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REVIEW ARTICLE

Polymers: Excellent Formulations Devising Agent

Basudev Sahana*, Kuhu Bhaduri

Department of Pharmaceutics, Institute of Pharmacy, Jalpaiguri, Dept. of Health and Family Welfare, Govt. of West Bengal, India.

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ABSTRACT

Polymer is a large molecule made by linking many monomers together. A wide variety of polymers have been discovered with the great efforts of polymers scientists. Polymers are the backbone of pharmaceutical formulation design and development for both the conventional and controlled release drug delivery systems. Varieties of polymers have been utilized in pharmaceutical product development for their appreciate biodegradable, biocompatible and mucoadhesive characteristics. The chemical characteristics of polymers depend on the chemistry of their monomer units and nature of the link between two monomers. Most of the pharmaceutical formulations have been devised based on the polymeric materials. The present study is highlighting the polymeric substances with specific properties such as solubility, sensitivity, biodegradability, biocompatibility, antigenicity, film forming nature, mucoadhesiveness etc. and their utilization in pharmaceutical formulation development, drug carrier activity, mucoadhesive formulations, food industries, dairy and meat products and tissue engineering fields. The biodegradable, biocompatible and mucoadhesive polymers have been specially discussed with their chemistry and pharmaceutical applications as an excellent excipient in controlled release drug delivery systems. The biodegradable polymers poly lactic acid (PLA), poly glycolic acid (PGA) and their conjugate poly lactide co glycolic acid (PLGA) (85:15) based parenterally administrable nanoparticles containing anti cancer drug tamoxifen citrate as depot formulations for long term activity has been specially highlighted in this article.

KEYWORDS

Controlled Release, Nanoparticles, Depot, Mucoadhesive, biodegradable, PLGA.

INTRODUCTION

The pharmaceutical research laboratory and industry have constantly been engaged in devising dosage forms with the objectives of optimization of pharmacological / therapeutic effects and minimization of drug toxicity or formulations related hazards.

*Address for Correspondence:
Dr. Basudev Sahana
Department of Pharmaceutics, Institute of Pharmacy, Jalpaiguri, Govt. of West Bengal
P.O. & Dist. - Jalpaiguri, West Bengal,
PIN – 735101, India.
E mail ID: bsahana_29@yahoo.com

The new formulations have been designed and developed for maintaining the effective or therapeutic blood levels of drugs for prolong period without causing dose dumping in the patient's system. The controlled release formulations based on polymers where poly (sebacic acid) and poly (lactic acid) have been used as drug carrier for methotraxate[1] at a predetermined rate may provide prolong action through the maintenance of therapeutic blood level and spatial placement of the several drug formulations made of varieties of mucoadhesive polymers or agents[2] in the site of action or absorption fulfill the goal for providing an

effective amount of drug to the proper site in the body to achieve action promptly. **Polymeric materials** based drug delivery systems (PMBDDS) is now very much important and glorious fields among the several controlled drug delivery strategies such as micro and nanoparticles formulations, depot delivery systems, polymer matrices, microemulsion, nanosuspensions, floating tablets, mucoadhesive polymers based dosage forms, etc. Specially devised biodegradable polymer PLGA (85:15) based nanoparticles containing anticancer drug (Figure-1 & 2) has been developed for delivery as depot formulation[3],

