

Smart Packaging: A Tech-Enabled Healthcare Requirement



Harsha Farenjiya Khatik, Anshita Shukla & Preeti K. Suresh

University Institute of Pharmacy, Pandit Ravishankar Shukla University, Raipur, 492 010, Chhattisgarh, India.

suresh.preeti@gmail.com

Introduction

Packaging has emerged as a key battleground in the highly competitive pharmaceutical industry. By 2027, it is anticipated that the global market for smart packaging would cost total of \$144.23 billion (1). Smart packaging is not a single type of packaging, but rather a technology-enhanced category of packaging systems that aims to provide a far more active service than just passively containing consumer goods. It provides a total solution by serving dual purposes viz., monitoring product changes or its environment (intelligent) and act upon these changes (active) (2,3,4). Every stakeholder in the pharmaceutical supply chain would get benefits from smart packaging. It can improve patient compliance, confirm authenticity, assist tracking, anti-counterfeiting, deter addiction, extend product shelf-life, and reinforce sustainability profiles (2).

Types of Smart Packaging

Active Packaging

Active packaging is crucial, as it not only safeguard product quality, safety and shelf-life, but it also adds value to the product. It involves the use of protective materials in/on the packaging to lessen damage and deterioration. Active packaging serves this objective by coming into immediate contact with the contents of the product, interacting with them, and releasing chemicals. Active packaging is vital because oxygen and moisture can both contribute to product damage and deterioration.

Active packaging improves the functionality and includes technology such as scavengers, desiccants, and color-changing inks (2) . For example,

- Novel bag-type combination products for easy reconstitution of dry powder before administration (5)
- Intelligent ink that changes color when exposed to heat or light, assisting in proper medication storage (Figure 1) (2,5)
- Patient-controlled self-dose injectors that lessen the discomfort for patients receiving regular doses of medication (5).

