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REVIEW ON: PHARAMCEUTICAL PACKAGING AND INNOVATIVE PACKAGING METHODS

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ABSTRACT
Pharmaceutical packaging plays a critical role in ensuring the safety, efficacy, and integrity of medicinal products. This abstract highlight recent developments and innovations in pharmaceutical packaging, emphasizing the industry's ongoing efforts to address challenges such as patient safety, regulatory compliance, and environmental sustainability. In response to the growing complexity of pharmaceutical supply chains, innovative packaging solutions are emerging to enhance traceability and counteract issues related to counterfeit drugs. Advanced technologies, including RFID tags and QR codes, are being integrated into packaging designs to enable real-time monitoring and authentication, ensuring the delivery of genuine and uncompromised medications to patients. Moreover, patient-centric design is gaining prominence in the pharmaceutical packaging landscape. Tailoring packaging to improve medication adherence and ease of use has become a priority, with features such as smart blister packs and interactive labelling systems providing patients with valuable information and reminders. Environmental concerns are also shaping the future of pharmaceutical packaging. The industry is witnessing a shift towards sustainable materials, reduced packaging waste, and eco-friendly designs. Biodegradable and recyclable packaging materials are being explored to minimize the environmental impact of pharmaceutical products throughout their life cycle.

KEYWORD: Packaging, innovation, counterfeit drugs, RFID.

INTRODUCTION
The collection of various elements that surround a pharmaceutical product from the point of creation until it is used is known as pharmaceutical packaging materials. Therefore, the science, art, and technology of enclosing or safeguarding items for distribution, storage, sale, and usage including printed material used in the finishing of pharmaceutical medicines-can be collectively characterized as pharmaceutical packaging.[1, 2]

Giving security, introduction, differentiating evidence, data, and convincing arguments for a pharmaceutical product from the moment of creation until it is used or administered is a conservative approach. Packaging is the structure or system that ensures that the product travels from the manufacturing facility to the buyer safely, soundly, and with the least amount of overall misery. A bundle or display bundle refers to the labelling and container closure structure, associated parts (such as spoons, droppers, and dosage glasses), and exterior wrapping (such as cartons or recoil wrap).[3,4]

Ideal Qualities of a Pharmaceutical Package[5,6]
1. It should have sufficient mechanical strength to withstand handling, filling, closing and transportation.
2. It should not react with the contents stored in it.
3. It should be of such shape that can be elegant and the contents can be easily drawn from it.
4. It should not leach alkali in the contents.
5. The container should not support mould growth.
6. The container must bear the heat when it is to be sterilized.
7. The contents of container should not be absorbed by the container.
8. The material used for making the container should be neutral or inert.
9. Any part of the container or closure should not react with each other.
10. Closure should be of non-toxic nature and chemically stable with container contents.

Types of Packages[7,8]
1. Primary Packaging
Packages that come into direct touch with the pharmaceutical formulation are referred to as primary packaging. Protecting the formulation from mechanical, chemical, environmental, and/or other risks is the primary goal of the primary package. The principal packaging type utilized is contingent upon the nature and chemical makeup of the product. Liquids are typically

put in vials or ampoules, while capsules and tablets are frequently kept safe in blister and strip packaging.

2. Secondary Packaging
The outside packaging for Secondary packages is referred to as primary packages. In addition to offering extra security during storage, this packaging contains information on pharmaceutical products, such as leaflets.

Features
- Defence against forceful hands the advantages of additional packing
- Developing your brand; Boosting revenues; Streamlining your shipment procedure; and Lowering transportation-related harm.
- Guard the pliable receptacles.

3. Tertiary packaging
It shields the items from harm and is the outer package of secondary packing. It is employed in shipping and bulk handling. The advantages of three-tier packaging the goal of an optimal tertiary packaging solution should be to integrate items firmly and compactly without straining or damaging them, utilizing the least number of materials feasible.