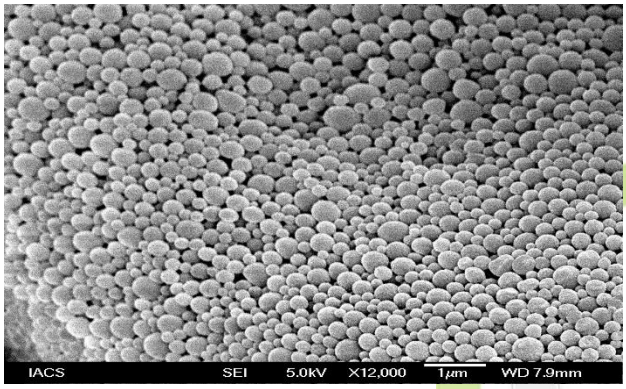

Figure 1

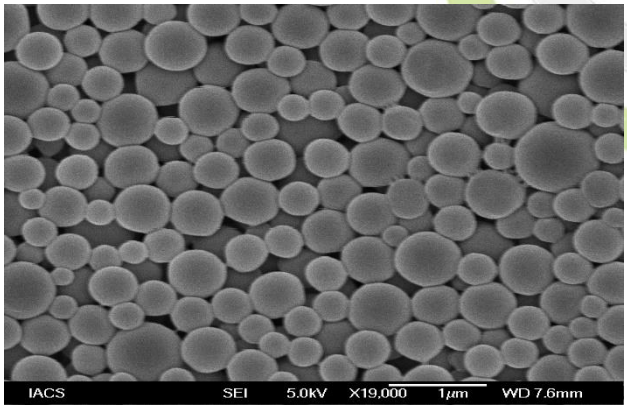

Figure 2

diffusion, swelling and erosion are the rate controlling mechanism utilized in HPMC polymer based matrices incorporated buflomedil pyridoxal phosphate, triflupromazine HCl and 5-fluouracil delayed release formulations have been developed[4], natural mucoadhesive agents or polymers based tablets have been designed and developed[5] and polymer based floating systems[6] formulations development affecting gastric retention through the physiological and formulation variables**,** polymeric materials based liposomes[7] containing drugs and genetic materials (Figure 3), polymers used emulgents and stabilizers

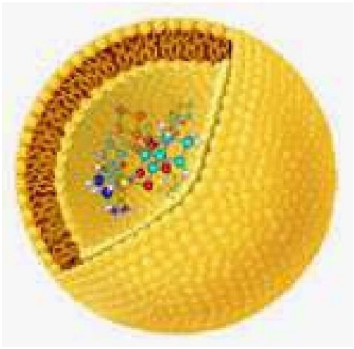

Figure 3: Drug Loaded Liposome

microemulsions based hydrogel for topical delivery[8]**,** solubility and stability enhancing solid dispersions containing ofloxacin[9], polymer based long acting transdermal systems[10]**,** cyclodextrin inclusion complexes drug delivery systems[11]. The placement and long term action can be achieved from the special formulation based on mucoadhesive[12] polymers interacting with the mucus membrane that lines organs and body cavities such as mouth, gut, rectum, genital area, nose and eye lid.

Objectives and Advantages of Polymers through Devising Controlled Drug Delivery Systems (CDDS)

The study lays emphasis mainly on the polymers used in CDDS, and design and development of CDDS with the natural polymers**.** Specially designed dosage form using different grades of polymers with controlled release of drug at a predetermined rate and spatial placement of the drug formulations in the site of action or absorption fulfill the goal for providing an effective amount of drug to the proper site in the body to promptly achieve action and then maintain the desired drug concentration for a long time. Polymers are advantageous for prolongation of residence time of dosage forms[13], controlling of drug release from dosage forms used to optimize therapeutic efficacy, to reduce dosage,

toxicity or side effects of drugs[14] and site specific delivery of drugs[15].

Polymers as Excellent Dosage Form Devising Agents

Controlled drug delivery systems based on polymers obtained from natural, semi-synthetic, synthetic sources and specially obtained from edible plants or vegetables have been designed in such a way that make the active pharmaceutical ingredients (API) or drug available for the target, providing the sufficient release rate and prolong duration to produce the desired effect. Several polymers used in pharmaceutical formulations have been enlightened with brief discussion as follows-

Natural Polymers

Protein based Polymers

Collagen, gelatin, albumin.

Collagen is a major natural protein component. It is a triple helix molecular structure[16]. Nineteen types of collagen molecules have been isolated, characterized, and reported in both medical and pharmaceutical applications[17], Collagen gels are one of the first natural polymers used for drug delivery and tissue engineering because of its good biocompatibility, low antigenicity and degradability upon implantation[18].

