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Review Article

A review on transdermal drug delivery through patches

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ABSTRACT

A transdermal drug delivery system (TDDS) falls under the controlled drug delivery category, aiming to administer drugs through the skin at a predetermined and controlled rate. This approach presents numerous benefits, such as extended therapeutic impact, reduced adverse effects, increased bioavailability, enhanced patient adherence, and convenient discontinuation of medication. The outermost layer of the skin, the stratum corneum, plays a key role in controlling the transdermal penetration of most substances. Three main routes facilitate drug penetration: appendageal, transcellular, and intercellular. When administering drugs through this pathway, it is essential to consider diverse factors, including the age and condition of the skin, physicochemical properties, and environmental influences. Crucial elements of Transdermal Drug Delivery Systems (TDDS) include a polymer matrix, membrane, drug, penetration enhancers, pressure-sensitive adhesives, backing laminates, and a release liner. Transdermal patches fall into categories such as reservoir systems, matrix systems, and micro- reservoir systems, all specifically engineered to introduce active ingredients into the circulatory system via the skin. A standardized approach is utilized to evaluate various aspects, including adhesion properties, in vitro drug release and stability. The purpose of reviewing the topic of transdermal drug delivery system through patches is to comprehensively evaluate the advancements, challenges, and potential applications of this innovative drug delivery method.

1. Introduction

Transdermal drug delivery systems (TDDS) refer to formulations created to administer an appropriate medicinal dosage through a patient's skin, ensuring the delivery of a therapeutic dose of the drug into the body. In order to achieve systemic effects by transmitting therapeutic substances through human skin, it is essential to consider the skin's biophysical, morphological, and physicochemical properties comprehensively. Transdermal drug delivery presents notable advantages compared to injectables and oral routes, as it improves patient compliance and circumvents the first-pass metabolism.[1] It ensures a controlled and consistent drug administration, particularly beneficial for drugs with short biological half-lives, preventing abrupt entry into the systemic circulation that often leads to adverse effects. As a result, various innovative drug delivery systems, such as Transdermal drug delivery systems, Transmucosal delivery systems, and Controlled release systems, have been developed. The benefits of transdermal drug delivery include improved therapeutic efficiency, reduced hepatic first-pass metabolism, and the maintenance of a stable drug concentration in the bloodstream. The first transdermal system was FDA-approved in 1979 for preventing nausea and vomiting. Confirmation of percutaneous drug absorption can be established through measurable blood levels, detect excretion of the drug and its metabolites in urine, observing the patient's clinical response to the administered drug therapy.[2] A transdermal patch is a

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specialized medicated patch designed to release drugs into the bloodstream at a controlled rate through the layers of the skin. These patches offer a highly convenient method of drug administration, as they are painless and can provide continuous treatment for several days. Additionally, they can be easily discontinued at any time. Transdermal patches come in various sizes and can contain multiple active ingredients. When applied to the skin, these patches use diffusion processes to deliver these active ingredients directly into the systemic circulation. Some patches may contain high doses of the active constituent, which remains on the skin for an extended period. Nitroglycerin was the first transdermal patch developed in 1985, marking a significant milestone in this drug delivery method. Gale and Berggren developed patches that incorporate a rate-controlling ethylene vinyl acetate membrane. Various drugs are formulated as transdermal patches, such as nicotine, estradiol, fentanyl, clonidine, scopolamine (hyoscine), and estradiol with norethisterone acetate. The specific site of patch application depends on the type of drug therapy.[3] For instance, estradiol patches are typically placed around the buttocks or abdomen, while nitroglycerin patches can be applied around the chest area. The duration of drug release varies, ranging from as short as 9 hours to as long as 9 days, depending on the intended usage.

1.1. Advantages of TDDS

1. To prevent first-pass metabolism, transdermal delivery ensures a sustained and continuous permeation of a substance over an extended period.[4]
2. Increase Patient compliance.
3. It does not interfere the liquid of the stomach and intestines.[5]
4. Sustains stable and constant blood levels, providing control over an extended period.[6,7]
5. Reduced plasma concentration levels of drugs.
6. Reduce fluctuations of drug in plasma levels, Utilize drug candidates with short half-life and Low therapeutic index.[8]
7. In case of toxicity drug delivery is easy eliminated.
8. Reduce of dosing frequency an enhance Patients compliance.[2]
9. Transdermal delivery enhances the effectiveness of numerous drugs by circumventing certain issues related to the medication, such as poor absorption and gastrointestinal irritation.
10. The streamlined medication schedule results in decreased differences in drug response both within and among patients.

