**The Future of Cost Management and Innovation in Pharmaceutical and Cosmetic Packaging**

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**1. INTRODUCTION**

 Packaging is defined as a technique which allows containment of pharmaceutical product from the time of production in a unit till its use. Role of pharmaceutical packaging is to provide life saving drugs, surgical devices, blood and blood products, nutraceuticals, powders, poultices, liquid and dosage forms, solid and semisolid dosage forms.

The global packaging industry has shown tremendous growth in recent years. It is expected to grow further in the coming years. The packaging sector has been an important supporting factor in the growth of various industries like food, FMCG, and agriculture.

The packaging industry is the backbone of all industries. It plays a vital role in protecting products and ensuring their safe arrival at their destination. The packaging industry has come a long way in the past few years, with the introduction of innovative materials, technologies, and designs that make packaging more efficient and cost-effective. The demand for packaged goods will continue to grow with flexible imports and exports of goods, better management of the movement of goods, demographic growth, and the evolving consumer mindset to purchase products from national and international markets. Packaging also helps companies stand out from the competition and build their brand. From luxury to eco-friendly, packaging plays a key role in how companies present their products and services. By using recyclable materials and better packaging designs, companies can help reduce their environmental impact.

Packaging has become even more crucial with the increasing importance of hygiene and safety. Like all other industries, the packaging industry also shows advancement in technology. With the ever-growing consumer demands for innovations and necessities, the packaging industry has certain demands to meet in the future.

**Overview of the Packaging Industry**

Packaging is described as the art and science of storing and protecting products till they are distributed and used. Packaging primarily plays an important role to protect and store goods for logistics and warehousing. While the packaging is a part of various industries, the major user of packaging is the food and beverage industry. The growth of the packaging industry is also the result of the rising trend of eCommerce. Packaging helps maintain quality and lengthen the shelf life of a wide range of products. These products include processed and semi-processed food, drugs, medicines, electrical appliances, domestic appliances, and even industrial machinery.

The demand for increased specialization and sophistication with respect to health and hygiene is one of the major driving factors of the industry. The growing awareness about the hazardous effects of plastic on the human body and environment has made people opt for more natural packaging materials. The pandemic period has shown the importance of hygiene and packaging plays a crucial role in maintaining the hygiene of food products.

**2. What is the future of pharmaceutical packaging?**

“Need is mother of all Inventions”, phrase is best describing the emerging technologies towards pharmaceutical packaging. Indian Packaging market is expected to grow up to US$ 55 billion by 2020 from the 2009 levels of US$ 12.6 billion, as per a McKinsey & Company report titled "India Pharma 2020: Propelling access and acceptance realizing true potential".

 Counterfeit prevention with counterfeiting accounting for annual losses estimated at $75bn, packaging always been at the heart of the industry’s strategy to protect itself. It has employed an array of security techniques to combat this issue, with varying success, including : micro text, debussing and embossing, customized varnishes, holographic materials, tamper evident stickers, RFID (Radio Frequency Identification) track-and-trace tagging and customized graphics and fonts.

**1. Ink technology**

Technique allows color to reappear when rubbed or scratched. E.g. "Secur" labels, Ad Tape & Label, Menomonee Falls.

**2. Radio-frequency identification (RFID)**

RFID is another technology with anti-counterfeiting potential. RFID tags can help authenticate products and support data collection for pedigree records. Equipment that encodes and prints tag-equipped labels verifies the tag before and after encoding. If a nonviable tag is detected before encoding, the label is marked with a checkerboard pattern and ejected. Good labels are encoded and rechecked. If tags read properly, labels are printed and their bar codes are verified. If the bar code doesn't scan correctly, the unit pulls the label back in, imprints it with a checkerboard pattern, ejects it, and encodes and prints a new label "Smart line SL4M RFID" printer, Printronix Inc., Irvine.

For automated applications, encode, print, and apply unit is available. It performs all the checks of the RFID printer and applies the labels at a maximum rate of 100/min "Smartline SLPA8000" label printer applicator, Printronix. In multipanel labels, at least one label converter can incorporate ultrahigh-frequency (UHF) or high-frequency (HF) RFID inlays to support product security, inventory control, and track-and-trace functions "InfoPac label,"

Dual-function tags - RFID with temperature sensing, having cost less than traditional devices for temperature monitoring e.g. integrates a sensor, microchip, battery, and antenna on a paper-thin label e.g. 13.56 MHz “TempSens " smart label, KSW- Microtec, Dresden, Germany. This type of smart sensor label–equipped blister package is being used by the National Institutes of Health (Bethesda, MD), for a multiyear study of chronic obstructive pulmonary disease that will involve nearly half a million individual doses of medication.

Radio-frequency identification (RFID) tagging helps to simplify shipping, receiving, inventory location, and control has been mandated by the department of defense, several other retailers, and various hospitals. Carry and collect the data needed to track and trace product through the supply chain prevent counterfeiting and diversion coupled with sensors to monitor conditions during shipping and storage and provide alerts if parameters are exceeded.