Gelatin is a common natural water soluble polymer produced by denaturing collagen[19] useful in pharmaceutical and medical applications due to its outstanding biodegradability, biocompatibility and low antigenicity. It is used to control release of bioactive agents such as drugs, protein, and as support material for gene delivery, cell culture, and more recently tissue engineering. It is possible to incorporate liposome-loaded bioactive compounds into PEG-gelatin gel[20].

Albumin (Human serum albumin/HSA) is conjugated to poly-(ethylene glycol) (PEG) and cross-linked to form mono-PEGlycolated albumin hydrogels. HSA has been used as an excipient for devising pharmaceutical formulations and drug carrying tissue engineering scaffold materials[21].

Polysaccharides

Alginates, Dextran, Chitosan, Cyclodextrines, Agarose, Hyaluronic acid, Starch, Cellulose, Carrageenan, Polysialic acid, etc.

Alginate (ALG) is a group of naturally occurring anionic polysaccharides derived from brown algae cell walls[22], seaweed[23] including Macrocystis pyrifera, Laminaria hyperborea, Ascophyllum nodosum[24] and several bacteria strains such as Azotobacter, Pseudomonas[25]. Alginates are linear biopolymers consisting of 1, 4-linked β-D-mannuronic acid (M) and 1, 4 α-L-guluronic acid (G) residues arranged in homogenous (poly-G, poly-M) or heterogenous (MG) block-like patterns. ALGs are useful polymer as viscosity increasing agents, thickeners, suspension and emulsion stabilizers in food and pharmaceutical industry. ALG is useful for its mucoadhesive properties to prepare buccal, nasal, ocular, gastrointestinal and vaginal mucosa tissue[26].

Dextran is an extracellular bacterial homopolysaccharide composed of contiguous -(1,6)-linked d-glucopyranose residues and branches, stemming mainly side-chains of -(1,6) glucose units attached by -(1,3) branch linkages to -(1,6)- linked chains[27] used for devising sustain release dosage forms of proteins, vaccines, and drugs for its water solubility, biocompatibility and biodegradability properties.

Chitosan is a natural polycationic copolymer consisting of glucosamine and N-acetyl glucosamine units, mostly obtained by deacetylation of chitin derived from the exoskeleton of crustaceans. Chitosan has valuable properties of biocompatible and biodegradable for devising nanoparticulate pharmaceutical formulation[28].

Cyclodextrins are naturally available in three forms as alpha, beta and gamma consists of six, seven and eight D-glucopyranose residues respectively, linked by α-1,4 glycosidic bonds

into a macrocycle, useful for carrying drug materials. It can alter physical, chemical and biological properties of active molecules through the formation of complexes. Cyclodextrin - tamoxifen citrate complex is utilized for enhancing the solubility of tamoxifen citrate[29]. The different hydrophilic, hydrophobic and ionic derivatives of cyclodextrin are used as an excellent devising agent for novel drug carriers to administer drugs in various route such as oral route of drug delivery (Prednisolone; to reduce gastric ulceration), nasal drug delivery (Midazolam; to enhance bioavailability of drug)[11].

Polysialic acid is a linear polymer of sialic acid, covalently bound to proteins as a post-translational modification. 1. It is widely expressed in nature in bacterial capsules, fish, sea urchin eggs, embryonic tissues, amphibians, animal and human brains, and in a variety of cancers. 2. Polysialic acid, a homopolymer of α 2, 8-linked sialic acid, is one of the carbohydrates expressed on neural precursors in the embryonic and adult brain. Polysialic acid, synthesized by two polysialyl transferases (ST8SiaII and ST8SiaIV), mainly modulates functions of the neural cell adhesion molecule. Polysialic acid based micelles for encapsulation of hydrophobic drugs will be helpful for better therapeutic efficacy[30].