1.2. Disadvantages of TDDS

1. The drug must possess favorable physicochemical properties to permeate through the stratum corneum.
2. For daily dosages, the drug quantity should not exceed 5mg/day; if it surpasses 10-25 mg/day, transdermal drug delivery becomes challenging.
3. The patch constituents, including the drug, adhesive, and other additives, can potentially cause local irritation.
4. There should be a clear clinical requirement established for utilizing the transdermal delivery system.
5. High drug levels in Blood/ plasma could not be achieved.[9]
6. Large molecular size of drugs cannot be formulated.
7. Possibility of inflammation on the site of application.[10]
8. Not comfortable to wear.
9. May not be economical.
10. The skin barrier varies among individuals and can even change within the same person over time.[11]

2. Skin Structure

Indeed, the skin is the body's largest organ, acting as a crucial protective barrier safeguarding the body from a range of external factors and potential threats. Its large surface area, approximately 1.7 square meters in an average person, allows it to effectively shield the body from microorganisms, ultraviolet (UV) radiation, chemicals, allergens, and water loss. This protective function is vital for maintaining overall health and well-being.[8,12,13] Additionally, the skin also plays a role in regulating body temperature, sensation, and the synthesis of vitamin D through exposure to sunlight. Taking care of the skin is essential to support its functions and maintain good health.

The skin is commonly categorized into three primary layers: The outermost layer, known as the epidermis; (b) The middle layer, referred to as the dermis; and (c) The innermost layer, called the hypodermis.

Here's a brief overview of each layer:

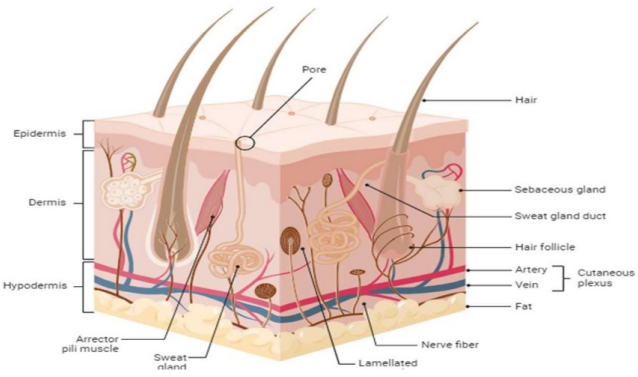

Figure 1: Structure of the skin

2.1. Epidermis

The epidermis constitutes the skin's outermost layer. It provides a waterproof barrier and contains no blood vessels. The cells in the epidermis include keratinocytes, which produce the protein keratin and help make the skin tough and protective. The epidermis includes melanocytes, responsible for skin color, and Langerhans cells, integral components of the immune system.

The epidermis has several sub- layers, including:

1. Stratum corneum
2. Stratum granulosum
3. Stratum spinosum
4. Stratum basale

It's different thickness in different parts of our body, about 0.8 mm thick on our palms and the soles of our feet.[13] The epidermis is made up of layers of skin cells. Most of these cells are called keratinocytes. They make up about 95% of the cells in the epidermis. The epidermis houses various cell types, including melanocytes, Langerhans cells, and Merkel cells.[14]

On top of the epidermis, there's a super thin layer called the stratum corneum. It's the very surface of our skin and touches everything around us. This layer is special because it keeps our body safe. Its thickness and how much water it has are important. The stratum corneum is made mainly of tough proteins (70% keratin) and some fats (20% lipid).[15] Water in this layer is connected to these proteins.[16]

2.2. Dermis

The dermis is located beneath the epidermis which is 3 to 5 mm and is thicker than the epidermis. The dermis is responsible for providing nutrients to the epidermis and housing the skin's appendages and sensory receptors.

It comprises diverse structures, such as:

1. Blood vessels
2. Hair follicles
3. Sweat glands
4. Sebaceous glands
5. Nerve endings
6. Collagen and elastin fibers.

Tiny blood vessels called capillaries are really close to the skin surface, about 0.2 mm away. These capillaries act like drains, pulling away most of the stuff that tries to get through the skin. This is essential because it keeps the concentration of substances that enter the skin very low. This difference in concentration between the inside and outside of the skin helps push things through it.

When it comes to delivering medicines through the skin, this layer is like a gel made mostly of water. For most medicines that dissolve in water, this layer doesn't offer much resistance, making it easier for the medicines to pass through. However, if a medicine is oily (like some lotions or creams), this layer can create more of a challenge for it to get through.[17]

2.3. Subcutaneous tissue (Hypodermis)

The subcutaneous tissue, also known as the hypodermis, constitutes the deepest layer of the skin, consisting of adipocytes (fat cells) and connective tissue. This layer serves as an insulator, helping to regulate body temperature and serves as a protective cushion, shielding the body's organs and bones from impacts.

