Utilization of biodegradable polymers in veterinary science and routes of administration: a literature review

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ABSTRACT
The development of innovative pharmaceutical forms is a constant practice in research, development and innovation in laboratories, being of interest to researchers in both academia and industry. The search for knowledge on these release platforms has been gaining considerable space in several areas of study and in the development of new products. One of these areas is veterinary medicine, in which we can describe about the administrations of drug doses that can be improved with the use of sustained release tools. In this review we refer to the main biodegradable polymers utilized in veterinary science and their utilization in pharmaceutical formulations.

1. Introduction
The development of innovative pharmaceutical forms is a constant practice in research, development and innovation in laboratories, being of interest to researchers in both academia and industry (Savela et al. 2016). Biodegradable polymers have been widely used for human health mainly due to their specific properties and ease of utilization. In the veterinary field, there is an increasing interest from companies and researchers to develop new drug formulations with these types of polymers. Drug delivery plays an important role in the development of pharmaceutical dosage forms for the animal health-care industry because often the duration of drug release needs to be extended over days up to several months. The majority of veterinary drug delivery systems are fabricated from non-degradable polymers, such as silicone, polyurethane and ethylene-vinyl acetate (EVA) copolymers; they are biocompatible and inexpensive (Rathbone et al. 1999).

The interest in biodegradable polymers as veterinary drug delivery systems, which control and prolong the action of a therapeutic agent, has grown in importance (Rathbone et al. 1999). When we think of polymers in veterinary science, one might think that because the subjects are not humans we do not have to beware of the risks to their health and well-being. Furthermore, we must pay special attention to food security when developing pharmaceutical products for production animals.

In the last few decades, there has been a great improvement in the development of new polymer-manufacturing techniques, decreasing the prices of the products and increasing their demand. Moreover, because of the non-toxicity of the reagents utilized in those products, the reliability on their safety is another factor contributing to their utilization by animal breeders. However, in the last few years, there has been great interest concerning the polymeric systems that do not require the removal of the device inserted in the animal (Winzenburg et al. 2004), thereby facilitating the handling, above all in large herds.

We provide this review of the main biodegradable polymers utilized in veterinary science and their utilization in pharmaceutical formulations. We will provide ample information on new technologies concerning polymer science, focusing on pharmaceutical platforms for controlled release (CR) of drugs.

2. Polymers utilized in veterinary science
There are several classes of polymers that are used in veterinary products. They can differ in their chemical structure, methods of synthesis, responsiveness to the environment and biodegradability. As mentioned before, the most utilized non-degradable polymers in veterinary science are the silicone, polyurethane and EVA copolymers. There are also biodegradable polymers. Poly(lactic-co-glycolic acid) and poly(lactide) (PLA) polymers are widely utilized examples of this class. The term degradation refers to the process of polymer chain cleavage which leads to a loss in molecular weight. Degradation induces the subsequent erosion of the material which is defined as mass loss of material due to the process of polymer chain cleavage (Rathbone and Gurny 2000).

2.1. Silicone polymeric systems
Silicone polymers are a class of organo-silicon synthetic materials with their chemical structure composed of chains of silicon and oxygen atoms (Mashak and Rahimi 2009).
This material is used primarily due its high stability and low temperature elastomeric properties (Rahimi and Shokrolahi 2001). In drug delivery systems, silicone has been used in a wide range of products. It is biologically inert, has blood compatibility, low toxicity and good environmental stability (Rahimi and Mashak 2013). This release system is indicated mainly when utilizing steroid molecules, because of its high solubility in hydrophobic silicone and low molecular weight/ volume favouring a rapid molecular diffusion (Mashak and Rahimi 2009).

In veterinary science, silicone is the major polymer utilized in hormone release systems. An example is the progesterone-releasing intravaginal device (PRID), utilized in dairy cows, and the controlled internal drug release (CIDR) loaded with progesterone, which may be administered in several species. The intravaginal route has been conceptually examined in horses using delivery systems designed principally for cattle. Although no specific intravaginal product has been formulated for use in horses, the commercially available PRID and CIDR products have been successfully used to control the estrous cycle in horses (Rathbone and Gurny 2000).

2.2. Polyurethane polymeric devices

Polyurethane is a polymer synthesized from chemical reaction of two components, polyol and isocyanate. It is one of the most utilized polymers in the health industry, both human and veterinary, because of its shape and texture versatility (Seymour and Kauffman 1992).