Carrageenans are high-molecular-weight polysaccharides made up of repeating galactose units and 3, 6-anhydrogalactose, both sulfated and nonsulfated[31]. The units are joined by alternating alpha 1-3 and beta 1-4 glycosidic linkages, obtained from several species of red seaweeds. It is useful for tissue engineering, wound healing, growth factor, drug delivery systems, immobilization of enzymes, and encapsulation of cells for *in vivo* delivery[32]. The gelling, thickening, stabilizing and strong interaction with protein properties of carrageenans are widely useful in the food industry, dairy and meat products.

Agarose is complex group of polysaccharide derived from seaweed, extracted from the agarocytes of *Rhodophyceae,* marine algae found predominately in the Pacific and Indian Oceans. It is comprised of a basic repeat unit consisting of 1, 3 - linked-d-galactopyranose and 1,4-linked 3,6-anhydro-α-l-galactopyranose[34] that undergoes thermal cross-linking and used as a matrix to encapsulate cells for cartilage tissue engineering[33, 34].

Hyaluronic acid is a major component of skin involved in tissue repairing and found throughout the body in various tissues, fluids and binds to specific cell surface receptors. Hyaluronic acid is the only non-sulphated glycosaminoglycan that consists of repeating units of N-acetyl-d-glucosamine and d-glucuronic acid and is degraded in the presence of hyaluronidases. Hyaluronic acid hydrogels are readily fabricated as microspheres, sponges and fibers depending on the intended application[35].

Starch is a branched polysaccharide composed of two substances: amylose and amylopectin. Natural starch contains 10-20% amylase and 80-90% amylopectin. Amylose forms a colloidal dispersion in hot water whereas amylopectin is completely insoluble. Starches are hydrolysed to simple sugars using acids or enzymes as catalysts. It plays an important role in pharmaceutical formulation development as binder, disintegrants, strong film forming agent[36].

Cellulose is the most abundant polysaccharide found in nature, a polymer of long, un-branched chains of β -D-Glucose, oriented with CH_2OH groups alternating above and below the plane of the cellulose molecule. The absence of side chains in cellulose molecules brings them close to each other to form rigid structures. Cellulose is mainly used to produce paper and paperboard[37].

Microcrystalline cellulose (MCC) is playing an important role in formulation design of solid dosage forms as multifunctional excipients such as compressibility enhancer, binder in granulations, thickeners and flow enhancer[38].

Semi-Synthetic

Cellulose Derivatives

Cellulose nitrate (CN), cellulose acetate (CA), cellulose ethers (CE), methylcellulose (MC), ethylcellulose (EC), hydroxy-ethylcellulose (HEC), Hydroxyl propyl cellulose (HPC), hydroxy propyl methylcellulose (HPMC), sodium carboxy methylcellulose (Sodium - CMC), Cellulose acetate butyrate (CAB), Cellulose acetate phthalate (CAP).

Cellulose ethers and esters are useful for formulation of dosage forms and health care products such as delayed and extended release matrices, osmotic drug delivery systems, bioadhesive and mucoadhesive formulations, compressed dosage forms. They are widely used as thickeners, stabilizers, binders, gelling agents, fillers, taste masker, flow property enhancer, coating materials and as pressure sensitive bioadhesive[39].

Alginic Acid Derivatives

Sodium alginate ($NaC_6H_7O_6$) is a linear polysaccharide derivative of alginic acid comprised of 1,4-β-d-mannuronic (M) and α-l-guluronic (G) acids. Sodium alginate is a cell wall component of marine brown algae, and contains approximately 30 to 60% alginic acid. Sodium alginate and other derivates are playing major role in several other biomedical fields, such as tableting agent[40], excipient for developing multiunit dosage forms, gastroretentive drug carriers, especially for substances unstable in the alkaline pH[41] due to its many properties such as biocompatibility, biodegradability, low toxicity, non-immunogenicity, water solubility, relatively low cost, stabilizing properties and high viscosity in aqueous solutions.

