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Applications of Biodegradable Pharmaceutical Packaging Materials: A Review

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Abstract: Exploitation of plastic packaging films at large scale lead to ecological trouble because of their non-biodegradability. Utilization of plastics as packaging material has to be controlled to protect environment. A supporting pollution free environment can be created by use of eco-friendly packaging. Consequently, the idea of biodegradability has the benefits of both user-friendly and eco-friendly features. Eco-friendly packaging materials are safe to enclose pharmaceutical products as they are non-toxic. There are various packaging materials to pack different dosage forms. Starches are widely used as eco-friendly packaging material, as it is from natural resources. They cause no harm to the environment and living species. In this review article, functions and selection factors of packaging eco-friendly materials are overviewed and also their future need is also highlighted.

Key words: Packaging Material · Eco-Friendly · Biodegradable · Environment

INTRODUCTION

Worsening of environment is directly caused by soil, air and water pollution. Industries of toxic chemicals are responsible for pollution. The toxic chemicals enter into the natural streams, which is hazardous to environment. In developing countries, anywhere plastics are thrown unsystematically; so there are chances that they can be consumed by grazing cattle. This may result in various problems in cattle including choking gastrointestinal tract, indigestion. Moreover, the additives present in plastics (such as synthetic colouring materials derived from coal tar dyes, plasticizers and other ingredients) may undergo metabolism and produce toxic compounds [1]. In India, daily about 80,000 metric tons of municipal solid waste is generated in which 3 % is plastic wastes [2]. On other side in USA, each day 400,000 tons of hard garbage is generated, in which plastics constitute 30 % of its volume. This solid waste disposal causes new challenges. Usual methods for managing plastic wastes comprise recycling, land filling, incineration and depolymerisation [3]. The main problem with plastics is their resistance to biodegradation. They preserve in nature undegraded even after composting by heat and radiation of sun. There is need for awareness regarding the alternative packaging materials fabricated from natural polymers. Bio-polymeric films are generally equipped by use of materials such as proteins, polysaccharides, lipids and their derivatives, which are abundantly available in nature [4]. Natural bio-polymeric films have the advantage over synthetic biopolymers since they are totally biodegradable by living organisms and are derived from renewable raw materials [5]. Bio-polymeric films have also desirable overall mechanical and barrier properties [6].

Packaging: Packaging requirements for pharmaceutical products are complex than those of other non-edible products. Pharmaceutical packaging is an art and science of preserving and protecting pharmaceutical product from damage by enclosing them. Packaging material is any materials which enclose/surround the product since the time of manufacturing to till final usage [7, 8]. The main roles of a packaging material are to protect and present the products. Packaging protects the product during storage (loss of colour, taste or odour), transportation and at the time of utilization. Packaging also enhances convenient handling and compliance to the product [8, 9]. Packaging material should be such that it protect product from atmospheric gas, for achieving a long shelf life [1].

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Functions Served by Packaging: The various functions served by packaging include the following [8, 10- 13]:

Protective Function

Environmental Protection:

Protection Against Temperature: A high temperature may increase the reaction rate and hence shortens the shelf life of pharmaceutical product. A good packaging plays an important role in protecting the product from such conditions.

Protection Against Moisture and Humidity: A stability problem to pharmaceutical powders which may occur at high atmospheric humidity is caking of powder. This caking of powder depends upon the moisture level inside and outside the product container. Packaging material and closures plays an important role in preventing such problems related to moisture. In the packs of moisture sensitive product, sachets of silica gel desiccant can be placed.

Protection Against Light: Amber coloured or opaque containers can be used to prevent photo-degradation of product.

Physical/mechanical Protection

Protection Against Compression: Secondary packaging helps in protecting product against compression. The cardboard are used to make secondary packs.

Protection Against Impact: Impact action occurs by dropping product. Cushioning the primary pack and also placing the primary pack in secondary pack, prevent or minimize the damage due to impact.

Protection Against Vibration: Cracking of emulsion during transportation is caused by vibration. So there is need of good packaging.

Biological Hazards Protection: Packaging prevents contamination of product from microbes.

Presentation of Information Regarding Product: Packaging provides information about the packed product such as date of manufacturing, expiry date, lot number, etc.

Provide Identification for Product: Pack serve as a tool for identification of packed product.

Providing Convenience During Handling: There are various types of packaging which helps in easy handling of product.

Tool for Advertising and Marketing of Product: Packaging and labelling serve as a tool for marketing of a product. The colour full print and eco-labels improves the organoleptic features of packing.

Ideal Properties for Eco-friendly Packaging Materials [10, 12]: Pharmaceutical industries are progressing to employ reusable packaging materials. Eco-friendly pharmaceutical packaging is one of the newest right global trends. It adds brand to a particular product [16].