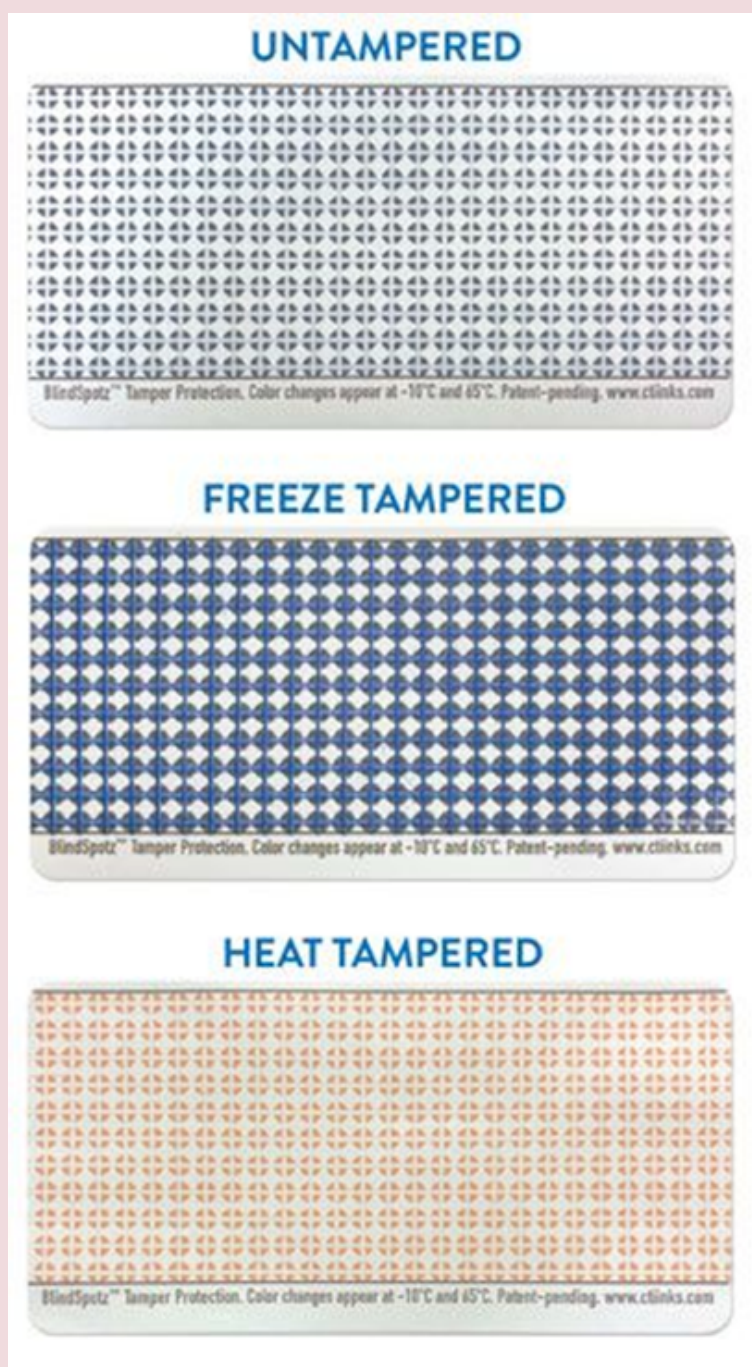


Figure 1: Color-changing inks from Chromatic Technologies make it possible to detect product tampering by product exposure to heat or extremely low temperatures. [2]

Intelligent packaging

Intelligent packaging is defined as "a packaging system capable of performing intelligent functions (such as sensing, detecting, tracing, recording, and communicating) to facilitate decision making to extend shelf life, improve quality, promote safety, provide information, and warn about potential problems." (4) For example, intelligent packaging allows for the creation of labels informing people about the temperature of the product during transit and/or storage, allowing pharmacists to determine whether the drug is safe to take or not. (6)

QR codes, near-field communication (NFC) and radio frequency identification (RFID), printed electronics, smartphones, smartphone apps, the Cloud, and the Internet are examples of related technologies. (2,7)

Some of the representative examples of these intelligent packaging are:

- Smart closures with NFC or Electronic Dose Packs, which send data for analysis to track medication adherence and record the date and time each dose of medication is taken (3,5,8,9)
- RFID tags are made of paper, which eliminates the use of plastic and are eco-friendly. (5,8,9)
- Sensor-equipped microchips capture data when a pill is taken out of its packaging and upload it to the cloud. This could potentially reduce overdosing as doctors will be able to see if someone is taking more than the recommended dose (3).

Color-tunable cellulose nanofoams as shelf-life indicator materials for use in medical and pharmaceutical applications such as thermosensitive drugs. Transparent HCTF films could be used in packaging to provide quick visual detection of proper food and pharmaceutical storage (10).

- Vaccine Vial Monitors contain a 2D barcode which store product data such as lot numbers and expiration dates. The crucial details about the product can be accessed, such as authenticity and safety considerations, by waving the smart device over the digital feature (5).
- Intelligent inhaler devices use breath actuation and instruct patients on how to use the device correctly. Patients can use their smartphones to connect to the intelligent control inhalers and set reminders as well as send feedback about the device and device usage (5).
- Automatic inventory tracking contributes to the hospital supply chain's efficiency and aligns with hospital operational and administrative goals. Novartis and Proteus Health have conducted a pilot study to track medicine consumption and patient activity levels with ingestible sensors for their antipsychotic pill Abilify (5)

Perks of Smart Packaging

Temperature regulation

If the pharmaceutical products are not kept at appropriate temperature, its integrity may be impaired with loss in stability and it may also become unsafe for consumption. Thus, manufacturers may design labels to apprise customers with the temperature of the respective products during storage and transportation. (9,16,17,18)

Adhering to medication

According to the World Health Organization, only 50% of patients with chronic illnesses adhere to their treatment regimens, despite the fact that at least 80% compliance is necessary for a medication to work at an optimum level. Smart packaging is an excellent way to remind patients to follow their prescriptions. NFC tags and QR codes can be used in smart packaging to provide patients with enough information to ensure they are using the medication as directed. (9,16, 17, 19, 20).