Acrylic Acid Derivatives

Poly (acrylic acid) polymers (carbomers, polycarbophil), Poly (hydroxyethyl methylacrylate), Poly (ethylene oxide),

Polyacrylic acid (PAA) is a weak anionic polyelectrolyte, whose degree of ionisation is dependent on solution pH. In aqueous solutions PAA can also form polycomplexes with oppositely charged polymers like chitosan, surfactants, and drug molecules like streptomycin[42]. They are also popular as thickening, dispersing, suspending and emulsifying agents in pharmaceuticals, cosmetics and paints. The neutralized polyacrylic acid gels are suitable to obtain biocompatible matrices for medical applications such as gels for skin care or skin disease treatment products. PAA films can be deposited on orthopaedic implants to protect them from corrosion.

Carbomer is a synthetic high-molecular weight polymers of acrylic acid. However, in aqueous solutions the sodium ions are free to move since they are replaced by positively charged hydrogen ions. Instead of an organized polymer chain, this leads to a swollen gel that can absorb a high amount of water.

Polycarbophil (semi synthetic fiber) is a bulk-forming agent, bioadhesive polymer useful to stabilize peptides by inhibiting proteolytic activity. Polycarbophil and Chitosan derivatives[43] have been reported to improve the permeation of the peptide drug 9-desglycinamide, 8-arginine vasopressin (DGAVP) across the mucosa. Polycarbophil polymers are used for its good bioadhesion, permeation enhancement and protease inhibition properties.

Poly (hydroxyethyl methacrylate)/(HEMA) is a hydroxyester and monomethacryloyl derivative of ethylene glycol. 2-Hydroxyethyl methacrylate is a hydrophilic polymer widely used in dental adhesive system for desensitizing dentin and numerous biomedical applications[44].

Poly (ethylene oxide) copolymers are used for nanoparticulate drug delivery systems, commercially available as polaxmers in a range of liquids, pastes and solids, have found a wide range of applications in the pharmaceutical and biomedical fields[45]. Soluble block copolymers based on PEO-PLA can self – assemble into novel supramolecular structures and are being investigated for delivery of anti-cancer agents, proteins and plasmid DNA[46].

Synthetic Polymers

Biodegradable Polymers

Polyanhydrides: Poly(sebacic acid)(PSBA), poly(adipic acid) (PAPA), etc.

Poly (sebacic anhydride) (PSA) prepared from sebacic acid, is a biocompatible and biodegradable polymers. Copolymerization of PSA with an aromatic anhydride decreases degradation rate, compared to PSA-alone[47]. Polyanhydrides and their degradation products are considered non-cytotoxic, non-mutagenic, non-carcinogenic[48] and are extensively metabolized by rat brain tissue[49]. A biodegradable local drug release system consisting of poly (sebacic anhydride) and polylactic acid has been developed for the purpose of osteomyelitis therapy. The drug release rate can be easily controlled by the molecular weight of the poly(sebacic anhydride) for long term action in the treatment of chronic osteomyelitis, as well as for other medical applications[1].

Adipic acid is the most important dicarboxylic acid, used as a comonomer with hexamethylenediamine to produce nylon 6-6, polyurethanes. Adipic acid has been incorporated into controlled-release formulation matrix tablets to obtain pH-independent release for both weakly basic and weakly acidic drugs and also incorporated into the polymeric coating of hydrophilic monolithic systems to modulate the intragel pH, resulting in zero-order release of a hydrophilic drug. The disintegration at intestinal pH of the enteric polymer shellac has been reported to improve when adipic acid has been used as a pore-forming agent without affecting release in the acidic media. Other controlled-release formulations have included adipic acid with the intention of obtaining a late-burst release profile[50].

Polyamides: Polyglutamic acid, Poly (imino carbonates) (PIC), polyamino acids (PAA) etc.