In the veterinary field, polyurethane is applied in the production of urethral catheters, as membranes for skin healing in surgery, as fluid support for calves that are sick or with nutritional disorders (Ahmed et al. 2005), and in implants for estrous control in several species (Medicott et al. 2004).

Ponnet (1996) has designed a polyurethane device. It is utilized for orthopaedical and surgical purposes. The device has a thermoplastic property, making it possible to shape this material in many forms. This process is very attractive for researchers and companies to develop a variety of types of products, for the most varied areas of industry.

2.3. EVA copolymers

EVA is a copolymer utilized in many areas of the industry. It can be very versatile, and is mostly found in the resistant foam textures. This class of polymer is synthesized by the polymerization of ethylene and vinyl acetate monomers (Lee et al. 2007).

EVA can be chemically blended with other molecules to change its structure and properties. For example, blends of aliphatic-aromatic copoly(ester)s (AACE) with EVA polymers display a higher melt strength than AACE alone, and this blend provides biodegradability.

In the drug release field, EVA can be applied utilizing the extrusion technology. The utilization of this system is based on a fibre on which the drug is dispersed or dissolved. The release of the drug is proportional to the concentration gradient of the fibre. The solubility of the drug is altered by the temperature and extrusion method (Van Laarhoven et al. 2002). One product that utilizes this technology is an anthelmintic bolus for Cattle (Paratec Flex Bolus – Pfizer Inc.). It has a matrix made of EVA loaded with an anthelmintic drug, and it can prolong and maintain the release of a therapeutic drug for many days (Hertzberg et al. 1994). Another form of drug delivery, utilizing EVA, is described by Burkoth (1993). In this device the material is designed for transdermal drug delivery in the animal’s ear. The drug is loaded in the polymer matrix, providing a slow drug releasing property. Other products utilizing this type of matrix have also been developed for intravaginal drug delivery.

2.4. Poly(lactic-co-glycolic acid)

Poly(lactic-co-glycolic acid) (PLGA) is one of the most utilized biodegradable polymers in the veterinary industry. This polymer is synthesized by the process of ring-opening copolymerization of two distinct monomers, lactic acid and glycolic acid. One can modify the ratios of each monomer, modifying the polymer’s characteristics.

These differences in the monomers’ ratios allow the control of degradation of the polymer (Winzenburg et al. 2004). Polymer degradation is described as the process of cleavage of the polymer chains. This process leads to a loss of molecular weight of the polymer. Consequently, the degradation leads to erosion of the material (Göpferich and Teßmar 2002).

There are two types of erosion for degradable polymers, homogeneous or bulk erosion, and heterogeneous or surface erosion (Li et al. 1995). The erosion process occurs by the penetration of water into the polymer bulk. In the surface eroding polymers, the degradation process is faster than the penetration of water in the polymer core.

This class of polymer is much utilized for developing many types of physiological devices due to its biocompatibility and biodegradability properties (Astete and Sablòv 2006). The hydrolysis rate is influenced by factors such as molecular weight, copolymer ratio, polydispersity and crystallinity. These factors can change the drug release rate from weeks to years (Winzenburg et al. 2004).

In pets, PLGA microparticles are already being utilized for GnRH analogues in chemical castration of dogs of 1–6 months. Ivermectin in microparticles is already being utilized for treatment in cattle. This device contained a copolymer ratio 50:50 and 90:10, and another polymer, poly(lactic acid), forming the matrix of the device (Miller et al. 1998). For cattle, a parasite-controlling product has been designed combining PLGA (75:25) with other polymers. The device has the anthelmintic molecule, eprinomectin, providing an extended protection against parasite infestation. Product effectiveness was tested and it was able to prevent significant infestation for over 120 days (Kunkle et al. 2013).

2.5. Poly(lactide)

PLA and lactide copolymers are aliphatic polyesters suited for disposable applications. They are biodegradable, nontoxic to humans and the environment and producible from renewable resources (Tsui 2005). PLAs are produced by ring-opening polymerization (ROP) of lactides and the acid monomers used
are obtained from the fermentation of sugar feed stocks (Lunt 1998).

There has been much effort to improve the PLA properties for it to compete with low-cost and flexible commodity polymers, by modification of PLA with biocompatible plasticizers or blending PLA with other polymers (Martin and Averous 2001).