Ex: Barrel, crate, container, pallets, and slip sheet are a few examples.

This facilitates
- Reduce CO2 emissions;
- Boost pallet stability;
- Cut transportation expenses

Materials used for Pharmaceutical Packaging[9]
Most drugs (51%) have traditionally been taken orally as tablets or capsules, which are either put inside plastic pharmaceutical bottles or sealed in blister packs, which are quite common in Europe and Asia, particularly the United States. Additionally, liquids, pastilles, and powders are used to take oral drugs. On the other hand, many people are increasingly using alternate methods of administering medications. These include parenteral or intravenous (17%), intravenous inhalation (29%) and transdermal (3%) methods. These developments have had a substantial influence on the packaging industry, and there is a growing need for customized, specialized packaging solutions that guarantee the effectiveness of pharmaceuticals. The current review article highlights several significant advancements that have an impact on the packaging industry and provides some future packaging predictions for injectable and solid oral dosage forms.

Different material used in pharmaceutical packaging.
The quality of the product is significantly influenced by the packaging used. When packaging serves as a source of information, the material utilized needs to be large enough to hold printed text or graphics. We examined a variety of packing materials in this area, emphasizing their suppliers and manufacturing processes. The quality of the packing material serves as a bridge between the maker and the clients, ensuring the latter's confidence in the product. A key component of product display and preservation is the choice of packing materials. When it comes to selecting packing materials, the nature of the product also plays a significant role. The best materials for different businesses' goods and services include meat, cosmetics, food, and medicines. As a result, a thorough description of the various materials is required.[10]

PLASTIC
Plastics are useful and adaptable materials that may be used to store and transport complex medical equipment, medications, and other items. Plastic packaging is ubiquitous in the healthcare setting. It can be found in thermoformed blister packs and trays, caps, bottles, vials, pouches, bags, and overwrap. In general, plastic packaging needs to meet quality standard standards to optimally accomplish the goals of pharmaceutical packaging.

Most packing materials are made of plastic, and packaging accounts for the greatest use of plastic materials with around 26% of all polymer usage. Since plastic is quickly replacing other materials used for packaging, its consumption is predicted to quadruple over the next 20 years. This is because to innate qualities like strong barrier Plastic packing materials have many advantages, but they also have drawbacks because of their detrimental effects on the environment. CO2 is released into the environment during the manufacture of products derived from petroleum. Additionally, if plastic packaging is handled improperly during collection or recycling, it will wind up in landfills and other waterways, contaminating and poisoning both the land and the oceans. Environmentally friendly and sustainable alternative materials are being investigated by several sectors' attributes, a lightweight nature, affordability, etc.[11-14]

Glass
It is an inorganic product that is cooled to a stiff state without crystallizing; it is an amorphous, non-crystalline solid of fusion. Glass may be made into optical lenses, prisms, and other objects by cutting and polishing it to improve its ability to transmit, reflect, and refract light. For more than nine decades, alkali borosilicate glasses have been utilized in medicine packaging due to their exceptional chemical endurance, strength, hermeticity, cleanliness, and transparency. These glasses may easily be shaped into ampoules, cartridges, syringes, and vials.

Issue associative with glass
Breakage of glass is one problem. A break in the glass container has the potential to produce glass fragments that might find their way into the medication and jeopardize its sterility. One such problem is delamination. Glass flakes are a byproduct of a particular kind of glass corrosion called delamination. Although

delamination has been regularly noted in soda-lime silicate glasses for over 50 years, it has only seldom been noted in pharmaceutical borosilicate's, however the incidence appears to have increased noticeably in recent years.