When medicines are applied to the skin, like creams or patches, they have to go through these three layers to get into our bloodstream. For some medicines, they need to go even deeper, reaching our body's circulation. But for most skin treatments, they just need to get through the outermost layer, the stratum corneum, and stay in the skin layers to work effectively.[18]

3. Routes of Drug Penetration Through Skin

Drug penetration across the skin can occur through two routes: the transepidermal pathway, which involves penetration through the epidermis, and the transappendegeal pathway, which involves penetration through appendages such as hair follicles and sweat glands.

1. Transepidermal Pathway: In this pathway, drugs permeate through the skin's outermost layer, known as the stratum corneum. This layer is a structurally complex, multi-layered, and multi-cellular barrier.[19]
   (a) Intra-cellular Route: Some drugs can go through specific skin cells called corneocytes, which are specialized skin cells. This route is for substances that dissolve in water (hydrophilic or polar solutes).
   (b) Inter-cellular Route: Other drugs can move through the spaces between these skin cells. This route is for substances that dissolve in fats (lipophilic or non-polar solutes). They travel through the continuous fatty layer of the skin.
2. Transappendegeal Pathway: This pathway involves drugs passing through sweat glands and hair follicles in the skin.
   (a) Sweat Glands and Hair Follicles: These are like tiny tunnels or openings in the skin that some substances can travel through.[20,21]

So, when drugs need to get into our body through the skin, they can either go through the outer layer of skin cells or use these tiny tunnels created by sweat glands and hair follicles. Each pathway has specific characteristics, allowing different types of substances to enter the body.

Table 1: Classification of penetration enhancers and techniques

Types/Techniques of penetration enhancers	Mechanism of action	Examples
1.Chemical enhancers	1. Distruption of the organized arrangement structure of stratum corneum lipid. 2. Engagement with intercellular protein. 3. Enhancement of the drug or solvent's penetration into the stratum corneum. [22]	1. Azones 2. Cyclodextrins 3. Sulphoxides: dimethyl sulphoxide (DMSO), dimethyl formamide (DMF), dimethyl acetamide (DMAC) 4. Pyrrolidones 5. Amine and Amides: Urea 6. Fattyacids: Lauric acid, capric acid and Myristic acid 7.Oxizolidinones(4-decycloxazolidine-2-one) 8. Surface active agents: SLS, Benzalkonium chloride
2. Drug Vehicle Based	Engagement between enhancers and the stratum corneum, along with the establishment of Structure-Activity Relationships (SAR) for enhancers possessing ideal traits and minimal toxicity. [22]	Ion pairs and complex coacervates chemical potential adjustment.
3. Natural Penetration enhancers	Terpenes' Mechanism: 1. Augmentation of the partition coefficient. 2. Augmentation of the diffusion coefficient. 3. Extraction of lipids. 4. Augmentation of drug solubility. 5. Macroscopic perturbation of the barrier. 6. Molecular alignment of terpene molecules within the lipid bilayer.	1. Terpens: Menthol, Linalool, Limonene, Carvacrol. 2. Essential oil:Basil oil, Ylang- Ylang, Neem oil, Eucalyptus, Chenopodium.
4. Physical Enhancers	These techniques are diverse methods employed to enhance penetration by physically separating skin layers, utilizing magnetic fields, and employing ultrasonic waves.	1. Radiofrequency 2. Sonophoresis 3. Needleless injection 4. Magnetophoresis 5. Electroporation 6. Phonophoresis 7. Thermophoresis 8. Iontophoresis 9. Hydration of stratum corneum 10. Stripping of stratum corneum
5.Biochemical Approach	Modification of substance by converting them into suitable form.	1. Synthesis of bio-convertible prodrugs Co-administration of skin metabolite Inhibitors
6.Miscellaneous Enhancer	Having Various Mechanism	1. Clofibric acid 2. Lipid synthesis inhibitors 3. Phospholipids Dodecyl –N, N-Dimethyl

4. Penetration Enhancers

Penetration enhancers, also referred to as permeation enhancers or skin penetration enhancers, are substances employed to enhance the permeability of active compounds, such as drugs, through the skin. They function by temporarily modifying the structure and properties of the stratum corneum, the skin's outermost layer. This alteration allows for better penetration of the active ingredients into the bloodstream or deeper layers of the skin, enhancing the effectiveness of topical medications.