Gavini et al. (2004) developed spray-dried poly(D,L-lactide) microspheres containing carboplatin for veterinary neoplastic treatment. The microspheres can be useful for local drug delivery in the tumour, lowering the chances of tumour recurrence and minimizing systemic adverse effects (Gavini et al. 2004). PLA can be used in medical implants in many forms such as screws, plates, pins, rods and a mesh (Auras et al. 2011). It can last inside the body from 6 months to 2 years depending on the type of PLA utilized. It is very appropriate for supporting structures such as bone, because of its strength. Burns et al. (1994) were successful in utilizing microspheres for estradiol delivery in horses. PLA was also utilized in cattle for estrous control, utilizing the progesterone molecule (Whisnant 1999). Poly(D,L-lactide) has been used to produce steroid-containing microspheres by a solvent extraction process and currently one formulation is commercially available for accurate control of ovulation in mares (Winzenburg et al. 2004). The microspheres were prepared using a solvent extraction process where a mixture of poly(D,L-lactide), drug and solvent were emulsified in water with the subsequent removal of the solvent to afford discrete particles (Rathbone and Gurny 2000). Intramuscularly administered products for estrous control of horses have revolved around the formulation of biodegradable polymeric microspheres. Poly(D,L-lactide) has been used to produce steroid-containing microspheres (Rathbone and Gurny 2000). Microspheres have been designed to deliver in a single injection the entire dose of progesterone and estradiol at a controlled rate for a duration of 12–14 days. This formulation resulted in accurate control of fertile ovulations in late transitional mares with follicles more than 30 mm (Burns et al. 2006). Microspheres loaded with either ofloxacin or clarithromycin or both macrolides are other examples of the potential application of biodegradable polymers to release antibiotic drugs in animals (Winzenburg et al. 2004).

2.6. Polycaprolactone

Polycaprolactone (PCL) is an aliphatic polyester composed of hexanoate repeat units. It is a very important polymer due to its mechanical properties, miscibility with many other polymers and biodegradability (Labet and Thielemans 2009). PCL can biodegrade from several months to several years, depending on the molecular weight, degree of crystallinity of the polymer and the conditions of degradation (Gross and Kalra 2002).

There are two methods to prepare PCL: condensation of 6-hydroxyhexanoic (6-hydroxyhexanonic) acid and the ROP of ε-CL (Gross and Kalra 2002).

Among many uses for PCL, it can be used as a long drug release platform. Many microbes are able to biodegrade PCL (Gross and Kalra 2002). With increased temperature the polymer degrades by end chain scission, and at lower temperatures, the polymer degrades by random chain scission (Joshi and Madras 2008).

PCL already has been combined with methoprene for tick infestation control (Jaffe et al. 1981). In another study, Rathbone et al. (2002) utilized this polymer in combination with progesterone, for estrous control in cattle. In a comparative study, Bunt and colleagues (1999) used a PCL polymer combined with progesterone and administered it for 7 days in cows. They compared this device with a non-degradable silicone insert (CIDR-B™) administered for 7 days as well. Both had 10% w/w progesterone. The PCL device was able to maintain similar progesterone in plasma concentrations compared to the silicone device over the period analysed (Bunt et al. 1999).

2.7. Hydrogels

Hydrogels are polymers that can be classified into two different groups, the preformed gels and in situ forming gels (Beebe et al. 2000). They have the ability to swell in water or aqueous solvents, and induce a liquid–gel transition (Kim et al. 1992). This class of polymer is an attractive vehicle for localized administration of pharmaceutical agents such as proteins and small molecules that can be released in a temporally and spatially controlled manner (Lieberthal and Kao 2016).

The preformed gels can be defined as simple, highly viscous solutions, which do not experience further modification after administration. In situ hydrogels, on the contrary, can be described as viscous liquids or suspensions that upon environmental alterations such as pH, temperature and ionic strength shift to a gel phase (Miyata et al. 1999).

These materials has been already applied to various areas such as hygienic products, agriculture, drug delivery systems, sealing, coal dewatering, artificial snow, food additives, pharmaceuticals, biomedical applications, tissue engineering and regenerative medicine, diagnostics, wound dressing, separations of biomolecules or cells, barrier materials to regulate biological adhesions and biosensor (Ahmed et al. 2005).

The ideal hydrogel characteristics have already been defined. It should present the highest absorption characteristics, highest absorbency under load, lowest soluble content and residual monomer, lowest price, highest durability and stability in a swelling environment and during storage, highest biodegradability without forming toxic species, pH neutrality after swelling in water, colourlessness, odourlessness, photo stability and re-wetting capability (Zohuriaan-Mehr et al. 2006).