Stock control

Smart packaging with sensors can be a valuable tool for the pharmaceutical manufacturers to oversee and monitor their inventory with its better management. This permits the companies to keep an eye on the stock levels and accordingly adjust production and supply to evade understocking or overstocking of goods.(9,16-18,21)

Improves clinical trials

There are better clinical trials by addressing 'false negatives ' caused by volunteers taking drugs on time. (9,16,17)

Safety and Authenticity

Smart packaging has embedded technologies that fortifies package security and cut down on counterfeiting. The in-built sensors give assurance to both the pharmacists and patients that the medicinal product inside the package is authentic and tamper-free. This may also aid in the transition to more personalized and stratified medical treatment. (9,12,19,21)

Counterfeit prevention in the pharma industry

Counterfeits are reported to claim almost one-third of the market share, worth approx. \$200

\$200 billion. Unfortunately, nearly one million lives are lost per annum due to these toxic or ineffective drugs. The incorporation of holograms and microtexts aids in the fight against counterfeit medications. Moreover, the circulation of lower-price fake goods can take away a significant portion of the pharma company's profits and harm the brand's reputation. (7,9,18,21,22).

Transparency in the supply chain

Smart packaging can be used to track a product from production to market using embedded e-printed circuits. This enhances product quality and safety, assisting logistics professionals in adhering to regulations governing the transportation and delivery of drugs. Additionally, it can support serialization as it is simple to track serial numbers during distribution, making it easy to identify lost shipments. (18,22).

Smart Packaging Adoption Concerns

- Poor adherence leads to compromised patient health outcomes and, additionally, pharmaceutical companies lose hundreds of billions of dollars each year as a result of non-adherence (20).
- Price is another major concern for the smart materials to be commercially accepted for packaging. They must be economical in comparison to the product's value, reliable, accurate, and reproducible in their range of operation.²³ Nonetheless, this process is still in its early stages and may still be out of reach for the vast majority of firms, particularly those that are not outsourcing, operating locally, or working with a limited budget (21).
- Other barriers include legislation and sustainability. The recycling of e-printed circuits (of conductive ink) will be a challenging task (5,23).
- There is a need to develop an effective production supply chain with enough volume, speed, performance, and price to facilitate mass market adoption (12,21)
- Patients generally do not adapt to changes quickly; it may appear to them as a barrier because data collection is very personal; they may be uncomfortable with their information being collected and shared. It raises numerous concerns about data ownership, privacy, and security in relation to regulations such as the Health Insurance Portability and Accountability Act (HIPAA) and the General Data Protection Regulation (GDPR) (5).

Another concern that comes with collecting and using the product and customer-sensitive data is the ability to do so with security in place. Not all real-time monitoring and tracking systems protect the security and data privacy of consumers and business and that may be a major apprehension (1,3,21,22).

Conclusion and Future Aspects

Smart packaging options have been slow to gain traction, but there is clearly a growing interest. According to one study, smart packaging has the potential to increase patient adherence by 23 percent (22). European-funded research and development projects, such as CPI's SCOPE and REMEDIES, are identifying new processes, equipment, and applications that will enable the mass production of billions of printed electronic components which would result into a viable supply chain (12,19). Selecting environmentally and socially responsible sustainable materials for smart packaging, like molded fiber would help in protecting the environment. Stora Enso's ECO sustainable RFID tag technology eliminates the non-recyclable