Variation in hydrolytic performance, a gauge of the glass's resistance to chemicals in neutral solutions, is another problem. The composition of the glass and the pH of the solution are two of the numerous variables that affect chemical durability.[15-17]

Metal

Materials utilized in Pharmaceutical Packaging: The periodic table contains more than seventy metals, however only tin, lead, aluminium, and iron are important materials used in pharmaceutical packaging. Building materials for containers are metals. Lead, tin, stainless steel, aluminium, and tin-plated steel are the metals used for this.[18]

Aluminium

Because aluminium tubes are lightweight, they may save a lot of money on product shipment. They offer a nice look.

Lead; Lead is the least expensive tube metal and is used extensively in non-food goods including paints, lubricants, adhesives, and inks. Due to the risk of lead poisoning, lead should never be used alone for anything that is intended for internal consumption. Lead tubes with coated inner surfaces are used to hold items like toothpaste with fluoride.

linings

Although resins and lacquers are often sprayed on, the interior can be flushed with wax-type formulations or resin solutions if the product is incompatible with bare metal. The cost of an epoxy-lined tube is approximately 25% more than that of an uncoated tube.

Although phenolics, epoxides, and vinyl's provide better protection than wax, they are more expensive. Wax linings are often utilized with water-base compounds in tin tubes.[19]

Rubbers

Systems used in the production, packaging, and delivery of pharmaceutical items frequently involve rubber materials. Although the type and content of the rubber material provide it its required and desired performance qualities, these material attributes can have significant and potentially harmful effects on pharmaceutical goods. The ideal rubber formulation for the product will depend on the physical and chemical characteristics of the rubber.

The ideal rubber composition also depends on the characteristics of the medicinal product that the rubber is closing, as well as how the rubber will be utilized (as a plunger, septum, or closure, for example). Elasticity, hardness (durometer), tendency to fragment, permeability to oxygen and/or water vapor transfer, pressure to puncture, coring, reseal ability, break force, vacuum retention, and specific leachable/extractables are among the physical qualities taken into consideration when choosing a specific rubber formulation. Although some functionality tests, such as determining the break force needed to start a rubber plunger in a syringe or cartridge, are carried out by the product maker, these data are often generated by the rubber producer.[20-22]

Bio degradable

Microorganisms including fungus, algae, and bacteria may decompose biodegradable packaging materials in about a year. Typical examples of biodegradable materials include mushrooms and cornstarch. Scientists are testing the integration of these materials into their package manufacturing process.

Seaweed has been identified by some researchers as a viable substitute for sustainable bio-packaging in the food, cosmetic, and pharmaceutical sectors.

Recently, the Japanese pharmaceutical company Astellas produced blister packs using plastic made from biomass and plant matter. In line with their press statement, they used sugarcane, which makes up half of the package's basic material, to create polyethylene, a plastic based on biomass.

Eco-friendly Packaging Material Examples: Board and paper: Paper is a naturally occurring, easily recyclable, and biodegradable packing material. These can therefore be used to create environmentally friendly pharmaceutical packaging materials. The material used to package pharmaceuticals is wood. The source of cellulose fibers is wood. Networks of cellulose fibers make up paper and paperboard. Paper and paperboard have been used for packaging for a long time. Papers are less heavy than other types of packing material. The primary drawback of paper packaging is its permeability to moisture and gasses. It is also readily torn. Paper is used to prepare the exterior containers, such as envelopes, boxes, and cartons. Take a look at a sample of a board carton-packed blister and strip of pills, suppositories, and capsules. That are packed in board carton.[23-25]

INNOVATIVE PACKAGING METHODS

Over the past few decades, pharmaceutical packaging innovations—particularly for prescription drugs—have undergone very little reinvention or change. Smart infographics may be used to illustrate the important role that packaging plays in educating customers about the contents and potential hazards associated with using prescription or over-the-counter medications. This is especially true for current pharmaceutical packaging. While around 75% of medication users are over 55, it can be difficult to design packaging that is simple for

them to open. On the other hand, the pharmaceutical sector must also make packs that are resistant to children. In addition to enhancing product confidence, the outside picture of the box must clearly and concisely identify the product and other features.[26,27]