In the preformed hydrogels, we have many types of polymers utilized in veterinary medicine, such as methylcellulose, hydroxyethylcellulose, hydroxypropylcellulose, hydroxypropyl methylcellulose (HPMC), carboxymethylcellulose sodium, polyvinyl alcohol, Carbopol®, sodium hyalurionate, xanthane, carrageenan and dextran (Rathbone and Gurny 2000). In the in situ hydrogels category, we have the poloxamers, cellulose acetate phthalate latex, Gelrite™ and polyvinyl pyrolidone.

Many studies have been already published on utilizing these polymers in combination with other molecules for drug release, mainly for ocular diseases in the veterinary field. Among them there is a work that utilized the drug Benzadac in combination
with xanthan gum and HPMC, for utilization in rabbits as an animal model (Romanelli et al. 1994). Another project utilized Carbopol® combined with Gentamycin, an antibiotic, for tests in rabbits (Lehr et al. 1994). In horses, propylene glycol hydrogel has already been tested for skin wound treatments (Dart et al. 2002).

In our study group, a sustained release platform of a thermosensitive hydrogel using a highly hydrosoluble molecule as a template drug was developed and evaluated in vitro. It was possible to achieve a gradual release of the molecule for a relatively long period, so that it had a gelation temperature close to the physiology of an animal (De Lima et al. 2016).

3. Animal sanity and handling

It is very important to emphasize that when we are developing a new polymeric device, it should interfere as little as possible in the animal’s welfare. Therefore, all the possible variables should be taken into consideration when designing the system, such as polymer composition, possible toxicity, allergic reactions, ease for application/administration, concentration, quantity, viscosity, texture and necessity for reapplications.

For livestock reproduction, for example, these issues are far more important than companion animals. Primarily, because usually the producer handles large groups of animals, and has to treat or supplement all of them in specific predetermined periods, there is difficulty in the control of applications, which at times contributes to skipping a treatment/supplement dose. Additionally, any mistake in choosing the right product formulation, with the correct variables mentioned previously, might result in less productivity, welfare and, consequently, much money lost.

In livestock breeding, sanitation is perhaps the main issue to control in the herd. This issue is especially important for two reasons: first of all, human health. If not well treated, these animals might carry diseases that are able to infect humans, zoonoses, and because of that, the animals must have a good infestation/treatment/vaccine control planning. A good example is the Toxoplasma gondii, a protozoan that can infect bovines and humans as well, and might lead to blindness in humans (Jones et al. 2001). Therefore, the health of these animals might influence our own health. Consequently we, as the final consumers of these products (meat, milk) of animal origin, must fully understand the importance and exercise extreme caution in utilizing the right products, for the right period. Hence, it is very important to select the right polymer to be used for the right time period in the animal and the amount of drug released over time.

In large herds, handling might be a challenging step towards satisfactory farm management. One can plan a schedule of application in order to not skip administration of a product dose. Besides it facilitates the control of a large number of animals, making it easier for selecting the specific animals for treatment/supplementation. In a subsequent topic, we will elucidate more thoroughly the CR system, a method that can facilitate handling and sanitation much more in a livestock breeding system.

For companion animals, on the other hand, it is much easier to control applications of a desired product at the right time. As the name already suggests, the pet is already in our residence at all times. This makes it easier to control the treatment of the pet as well as any possible complication regarding the product administered to the animal.

The sanitation issue for pets is of great importance as well. Their proximity to humans might interfere with our own health if the animal is not in a good condition. Like cattle, pets might transmit diseases that can make humans ill, zoonoses, and for this, we must take extra care to always keep them free of parasites and other infectious agents. Controlled release polymers can facilitate our lives in this process.

4. Routes for drug administration

When developing a polymeric device, the route of administration is something very important to consider, mainly because each type of formulation has its specific properties and it can interact with the physiological environment in which is placed. Thus, all administrations must be performed with the knowledge of the chemical and physical characteristics of the substance, such as the pH, viscosity, concentration, sterility, pyrogenicity, toxicity as well as harmful substances (Shimizu 2004). There are several routes of administration for veterinary therapies. Among them we will discuss the subcutaneous, intramuscular, intraperitoneal, intravenous, intraruminal, transdermal, vaginal and rectal routes.

All routes have different absorption rates and bioavailability, as well as a potential duration of delivery, depending on the polymer type and body site. In the application procedure, the animals must remain as calm as possible in order to facilitate the administration of the device and prevent stressful situations.