Biodegradable Materials for Pharmaceutical Packaging: Marine food processing industry wastes and agricultural feed stocks wastes are employed to prepare the raw materials for manufacturing biodegradable packaging materials [17]. Thus, capitalization on natural resource conservation is helpful in creating environmentally friendly and safe atmosphere. Biodegradable packaging materials on composting or biodegradation they may act as soil conditioner and fertilizer, which are the additional benefit produce by them. Bio-packaging is important for future packaging [18]. Hydrocolloids and lipids are generally used for preparing biodegradable packaging materials [19]. Glycerol, polyethylene glycol and sorbitol are used in the film formulations as plasticizers, to impart flexibility [20]. The major polysaccharide hydrocolloids have the ability to produce thin films are pectins, starch, cellulose, chitosan and their derivatives [21].

Examples of Eco-friendly Packaging Materials: Paper and board: Papers are the naturally occurring packaging material which is biodegradable and recycled easily. Therefore, these are suitable for making eco-friendly pharmaceutical packaging material [22, 23]. Wood is the source for cellulose fibers [24]. Cellulose fibers network form paper and paperboard. Since, long time paper and paper boards are used for packaging. Papers have light weight as compared to other packaging material. Permeability to gases and moisture is the main disadvantage of paper packaging. Also, it is easily tear-able. Paper are used for preparing the outer containers examples are boxes, cartons, envelops etc. Consider an example of blister and strip of tablets, suppositories, capsules that are packed in board carton. Collapsible tubes containing creams, ointments are be packed in an outer paper board carton. The coating and impregnation of paper with resin solution, waxes are usually done. This help to enhance the protective and functional properties [25- 27]. Depending on the type of chemical treatment, the papers are classified into various types, such as glassine paper, grease proof paper, kraft paper, sulphite paper etc. Paperboards in comparison to paper are thicker and composed of multiple layers of paper. Paperboards are used for secondary packaging for pharmaceutical products [28, 29]. There are different types of paperboards and some of them are as following:

White Paperboards: Generally, chemically bleached pulp is employed to manufacture white paperboards. To make these paperboards heat sealable, lamination is applied on this board. Polyethylene or waxes are used for lamination. The laminated white paperboards are used for primary packaging. The internal coating of a carton can also be done by using white paperboards [8].

Chip Paperboards: It can be used to make outer covering of a carton. This paper board is made from recycled papers. By using white paperboards the lining of chip board is done, which improves its mechanical strength and appearance [8].

Solid Paperboards: It is composed of multiple layers of board. Bleached sulphate boards are commonly used to manufacture solid paperboards. These boards are generally laminated with polyethylene [8].

Fiber Paperboards: There are two types of fiber paperboards including corrugated and solid fiber paperboards. Corrugated type of paperboard is composed of two layers of kraft paper which are having corrugate material between them. This type of fiber paperboard possesses high resistance against impact. It is commonly used for packing materials which are transported by ships [30]. On the other hand, solid paperboard is composed of two layers, an inner and outer layer. White paperboards constitute the inner layer and kraft paperboard fabricate outer layer. Lamination of solid paperboard is done by plastic or aluminium. This lamination keeps the packed product in dry form [8].

Cork: Generally cork is obtained from bark of oak tree. The chemical inertness of cork makes it useful. It also does not impart flavour, odour to the packed product [8].

Starch: Starch is a polysaccharide and obtained from legumes, cereals, tubers [31]. Rice, corn and wheat are the major source of starch [32- 36]. Starch is used to prepare eco-friendly packaging material. Starch is pressed into sheets and used to protect the glass dishes, trays etc [37-38]. Starch beads are used as a loose fill for packaging, bags and sacks, flexible and rigid packaging. In preparing starch packing material, plasticizers are used to make starch materials less brittle. Mainly plasticizers which are biodegradable such as glycerol, polyether, urea and polyhydroxy components are used. Another role of plasticizer is, to inhibit the growth of microbes. There are following types of starch based polymers [8, 38-40]:

- Starch based thermoplastic products
- Starch-polyvinyl alcohol
- Starch-synthetic aliphatic polyester
- Starch polybutylene succinate

Cellulose: It occurs in nature abundantly. There are various commercial products of cellulose derivatives including ethyl cellulose, methyl cellulose, cellulose acetate, carboxy methyl cellulose, hydroxyl ethyl cellulose and hydroxyl propyl cellulose. Commonly cellulose acetate is used for laboratory purpose and to prepare pharmaceutical packaging material [38, 41- 43].

Xylan: It is a carbohydrate and plant cell walls are the main source of xylan. It is also obtained from various algae. Biodegradability is the main advantage of xylan. Hence it can be used for preparing eco-friendly packaging material. Xylophane is commonly used for this purpose [8, 44, 45].