Polyglutamic acid is a polymer of glutamic acid, water soluble, biodegradable, having multiple carboxyl groups which are amenable for chemical modification, low immunogenicity and low toxicity, favourable for controlling in vivo disposition characteristic of anti-tumour agent. Poly-L-glutamic acid has been glycosylated to facilitate liver-specific targeting. Nanoparticles based on poly glutamic acid have been used to deliver the drugs like peclitaxel, doxorubicin in cancer therapy and research is underway for its application in a treatment of type I diabetes and its potential use in the production of an AIDS vaccine[51].

Poly (imino carbonates) are 'pseudo' polyamino acids, have been synthesized from tyrosine dipeptide to overcome , polyaminoacid's limitation as their antigenic potentials and poor control of release due to dependence on enzymatic biodegradation[52].

Polyamino acids is a good biocompatible polymer which have been investigated for the delivery of low-molecular-weight compounds. However, their widespread use is limited due to antigenic potentials and poor control of release because of the dependence on enzyme for biodegradation. The use of amino acids as building blocks for synthetic absorbable polymers would seem logical. Attachment of methotrexate to poly -L-lysine enhanced transport into the cells where the drug has been released due to degradation of the poly (amino acid) moiety by lysosomal enzymes. Enzymatically degradable synthetic peptides have also been used to form cross links in drug releasing synthetic hydrogels[53]. These hydrogel implants would otherwise be nondegradable if standard chemical cross-linking methods are employed.

Phosphorous-based: polyphosphates, polyphosphonates, polyphosphazenes etc.

Poly (phosphoester)(PPE) - These polymers are generally referred to as Phosphonates , polyphosphonates or polyphosphites depending upon the nature of the side chain attached to the phosphorus[54]. This undergoes hydrolysis to alcohol and phosphates which easily undergo excretion and metabolism respectively. A controlled gene delivery system with PPE has been developed in 2008 and has been patented.

Polyphosphazenes is a relatively new class of biodegradable polymers belonging to

polyphospho esters has a unique backbone consisting of phosphorous atoms attached to either carbon or oxygen. The uniqueness of this class of polymer lies in the chemical reactivity of phosphorous, which enables a wide range of side chains to be attached for manipulating the biodegradation rates and the molecular weight of the polymer[55].

Others: Poly (cyanoacrylates) (PCA), Polyurethanes, Polyortho esters, Poly dihydropyrans, Polyacetals, etc.

Ethyl cyanoacrylate (ECA) is a clear, colourless liquid with a strong, acrid odour. It reacts readily with water to form a solid polymer. It is soluble in methyl ethyl ketone, toluene, acetone, N,N-dimethyl formamide, and nitromethane. Polymerization may occurs when react with alcohols, amines, or water[56]. However, the main pharmaceutical applications for cyanoacrylates as adhesives include manicuring (attaching false nails, repairing cracks), dentistry, surgery and mortuaries.

Polyurethanes are a broad class of polymers consisting of a chain of organic units joined by urethane links. Concern about environmental protection and efficient energy utilization, one of the problems related to the production of PU nowadays is their dependence on petroleum-derived products. A great variety of building blocks is commercially available that allows the chemical and physical properties of PUs to be tailored to their target applications, particularly for the biomedical and pharmaceutical fields. Particular emphasis is placed on the use of PUs for the controlled release of drugs and for the (targeted) delivery of biotherapeutics[57].

Poly (orthoester) is a biodegradable polymers suitable for orthopaedic applications. With the addition of lactide segments as part of the polymer structure, tuneable degradation times ranging from fifteen to hundred days can be achieved. The degradation of the lactide segments produces carboxylic acids, which catalyze the degradation of the orthoester. POE-based norethindrone implants has been prepared along with water soluble excipients[58]. These water soluble osmogens attract water into the otherwise hydrophobic polymer and there is subsequent swelling and release of incorporated drug.

Polyesters: poly (hydroxyl butyrate) (PHB), poly (Ɛ-caprolactone) (PCL), poly (β-malic acid) (PMA), poly (dioxanones) (PDA), Poly (lactic acid) (PLA), poly (glycolic acid) (PGA), poly 9lactide co glycolide) PLGA, etc.