The subcutaneous administration route is one of the easiest forms to apply a formulation in an animal, primarily because of its superficial administration site, and because it is rarely painful (Wolfensohn and Lloyd 2008). The absorption rate is lower than the intraperitoneal or intramuscular injections (Simmons and Brick 1970). In the subcutaneous application, a portion of the skin is raised to introduce the needle into the subcutaneous tissue of the animal. The administration volumes must be low, and applied in more than one part of the body if utilizing a greater volume, for improved absorption. This route has been used mainly for antiparasitic CR formulations, for cattle and other species.

In the intramuscular route, the formulation is applied in the muscle tissue. In this particular body site, higher amounts of the formulation can be administered. The animals might experience a higher amount of pain, compared to other administration methods. Besides pain, haematoma and nerve damage can also occur depending on how the application is performed. In this administration route, the absorption is very efficient and fast, mainly because the muscular tissue is highly vascularized and the drug does not suffer first-pass metabolism.

The intraperitoneal route is appropriate to administer greater volumes than other methods, and its utilization normally is for testing new experimental drug formulations. The injection is given in the animal’s peritoneum region. Its absorption rate is usually one-half to one-fourth as rapid as that from the intravenous one (Woodard 1965). The person performing
this method must be experienced in order to avoid accidental viscera penetration.

The tissue might get irritated with certain substances applied on this body site. Formulations with non-physiological pH might have a greater negative implication in this body site. The intravenous administration is one of the most utilized administration routes. It has many advantages over the other routes. It can be utilized for large volumes administered in small amounts over time. It is a pain-free procedure. The absorption is the fastest in this method, because the formulation is injected directly in the animal’s vein. There are compounds that are poorly absorbed by the digestive tract that might be given intravenously (Shimizu 2004). When utilizing this procedure, the concentration of the drug is an important concern, as it can rise rapidly in the blood stream, possibly causing an adverse reaction in the animal.

The intraruminal pathway, mainly for cattle and other ruminants, is utilized when we need to insert a device in the reticulo-rumen compartments of these animals. This body part is where the bacterial fermentation and breakdown of food occurs (Cardinal 1997). Usually, this method is applied for anthelmintic therapies and for providing nutrients to the ruminal microorganisms.

The transdermal route is utilized with a device attached to the animal’s skin. The absorption rate usually is slower than other methods. However, it can fluctuate depending on the physical characteristics of the formulation chosen, the lipid solubility and site of application. This route is not widely utilized in the animal field mainly because it is relatively easy for the animal to attempt to or even accidently remove the device from the skin, because it is in a superficial body site.

The vaginal delivery system is an accessible method for drug delivery, due to it being an easy application, painless and non-invasive method (Ferguson and Rohan 2011). This route avoids the first-pass metabolism, providing an improved bioavailability of the drug. The vaginal tissue is highly vascularized, and this characteristic facilitates the absorption of the device components. In many animal breeding farms, most of the farmers utilize this route for estrous synchronization utilizing devices that have hormones, such as progesterone.

The rectal delivery route is a pathway highly utilized in animal science for polymeric drug delivery. It is very similar to the vaginal delivery system. The rectum is highly vascularized, and this facilitates the body absorption of drugs. Unless the device has a strong bioadhesion, the drawback of this route is the possible loss of the device when the animal evacuates. Therefore, the system must be designed for a short releasing process or it must have strong adhesion characteristics and must not be disturbed by the passage of faeces.

5. Modified drug delivery

Polymeric systems utilizing the CR methodology have been widely utilized in human and veterinary medicine because of their advantages over the conventional releasing devices. These include reduced toxicity and improved efficacy (Uhrich et al. 1999). In controlled drug release, the main objective of the system is to deliver the drug in a consistent, therapeutic, not toxic manner and for a long period.

In a study by Feijo et al. (2014), a biodegradable intravaginal CR platform was developed to deliver a calcium formate for use in ruminants. The intravaginal device presented higher calcium bioavailability compared to the commercial oral solution, maintaining its high levels for up to 4.5 h. The drug efficacy can be enhanced by maintaining the concentration within the therapeutic window. Polymers in this class can be loaded with drugs and the release can be controlled in a temporal and spatial manner. This can be achieved through controlling the diffusion, rate of dissolution and degradation of the polymer. Compared to the conventional systems, there is a great advantage in the administration and therapeutic periods.