1. Child Resistant Packaging[28-31]

Manufacturers utilize child-resistant packaging, sometimes referred to as CR packaging, as a specialized packaging option to lower the possibility of children eating harmful components. Pharmaceutical packaging designed to keep children away is designed to be challenging to open. Manufacturers, however, make it such that the majority of adults may reach the contents of the packaging. A packaging design aimed at making it difficult for young children to open or access its contents is known as a child-resistant container. Nonetheless, grownups should not have too much trouble using it appropriately. Youngsters, particularly those who are a year or younger. Over 100,000 incidents of drug-related child poisoning are recorded annually in Union member states.

This alarming trend emphasizes the necessity of raising awareness and implementing preventative actions in order to protect the welfare of our youngest citizens. It has been demonstrated that the adoption of Child-Resistant Packaging (CRP) significantly lowers the death rate of children who unintentionally swallow prescription medications. These packages are a vital safety precaution in homes where medicines or dangerous items are kept because they include mechanisms or features that call for strength, dexterity, or cognitive capacity higher than that of a little kid.

Kinds Of Closures That Ignore Children.

Packaging that is not re closable and that can be reclosed are both considered to have child-resistant closures.

• **Non-Re closable closure:** Examples of non-re closable closures are opaque/clear laminated plastic (blister packaging) or aluminium foil (strip packaging). Typically, these containers include a single tablet—for example, a medication or dishwashing tablet.

• **Re closable closure**: Re closable packaging consists of a container with a child safety cap or a re-closable top, such the "Palm-Turn" or "Clicklocks" brands. For items like dishwashing powders or methylated spirits, this kind of packaging is typical.

2. Anti-counterfeit Packaging[32-34]

Assuring that goods are delivered from the production plant to the customer base securely and affordably is a major responsibility of packaging, which serves as a link between production and marketing. Counterfeiting is one of the main problems with product security. Products that are counterfeit are frequently sold after their expiration dates, disseminated through unapproved means, or have their packaging altered.

When a medical product's identity or origins are falsely represented, it is deemed counterfeit. This thorough grasp of counterfeiting emphasizes how crucial it is for the healthcare sector to guarantee the safety and authenticity of medical items. The most popular counterfeit medications in industrialized or affluent nations are sometimes referred to as "lifestyle drugs." These people frequently get these medications from unlicensed pharmacies via the internet.

Unfortunately, because they are a major source of sickness, death, and a decline in trust in the healthcare system, counterfeit pharmaceuticals pose a serious concern. Brand owners should aggressively work to educate customers about the risks associated with counterfeit goods. They should also prioritize managing the risk of counterfeiting by putting in place reliable systems for tracking, tracing, identifying, and reacting to suspected counterfeit items. Anti-counterfeiting technologies are essential because they prevent, identify, and manage counterfeiting, giving customers peace of mind when it comes to authenticating products.

Anti-counterfeit elements used in product packaging, however, must be extremely difficult to duplicate in order to be successful. Many cutting-edge anti-counterfeiting strategies, such as the use of smart packaging technology, are now being studied and put into practice. In addition to improving security, these technologies enable customers and individual consumers to examine products and verify their authenticity, which helps to stop the market's spread of fake goods.

Overview Of Some Anti-counterfeit Technologies

i. Product Authentication:
ii. Track and Trace Technology
iii. Holograms

3. Talk Pack; is a Wipak Wallride packaging system. Any printed picture or any of the package materials might be connected to it. It has a unique kind of pen-shaped reader inside. It is used to retrieve saved but inaccessible data, such as audio files that provide the audibility of voice, music, and other sounds. Customers may use this to learn more about different brands, manufacturers, shelf lives, and other relevant information. RFID technology and microchips are not included in this technology. Dot code is printed on the tops of text and images using a unique varnish. This sort of technology is applicable to all printing processes and packaging types.