Polyhydroxyl butyrate (PHB) is a biodegradable polymer occurs in nature and can easily be synthesized in vitro. Synthetic PHB is a high molecular weight, crystalline and optically active. PHB has been extracted from bacteria and proposed for use as absorbable suture59. Streptokinase loaded polyhydroxybutyrate-co-hydroxyvalerate (PHBV) prevented postoperative adhesion formation through continuous release. PHBV membrane alone also reduced the severity of adhesions due to its anti-adhesive properties[60].

Poly Ɛ-caprolactone (PCL) is synthesized from Ɛ-caprolactone. Polycaprolactone is a semicrystalline linear polyester produced by ring-opening polymerisation of *epsilon*-caprolactone, which is commonly derived from fossil carbon, widely used in tissue engineering field for its availability, suitability, slow degradation rate, poor mechanical properties, and low cell adhesion. Polycaprolactone has been widely used in long-term implants and a variety of drugs have been encapsulated within PCL beads for controlled release and targeted drug delivery[61].

Poly β-malic acid (PMA) is a biodegradable polymer used as a macromolecular prodrug. It is expected that poly- beta -malic acid, which is an intermediate in the Krebs cycle and, therefore, would be readily metabolized in the body[62], used as bioresorbable polyvalent drug-carrier. It is shown that the rate of degradation obeys first order kinetics at the begining and that poly (β -malic acid) degrades to malic acid at last[63].

Poly dioxanones (PDA) is analogous to glycolide but yield a poly-(ether-ester). The first clinically tested monofilament synthetic absorbable suture is made from polydioxanone

(Ethicon). Polydioxanone monofilament fibers retained tensile strength longer than the braided polyglycolide and has been absorbed in about six months with minimal tissue response [59]. PDA coated nano-fibers have been used for increasing long term immune responses in immune cells[64].

Poly lactic acid (PLA) is linear aliphatic polyester derived from renewable resources such as corn, sugar, potato, and other agricultural products having different isomeric components and molecular weight. PLA is widely used in biological areas due to its excellent compatibility, bioabsorbability, and degradation behavior in human bodies. Different kinds of PLA based nanocomposites[65] in recent researches that have great potential to be used in biomedical fields including bone substitute and repair, tissue engineering, and drug delivery system[66].

Poly glycolic acid (PGA) is totally synthetic biodegradable and bioabsorbable polymers, first introduced in 1970 as bioabsorbable suture. The advantages of these synthetic materials are control over uniformity and mechanical properties. Combination of PLA (Figure-4) and PGA (Figure-4) based controlled release nanoparticulate formulations have been developed for depot delivery[65].

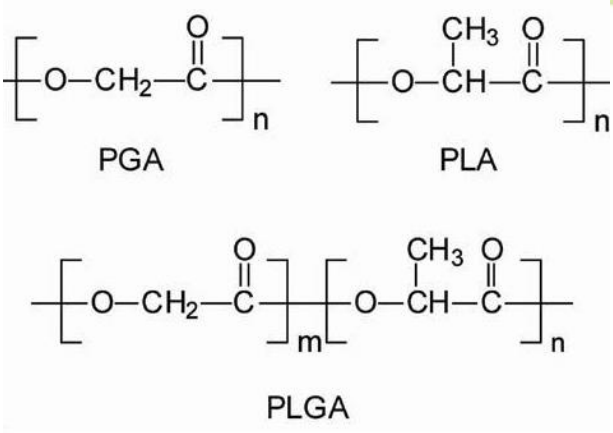

Figure 4

Poly (lactic-co-glycolic acid) (PLGA) is a conjugate biodegradable polymer of PLA and PGA, used as drug-carriers. It has been a preferred candidate for its preferable physico-chemical properties and varieties availability for developing controlled release nanoparticulate formulations[65] to achieve greater bioavailability and better efficacy for long term. The biodegradable polymer poly (D, L-lactide-co-glycolide) (Figure-4 & 5) have been utilized for controlled drug delivery, focusing on nanoparticulate[3] delivery systems for the betterment in cancer therapy. The review highlights the characteristics of the polymers, their applications in drug delivery systems in context to nanoparticles, other controlled release formulations and updates the progress of research in the field in an abridged manner.