**3. Tamper-evident stickers**

Needs a special substrate designed for the purpose. The cellulose acetate film is very intricately designed so that it has adequate strength to undergo conversion into label stocks in roll form. The stickers can be automatically dispensed on automatic label dispensers and when attempted to be removed these break-up into very small pieces. Vinyl had now replaced acetate film being cost effective.

**4. Holographic materials**

Large and important part of the security label market and are an ideal choice for product authentication. The holographic foil an optically variable device is usually made using a polyester film base. The perception of the holographic image by the human eye makes it ideal for brand promotion and security. Packages reveal the holographic image when tilted against light source. By increasing the complexity of hologram manufacturer can make it difficult for counterfeiters to duplicate the products. Many holograms besides offering brand authentication also offer tamper evident properties. If the hologram is attempted to be removed, the top polyester layer will peel off leaving the hologram on package.

**3. What is the future of packaging industry?**

The global industrial packaging market has seen exponential growth in recent years. It is expected to continue the growth even in the coming years.

The industrial packaging market, which had a market share of USD 1015 billion in the year 2021, is expected to grow at a CAGR of 3.9% during the forecast period of 2021 to 2026 and reach a value of USD 1.22 trillion.

Asia comes out to be the most significant contributor accounting for 43% of the share, followed by North America, accounting for 23%.

The packaging industry offers applications for a wide range of industries to ensure the safety of goods. The growth of the packaging industry is a result of various factors. These factors include the increase in global wealth, rising e-commerce businesses, and faster growth of the FMCG sector, to name a few. The ever-increasing demand for sustainable packaging options and the emergence of newer technologies like smart packaging use of AI and ML have led to innovations in the packaging industry, leading to its growth.

**Future Demand Factors of the Packaging Industry**

* The packaging industry has seen tremendous growth in the last few years. The industry is expected to grow further in the coming years as well.
* With the growing concerns of changing environmental conditions and global warming, the demand for newer sustainable packaging materials will equally grow.
* Sustainable packaging options have gained importance in recent years and sustainable choices will be significant in the coming years too.
* The encouragement from governments and environmentalists is also a reason for choosing more sustainable materials. Moreover, consumers are also in favor of environmentally friendly and sustainable packaging.
* 61.5% of the Goodfirms’ survey participants would readily pay extra for sustainable packaging alternatives.
* The future of sustainable packaging will see multiple packaging options that will be eco-friendly and have a positive impact on the environment.  The use of plant-based material for packaging is one of them.
* The emergence of edible packaging is another interesting trend to look out for. The trend of edible packaging has been in existence for a while. However, it is getting more popular now, majorly in the food industry.
* Edible packaging is a new option for waste that is created with the use of wrappers, straws, bottles, cutlery, etc. Edible packaging can surely be a great substitute for the use of plastic, as they are biodegradable and can be easily disposed of even if consumers do not opt to eat the packaging.
* The main sources of edible packaging can be seaweed, potato starch, and milk proteins.
* One more trend that can see growth is the use of fabrics like jute or some textured cloth piece for wrapping instead of plastics or wrapping papers that can even help improve the aesthetic value of the package.
* Plastic packaging is the most versatile option. However, due to its hazardous effects on nature, the use of plastic has become a huge problem.
* The use of bioplastic has emerged as an alternative to plastic packaging. Bioplastics, mostly plant-based, exhibit better biodegradable properties. Although the adoption of bioplastics is slow in the industry, they have a bright future in the packaging industry.
* The market share of the bioplastic’s packaging market is estimated at USD 10.5 billion in the year 2022 and is expected to grow to USD 16.6 billion by 2027 at a CAGR of 9.5%.

**Applications of AI and ML will Make the Packaging Processes More Efficient**

Technologies like Artificial Intelligence and Machine Learning are coming to the aid of almost all industries. There is a vast range of industry-specific applications for these technologies. Similarly, these technologies have made a difference in the packaging industry as well.

The application of AI, ML, and other similar technologies will help make the functioning of the packaging industry even smoother and more efficient. Automating the fulfillment process can help businesses save both time and money.

Implementation of AI in the packaging process of a product is a great way to assess the final product being packed. The installation of AI-powered cameras is being adopted by several businesses, and it has helped them detect if some assembly parts of the product are missing. Such applications can help businesses cut down on shipping costs by avoiding the shipment of defective products.

Assessing the products is also crucial for e-commerce companies. Proper utilization of automation technology can also assist in selecting the proper packaging design for products. The giant e-commerce company Amazon has reduced the damage rate by 24% with the use of an AI-enabled algorithm to choose the right packaging type based on the product.

Technologies like ML work on the accumulation of data and its analysis. The implementation of such technologies plays a crucial role in data labeling. The availability of accurate data will help in the proper labeling of products which assists in standardizing procedures in order to satisfy customers.

**4. What is the future of packaging technology and design?**

Future of Pharmaceutical Packaging Pharmaceutical industry, research and manufacturing technologies are continuously evolving with demands of environmental ethics, patient compliance and novel medicaments this had driven significant developments in packaging and delivery systems.