Table 1. Technologies involved in smart packaging

Developer/Packaging Producer	Name of Technology	Function/Feature of Technology	Ref.
Amcor	MaXQ	A coding system that provides real-time brand protection as well as targeted consumer engagement. It enables quick and easy verification of the product's credibility.	[11]
GlaxoSmithKline & University of Cambridge	The REMEDIES project	Use RFID tags to address flaws in the supply chain to reduce malpractice and stimulate patient compliance	[9,11,12]
Aptar CSP Technologies (csptechnologies.com)	Activ-Seal closures/blisters solution	Allow for desiccant and scavenging functionality which eliminates the need for purging or secondary packaging	[13]
Closure Systems International (CSI) and Talkin' Things	NFC chip-equipped caps	One-stage tags facilitate communication with consumers directly and two-stage tags provide additional protection and real-time traceability to combat global counterfeiting.	[2]
Schreiner MediPharm	NFC-equipped label for autoinjectors	The patient can confirm if the product has retained its original sealed form. Integrated geo-tracking assists in sensing gray market activities.	[2,12]
August Faller Group with MSC Technologies and Pforzheim College	The Counting Device	It ensures that the patient has taken the tablet by pressing a button on the front of the folding carton. As the tablets are about to finish, the e-paper displays a warning as a cue for prescription refill	[2]
	Level Indicator	It determines the liquid left in an opaque container of fluid product	
	Medical Prescription carton	It performs tablet counting, send alerts to the patient of the forthcoming dose and sends Bluetooth refill requests.	
Systech	Digital e-Fingerprint	A printed barcode serves as a unique identifier that is entirely covert and impossible for counterfeiters to replicate. This eliminates the practice of smuggling drugs out of low- or no-cost areas and selling them for a large profit in high-priced areas.	[1]
AdhereTech	Smart Pill Bottle	It records patients' moods, symptoms, and reasons for non-adherence and sends reminders via light and sound, texts, and phone calls. The reminders can be personalized for each individual patient or a batch. Furthermore, pharmaceutical companies can modify these reminders and use them as branding visuals. On AdhereTech servers, the tracking data is examined for anomalies.	[14]
Information Mediary Corporation and Keystone Folding Box Co.	Ecoslide-RX Wallet-Pak	A smart blister package that monitors and transmits compliance information The pack contains an NFC tag that can be scanned by a smartphone to read compliance data via any compatible app, such as DoseCast The pack is made from 100% recycled material and does not require heat sealing during the process of production, which lowers both costs and energy consumption	[8,14]

Table 1. Technologies involved in smart packaging (cont...)

Burgopak Healthcare & Technology	Sliding Child Resistant blister pack	Burgopak won the award for the ‘Most Innovative Child Resistant Packaging Design’ This pack can only be opened by applying pressure at two different points on the packaging. The outer box contains the blister pack and information leaflets, ensuring that the product is never taken out of its packaging.	[8]
Wipac (GmbH in Germany) & VTT Technical Research Centre of Finland	Talk Pack	It involves a special pen-shaped reader used to retrieve the stored information and replay it as audio files and render speech, music, or sounds audible, and thus the consumer can obtain information regarding the manufacturer, brand, shelf-life, or other information. RFID or microchips are not required for Talk Pack. Using a special varnish, the dot code is simply printed on top of images and texts.	[8]
CYPAK	Advanced medication monitoring and report card systems	This record the time and date that a pill was taken based on when it is removed from its blister pack. This enables patients to record and upload feedback on side effects and treatment efficacy. This aids drug development by determining whether a drug is ineffective or simply not being taken correctly.	[15]

objection. Along with the paper label, the paper-based RFID tag obliterates plastic and is amenable to recycling (2,19). Furthermore, data theft issues could be addressed using cryptography systems, long-term encryption, and blockchain technology (21).

Smart packaging has enormous potential in increasing patient compliance and adherence. It may be useful in transitioning from generalized to personalized treatment. However, the smart packaging sector is still in its infancy, and there is a need to overcome the associated challenges. Therefore, more research is required to build a more efficient, compatible, and cost-effective supply chain which allows the industry to develop sufficiently to support and integrate smart packaging technologies with pharmaceuticals.

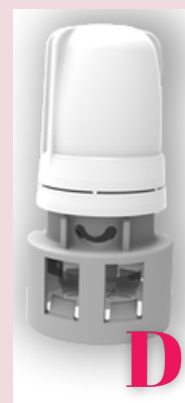
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Guess The Packaging & Its Use



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