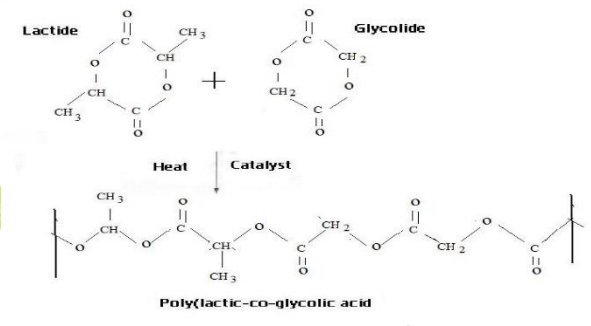

Figure 5

Biodegradable, Bioabsorbable and Biocompatible Polymers are Excellent Formulation Devising Agent

The controlled release drug delivery systems for maximizing efficacy with a reduction of side-effects represent one such approach by providing pre-programmed durations of action for offering several advantages over the conventional dosage forms[65]. Biocompatible, bioabsorbable and biodegradable polymeric materials possessing specific physical, chemical, biological and degradation properties to provide efficient therapy are preferred candidates for developing controlled release micro and nanoparticulate (capsules or spheres) formulations as they degrade in bio-system[65]. Biodegradable carrier matrices can be designed to deliver the therapeutic agents for periods ranging from a few days to months or to few years even[67].

Mucoadhesive Polymers or Agents Utilized in Devising Oral Controlled Release Formulations

A primary objective of controlled release formulations based on mucoadhesive polymers or agents administered through orally or other body cavity with mucus lining would be to achieve a prolong residence of the drug in the gastrointestinal tract. The mucoadhesive polymer in the capsule rapidly hydrated and attached to the mucin coating of the stomach. Stability problems of drugs or agents in the intestinal fluids can be overcome[68]. Therapeutic effect of drugs insoluble in the intestinal fluid can be improved, especially in the case of drug acting locally. Mucoadhesive agents such as polycarbophil-chitosan[43], hydroxyl propyl cellulose, hydroxyl propyl methyl cellulose[39], carbopol-934, carbopol-940[5] and extract from edible plant like Jute Leaf (*Corchorus olitorius* L), Vine Spinach Leaf (*Basella alba* L)[5], etc. have been used as adjuvant and as coating materials to develop oral mucoadhesive tablet for increasing residential time as well as absorption of drugs in gastrointestinal tract[5].

CONCLUSION

Pharmaceutical formulations or products design and development totally stands upon the applications of polymers for maximizing efficacy with a reduction of side-effects. Polymeric materials may provide the potential alternative dosage form for optimization of therapeutic efficacy with long term action and minimization of drug hazards. Now a days, the most useful pharmaceutical preparation have been devised by using biocompatible, bioabsorbable and biodegradable polymers to minimize the toxicity of polymers. This article enlightened the polymeric substances used in drug delivery system development especially biodegradable polymers have one of the greatest ranges of utility in controlled release of drug. They can be utilized in injectable formulations, oral formulations, bioadhesive or mucoadhesive systems and as the drug release-controlling component from formulations. The future opportunities for the in vivo use of polymers with advances in the field of formulation development are being made continuously. Researchers must also remember the possibilities for combining the natural or synthetic polymers and drug with desirable characteristics of controlled release formulations for an even wider range of applications. However, the major challenge of this area is to develop the cost effective highly accurate technology to produce the batches of formulations to fulfill goals. Huge expectation and tireless efforts of the pharmaceutical scientists and technologists may ultimately lead to the success in devising dosage forms using different polymers.

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