Increased investment in R&D sector had lead to formulation of large molecule biopharmaceutical drugs some are still in development pipelines this has led to an increase in the need for injectable packaging and self-administration systems. The earlier used old glass and elastomeric closure systems may not provide the effective barrier properties much needed for high-value, life saving therapies. Packaging R&D provided us with new materials and technologies that ensure extended drug-product shelf-life.

Lyophilization had led to the formulation of liposome’s and further the pro-liposome’s, the therapies which are unstable in liquid form are lyophilized or converted to dry powder dosage forms. Lyophilized drugs need special care for storage and administration for the optimal performance by products. Lyophilization chambers with proper, non sticky stoppers are used for dose accuracy. Advancement in research of pharmaceuticals development had always being dependent on the development in packaging technology.

To maintain integrity of pharmaceuticals during storage, shipment, and delivery, quality of packaging provides assurance for all these. So, development in field of packaging is correlated with development of NDA Pharmaceuticals in market. Use of 3D design software to design efficient pharmaceutical packages and their assessment with software’s like Finite Element Analysis (FEA) need to be promoted in Pharmaceutical Packaging.

This approach of virtual to real packaging can produce product right from scratch using software to create their models and then testing them with certain parameters virtually based on the data only the prototypes are created this eliminates the need for the customer to set up costly and time-consuming production runs at their sites for testing at all stages of development. Increase in self-administered therapies forces pharmacy research to formulate packages for self administration rather than for healthcare revolving around hospital care. In present healthcare often starts at hospitals/clinics but maintenance therapy revolves around the home. For treating chronic conditions such as arthritis, cancer, multiple sclerosis,

Alzheimer’s and other diseases that require frequent medication, self administration had led packaging to be evolved in such a way to provide compliance for therapy. Usually maintenance therapies are delivered by injection, demanding a need for patient-friendly administration systems. Packaging systems is required to ensure that the potency of the drug must be preserved and it should promote compliance with a dosing regimen, ensuring dosing accuracy, and be as safe, easy to use and painless as possible for patients.

Manufacturers involved in packaging for the self drug administration process need to provide delivery systems that will simplify drug reconstitution before use, especially for non-professional caregivers.

**5. What are the recent innovations in packaging?**

A changing pharmaceutical industry Changes in pharmaceutical industry research and manufacturing technologies have driven significant developments in packaging and delivery systems. An increase in the number of large‑molecule, biopharmaceutical drugs in development pipelines has led to an increase in the need for injectable packaging and administration systems. The old glass and elastomer closure systems may not provide the effective barrier properties needed for high‑value, lifesaving therapies. Component manufacturers have responded with new materials and technologies that ensure extended drug‑product shelf‑life.

 Many new biotechnology‑derived drug therapies are unstable in liquid form and therefore are introduced as lyophilized or dry powder dosage forms. Lyophilized drugs need special stoppers for optimal performance in lyophilization chambers. The stoppers must solve the problem of the stopper sticking to the lyophilization shelf after the cycle is completed. In addition, lyophilized drugs typically are reconstituted at the point of care, thus requiring patient‑friendly administration systems.

 The increase in self‑administered therapies Decades ago, healthcare revolved around hospital care. Today, healthcare often revolves around the home ‑ a situation that has largely resulted from cost constraints and the introduction of maintenance‑type drugs for treating chronic conditions such as arthritis, cancer, multiple sclerosis, and other diseases that require frequent medication. Many of these maintenance therapies are delivered by injection, spurring a need for patient‑friendly administration systems.

 These systems must ensure the potency of the drug, be tamper‑evident, help deter counterfeiting, promote compliance with a dosing regimen, ensure dosing accuracy, and be as safe, easy to use and painless as possible. An outgrowth of these changes is the move from the typical vial and disposable syringe to the prefillable syringe.

With prefillables, dosing accuracy is ensured but they present some challenges for the industry. A pharmaceutical company needs a prefillable system that protects the integrity of the packaged drug product over time and will function as represented over the full shelf life of the drug product.

The response from component manufactures was to develop syringe plungers with barrier films that minimize the interaction between the packaged drug and the components. At the same time, the industry has developed elastomers for molded plungers that maintain functional properties such as seal integrity, and break‑loose and extrusion forces.

**The Current Trends in Packaging (2024)**

* Internet of Packaging.
* Biodegradable Packaging.
* Digital Printing.
* Packaging Automation.
* Active Packaging.
* Custom Packaging.
* Recyclable Packaging.
* Edible Packaging.

Innovative packaging design can be a market-winner.
Such design consists of art, supported by knowledge and experience. To create an innovative packaging design, it is not enough to have an aesthetic sense. It must also be supported by experience resulting from a well-known problem.

**Conclusions**

 Pharmacosomes overcome some of the limitation of liposome, niosomes, transferosomes like oxidation, instability, lack of purity resp. Pharmacosomes have ability to include entrap liphophilic or hydrophilic drugs and release the drug at site of action.They could be used to improve aqueous solubility and permeability of liphophilic and hydrophilic drug resp.It can be give orally,topically,extra or intra vascular.

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