1. The "Talk Pack" can be subtly included into package materials; a unique scanning pen is required.
2. The VVT Technical Research Centre uses NFC-based tags to allow mobile phones to download product, text, audio, and website information. Information may be accessed, stored, and replayed as audio files, music, etc. by utilizing a specific pen-shaped reader. to find out the brand, shelf life, and manufacturer information.[35]

4.Radio Frequency Identification[36]

(RFID Beyond serialization and anticounterfeiting protection, radio frequency identification (RFID) technology is being used to improve supply chain management and help patients and caregivers, especially those with impairments. According to the research, packaging equipped with RFID—which employs radio waves for data transmission and reception—can assist combat medicine counterfeiting on the illicit market and lower medical blunders that happen in operating rooms of hospitals RFID (Radio Frequency Identification) is a system that tracks distant objects using small computer chips. This little chip is attached to an antenna that picks up electromagnetic radiation that a reading device emits. The reader device obtains the unique identification number from the chip when the energy is detected. This makes it possible to identify the object remotely. This technology facilitates effective inventory control, contributes to cost reduction, and fulfils patient safety commitments.

5. Blow-fill-seal technology[37,38]

The method known as aseptic blow-fill-seal (BFS) technology forms plastic containers, fills them with sterile filtered product, and seals them in a continuous series of steps inside a single machine's sterile, controlled environment. Systems that use blow-fill-seal technology provide a special blend of excellent sterility assurance, cheap operating costs, and packaging design flexibility. The machines have a modest area need and require a minimum number of persons to operate. The most common polymers employed in the process are polypropylene and low- and high-density polyethylene. The container may be specifically designed to fit the requirements of the application because of its inherent ability to form the container or closure during the aseptic packing process. This adaptability makes the container easier to use and allows for interaction with many of the cutting-edge medication delivery systems available today, particularly those related to respiratory treatment.

Advantages of BFS Technology

- BFS technology is a more reliable technique for the aseptic production of sterile medications since it requires less human interaction.
- Buying and stocking a variety of prefabricated containers and their closures is not necessary. Plastic bulk containers are needed.
- Prefabricated containers and closures do not need to be cleaned or sterilized. The BFS machine creates a sterile, clean container since filling calls for it.
- Material transportation, storage, and inventory control expenses are decreased.
- There are less validation requirements.

Recent years have seen a significant growth in the market focus on blow-fill-seal technology because of the growing interest in proteins, biologics, and other complicated solutions. These crucial goods frequently lose their active ingredients when exposed to high temperatures over prolonged periods of time. Because of this, using conventional terminal sterilization to create a "sterile" product is unacceptable.

CONCLUSION

In summary, the world of pharmaceutical packaging materials and cutting-edge packaging methods is always changing because of the twin goals of improving patient experience and guaranteeing product safety. It is impossible to exaggerate how important it is to choose the right packaging materials because they are essential to maintaining the effectiveness of drugs, shielding them from the elements, and maintaining regulatory compliance. A dedication to meeting the changing demands of patients and healthcare providers is reflected in the move toward creative packaging options. The pharmaceutical business is adopting innovations that protect the quality of medications and enhance prescription adherence and consumer convenience. Examples of these innovations include child-resistant packaging and smart packaging technology.

Moving forward, navigating the complicated terrain of changing safety standards and sustainability issues will require cooperation between pharmaceutical companies, package producers, and regulatory authorities. Achieving equilibrium between inventiveness and pragmatism will be crucial for fulfilling the requirements of a constantly evolving healthcare landscape. The pharmaceutical packaging industry is an essential component of the healthcare process rather than merely a means to an end in this dynamic environment. The ongoing quest of quality in packaging materials and methods demonstrates a dedication to patient welfare and the industry's overarching objectives. The future offers packaging options that not only fulfill the greatest standards of safety and performance but also make healthcare smoother and patient-centered by combining tradition and innovation in a harmonious way.

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