Cabbage	Monooriented polypropylene (OPP) trays versus PVC-PE trays	OPP trays prolonged shelf-life to 10 days unlike PVC-PE packed vegetable with 7 days shelf-life
Tomato	Plastic container versus cartons	Plastic container had 39.8% fruit loss while 80.6% was lost in carton stored fruit after 21 days storage at 10°C
Red pepper	Polyethylene bags versus unpacked	Fruit packed in polyethylene bags had no decay, whereas fruit inside polyethylene bags had 11.7% decay after 14 days at 3°C

5. PACKING OF FOOD CAN BE DONE BY A VAREITY OF WAY

5.1CorrugatedFibreboard (CFB)CFB is the most popular material for rigid transport packaging and it is used for a wide variety of products including fresh fruits and vegetables [50]. CFB packs (fig. 5.1) are widely used because they are safe andBending & Impact resistance[51]. CFBs are equally suitable for different modes of transport – by sea or air [52].

Figure 5.1: Pineapples packed in CFB boxes

5.2 PackagingWith Glass

Glass is used in rigid packaging form (fig. 5.2). Glass is inert, does not taint foodstuffs or affect its taste, is impervious to gasses, has transparency and is liked by consumers. It is a trusted and environmentally friendly packaging material because of its recyclability [53}.

Recycled broken glass is also used in glass manufacture. It is strong and durable and can be recycled many times without losing strength [54]. The molten glass can be formed into a container by a number of different techniques, but they all have in common the need for a mould to determine the final shape [55].

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Figure 5.2: Food packed in glasswares

5.3 PackagingWith Metal

Packages made from steel or aluminium offers a combination of excellent physical protection and barrier properties, formability and decorative potential [56]. Metal packaging (fig. 5.3) also contains a significant amount of recycled scrap material and can be recycled many times without loss of quality [57].

Figure 5.3: Food packed in metal cans

6. IMPACTOF PACKAGING ON FOOD QUALITY, SHELF-LIFE & SAFETY

The type of packaging exerts considerable effect on the sensory quality of produce. For instance, litchi packed in biorientated polypropylene (BOPP-3) were found to be of exceptional nutritional and sensory quality compared to fruit packed in BOPP-1 and BOPP-2 with less polypropylene layer [58].

Packaging is often used as a tool to extend shelf life by preventing or reducing water loss, especially in fresh produce. Studies showed that polyethylene bags reduced water loss and extended storability of various fruits and vegetables [59]. Unpacked foods are often exposed to a range of microorganisms which have the potential to reduce shelf-life. Harmful microorganisms feeding on unpacked food which are later consumed by humans can result in food poisoning, sickness or even death. Effective packaging contributes to reducing spoilage and maintaining food quality[60}.

7. CONCLUSION

Packaging is an essential component of the food system and plays a critical role in containing, protecting and preservation food and other agro-industrial raw materials from field to the end user. Researchers have shown that the use of appropriate packaging can contribute in reducing food losses and waste, and maintenance of product quality and safety.

Changes in consumer preferences have led to innovations and developments in new packaging technologies. Research and development in the field of active and intelligent packaging materials is very dynamic and develops in relation with the search for environment- friendly packaging solutions. The new advances have mostly focused on delaying oxidation and controlling moisture migration, microbial growth, respiration rates, volatile flavors and aromas.

Packaging is a major contributor to the cost of food, and packaging waste has been implicated as a major cause of municipal waste stream. Nanotechnology has potential to influence the packaging sector greatly. Nanoscale innovations in the forms of pathogen detection, active packaging, and barrier formation are poised to elevate food packaging to new height.

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