In CR technology, the polymers’ biodegradability and other properties are characteristics based on their carbon backbone and functional groups. Each type of polymeric structure is more suitable for a determined objective. For an example, the poly(EVA) is a polymer that has the drug permeability feature influenced by the ratio of vinyl acetate present. The poly(N-isopropyl acrylamide), for instance, is utilized in systems that require a stimuli-sensitive response polymer (Chen and Hoffman 1995).

The process of releasing the drug into the body differs according to the type of diffusion and dissolution of the drug within the polymeric structure. The polymeric systems protect the drug molecules from the environment during the programmed periods (Uhrich et al. 1999). This protection can involve delaying the dissolution of drug molecules, inhibiting the diffusion of the drug out of the formulation or controlling the flow of drug solutions (Jantzen and Robinson 1996).

There is another type of temporal CR, which is responsive drug delivery in which the drug is released in a pulsatile manner only when needed in the body. It has two main components, a sensor that detects alterations in the environment and stimulates the drug release, and the delivery device (Uhrich et al. 1999).

In the veterinary field, CR can improve the sanitary handling management in large herds, by the expansion of the drug therapeutic window. The necessity of subsequent reapplications of a drug dose is avoided, lowering the costs for the breeder and the necessity of stressful episodes for the animal.

In CR technology, there are many types of polymers based on their biodegradable capability, if it is biodegradable or non-biodegradable. There has been much interest in the first because it does not require removal after implanting in the animal’s body. There are the poly(esters): poly(lactic acid), poly(glycolic acid) and their copolymers, poly(ethylene glycol) block copolymers; the poly(ortho esters); poly(anhydrides): poly(anhydrides-imides), poly(anhydride-esters); poly(amicides): poly(iminocarbonates); phosphorus-containing polymers: poly(phosphazenes) and the poly(phosphoesters) (Uhrich et al. 1999).

Among the above-mentioned polymers PLGA is one of the most utilized in the veterinary industry, mainly because of its long sustainable duration, biodegradability and nontoxic characteristics. In the vaccine area, PLGA has been widely utilized in combination with many antigens in diverse species, like mice, swine and canines (Rathbone and Guny 2000).

CR polymers have been utilized most of all for peptides and proteins due to their short biological half-life period.
(Winzenburg et al. 2004). However, other types of molecules have been researched in combination with CR polymers, in order to economically raise the possibilities of CR utilization in the veterinary field, principally when we talk about large groups of animals.

6. Toxicity and meat/milk leavings

Most of the biodegradable polymers are nontoxic, nonirritable, with good tolerability and their components are rapidly converted in the body for excretion (Lu et al. 2015). However, a number of tests must be performed for assuring the safety of all components in the formulation. In one study with horses conducted by our study group after clinical, haematological and thermographic evaluation, no inflammatory reaction was observed after administration of a thermosensitive polymer containing steroid hormone test (Savela et al. 2016).

For drug approval, analytical methods need to be performed for detecting possible residues in the meat/milk. The formulation developers must describe most of the methods for the determination and quantification of the possible residues in the meat/milk. There must be research to determine the safe level for the formulation, which can be detected in the products of animal origin (Nollet and Toldra 2009).

7. Conclusions

The pursuit for new strategies in biodegradable polymer utilization is already a reality in veterinary science. The improvement in animal handling by using those polymers is, without question, of great help to animal breeders. With the advances in polymeric synthesis, researchers are being able to improve the polymer features, besides creating new polymers more suitable to each type of physiological tissue, specie and duration. Advances of in silico simulations for each type of combination between polymer and drug is a rising technology. This facilitates and speeds up the process of chemical synthesis of polymeric formulations, and it can simulate the physiological interaction of the polymer inside the animal’s body.

This review describes the importance and potential of the use of biodegradable polymers and nonbiodegradable polymers used in veterinary science of pets and animals of production. The polymers are present in many pharmaceutical and medical products used in veterinary medicine, such as diagnostic tests, surgical materials, equipment for routine therapies in hospitals or on farms, for drugs or nutrition products. The polymers in veterinary science are also important for the sanitation and handling of animals, allowing the use of different routes for drug delivery and have been widely used in modified drug release, due to their low toxicity and low residues in meat or milk, contributing to food security.

All these strategies contribute to the increase in new products for both farm and companion animals, each one with specific characteristics as well as the prices of those formulations. Above all, we have to understand the importance of developing safe products for animals, aiming at the smallest possible reaction or discomfort in the administration of the product, and ensuring their highest possible well-being.

Disclosure statement

No potential conflict of interest was reported by the authors.

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