Chitin: Invertebrates, insects and yeast are the main source of chitin [46, 47]. Chitin possesses antimicrobial activity, which make its wide use in packaging material. Heavy metal ions are easily absorbed by chitin, which make it perfect to prepare packaging material in edible coatings. Chitosan is a derivative of chitin. Usually biodegradable laminations are prepared by chitosan-cellulose. Chitin is a hard, white, inelastic, nitrogenous polysaccharide [48]. The average molecular weight of chitin is 1.03 to 2.5 × 106 Dalton [49]. Biocompatibility of chitosan allows its use in various biomedical applications [1]. The biodegradation of chitin is a very slow process. It results in accumulation of the crustacean shell waste in the seafood industry [50]. In India about 2000 tons of chitin is produced [51]. Amino polysaccharide chitin can be recovered from crustacean wastes by processes such as demineralization and deproteinization [52]. Chitosan as eco-friendly material can be used in waste treatment, water purification, paper finishing, as a proton conducting polymer in batteries, cosmetics, as preservative for fruits and to prepare packaging films [53-70]. Polyethylene glycol (0.25-0.5%) is used in chitosan modified films to reduce water vapour transmission rate of the film [71].

Protein: Packaging materials are prepared from protein, by modifying their side chains in structure. To make a biodegradable packaging film, cross linking of natural protein with the synthetic monomer unit is done [72]. Agricultural feed stocks are widely used for making protein based packaging materials. These are easily available and renewable. There are two sources of protein, namely plant and animal. Proteins obtained from plant include zein, gluten, soy etc whereas animal oriented protein includes whey, casein, gelatin, collagen, keratin etc. The followings are some proteins which are commonly used to prepare pharmaceutical packaging material [8, 73- 87]:

Gluten: To obtain gluten, corn and wheat are the main sources. It is a protein which possesses plastic like characteristics (example resistance to water). It is cheap in cost and can be used in manufacturing of edible films [8].

Zein: Zein includes alcohol soluble proteins. It is used in coating of pharmaceutical products and in manufacturing of biodegradable packaging materials [8].

Soy: There are three varieties of commercial soy and include soy isolate, soy concentrate and soy flour. It is used to manufacture biodegradable plastics and films. It is also used as a coating substance for pharmaceutical products [8].

Casein: It is a type of animal oriented protein. Milk is the source for casein, from which it is easily processed out. Casein is used in manufacturing of thermoset type of plastic. Due to its good adhesive ability, it can also be used for labelling purpose [8].

Whey: Basically, it is a by-product obtained from cheese industry. It is used to produce packaging films and to make edible coating on pharmaceutical products [8].

Gelatin: Bones and skin of animals are the main source of gelatin. Gelatin is used to prepare microspheres and to microencapsulate vitamins. A film of gelatin is usually used to prepare capsule shells and in fabrication of tablets [8].

Collagen: It is a fibrous protein and animal skin, tendons and bones are the main source for collagen. It is used to prepare packaging materials [8].

Keratin: Animal hair and nails are the main source for keratin. It is the cheapest protein among animal oriented proteins. Generally, biodegradable plastics are prepared from keratin [8].

Polylactic Acid: Polylactic acid (PLA) is prepared from lactic acid. It has a good potential for trade scale fabrication of renewable packaging material. PLA is chemically synthesized by condensation polymerization of lactic acid [88]. Polylactide polymers and co-polymers are used for manufacturing biodegradable plastics. PLA may be used to manufacture blown films and injection molded objects [89].

Pullulan: Pullulan is a viscous polysaccharide extracellularly produced by fungus *Pullularia pullulans* or *Aureobasidium pullulans.* These fungus are commonly known as black yeast [90]. Pullulan consists of maltotriose units. Films made up of pullulan are colourless, transparent and oil resistant. Pullulan can be used as packaging film material [91].

Miscellaneous Biodegradable Polymers:

- Polyhydroxyalkanoates (PHA) are produced as well as degraded by microbes [92]. They are thermoplastic polyesters and prepared by simple fermentation process. To produce PHA glucose and acetic acid are used in culture media.
- Polyhydroxy butyrates are natural thermoplastic polyesters. Thus, they may be used as substitute for plastics [93].

Conclusion and Future Prospectives of Eco-Friendly Pharmaceutical Packaging Components: Commercialization of biodegradable packaging materials has many challenges; however several opportunities are also possible. Chitosan, starch and other biodegradable packaging materials are best suited, because of their availability in native and chemically modified forms for preparing biodegradable packaging films. These films can be useful for shelf life extension of pharmaceutical products as well as several processed foods. Their total biodegradation make them eco-friendly products which have needs to be capitalized on to conserve ecology for future generations. Now days, multi-component coatings and films have gain additional attention. These materials show joint functional attribute. Example polysaccharides give cohesion and proteins give rise to a very tight structure (because of their inter-/intramolecular folding) and the lipid molecule contribute their hydrorepulsive nature. Eco-friendly packaging materials should comply with drug packaging legislation, which is major important requirement for them. More specifically there should no incompatibility between drug products and packaging material. Together these desired types of features result in no compromise in packaging material quality and eco-safety. Eco-friendly packaging materials are expensive, but they offer alternative routes for management of waste and helpful to control pollution in future.

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