4.1. Transdermal Patch

A transdermal patch, also known as a skin adhesive patch, is a device designed to administer a precise dosage of medication by placing it on the skin. This allows the drug to be delivered through the skin and into the bloodstream. [23] The specialized membrane regulates the passage of liquid medication from the patch reservoir through the skin and into the bloodstream. [24] Numerous patients encounter challenges swallowing tablets or receiving injections, and patches remain effective for more extended durations compared to tablets, so frequent dosing is reduced. Patches are utilized in various therapeutic areas, such as pain management, heart disease treatment, smoking cessation, motion sickness management, and hormone replacement therapy. [25]

4.2. Components of transdermal patch

4.2.1. Liner

During storage it protect the patch. The liner should be removed before using. It is a part of primary packaging, which inhibit the loss of drug from polymer matrix.

4.2.2. Adhesive

This component is employed to bind the elements of the patch together and attach the patch to the skin.

Examples of adhesives include Polyacrylate, Polyisobutadiene, and Silicon-based adhesive polymers.[26]

4.2.3. Membrane

The membrane regulates the drug release from reservoir and multi-layer patches. It is typically made from materials like chitosan and poly-2-hydroxyethylmethacrylate.

Examples: Silicones, polyester elastomers, polyacrylonitrile, ethylene vinyl acetate copolymer and high-density polyethylene.

4.2.4. Drug

It is active ingredient which is in direct contact with release liner.

4.2.5. Polymer

The polymer must exhibit both biological and chemical compatibility with drugs and other additives such as permeation enhancers, plasticizers, adhesives, etc.

1. Example: Natural polymers: Shellac, gelatin, chitosan, waxes, cellulose derivatives, natural rubber.
2. Synthetic polymer: PVA, polyurea, polyamide, polyethylene, polyvinyl pyrrolidone, polypropylene.
3. Synthetic elastomer: Polyurethane, polyisobutylene, polybutadiene, nitril, hydrin rubber, silicon rubber, butylrubber.[27]

4.2.6. Backing

It protect the patch from the environment, provides support to the patches and giving flexibility and appearance to the patch.[28]

4.3. Types of transdermal patches

4.3.1. Single layer drug-in-adhesive patches

A reservoir is employed as a singular polymer layer with adhesive properties to disperse the drug. Below this single layer, an impermeable backing laminate is applied. The medication, situated within and adhering to the polymer layer, is released from the backing laminate layer, which serves as support for the drug reservoir.[29] An illustration of a single-layer drug-in- adhesive transdermal patch is Daytarana, which contains methylphenidate.

4.3.2. Multilayer drug-in-adhesive patches

Drug release is controlled over a period of time consist of a drug reservoir layer and adhesive layer.[2,3] It contains a temporary protective layer and backing laminate in multilayer systems. Multi-layer patches can be prolonged for up to seven days are used to deliver pain medication, smoking cessation treatments, and hormone therapy.

4.3.3. Vapor transdermal patches

These patches consist of a single layer of adhesive polymer designed with a vapor release feature, allowing the release of vapors. Various vapor dermal patches are available for different purposes.[30,31] One example is Nicoderm CQ®, a nicotine vapor transdermal patch containing essential oils that aid in smoking cessation. Introduced to the European market in 2007, it helps individuals quit smoking by releasing these oils. Another type is altacura vapor patches, which contain essential oils and are used for decongestion purposes. Additionally, there are vapor patches available in the market designed as antidepressant medications or sedatives.

4.3.4. Membrane moderated transdermal reservoir patches

A transdermal patch consists of a drug reservoir, an impermeable backing layer composed of metallic plastic laminate, and a porous polymeric membrane responsible for controlling the release of the drug. This membrane is composed of polymeric materials such as ethylene vinyl acetate copolymer and hypoallergenic adhesive polymer. The drug within the transdermal patch is controlled through the molecular dispersion of the drug in a polymer matrix as part of the preparation process.[32,33]

4.3.5. Micro reservoir transdermal patches

Micro-reservoir transdermal patches integrate a drug reservoir with a matrix dispersion. The reservoir is created by suspending the drug in an aqueous solution of a hydrophilic polymer, followed by uniform dispersion of the drug suspension on a lipophilic polymer. This dispersion process involves high shear mechanical force, leading to the formation of numerous microscopic, non-leachable spheres. Drug release from these patches follows a zero-order kinetic rate, ensuring a consistent drug level in the plasma. To maintain thermodynamic stability, crosslinking polymeric agents are typically included in the drug dispersion.[34]

4.4. Matrix system

4.4.1. Drug-in-adhesive system

In this system, the drug reservoir is created by mixing the drug with an adhesive polymer. The medicated adhesive polymer is then spread either by solvent casting or melting. In the case of hot melt application, unmedicated adhesive

polymer layers are added on top of the medicated layer.[35]

4.4.2. Matrix-dispersion system

In this system, the drug is evenly distributed within a hydrophilic or lipophilic polymer matrix. This polymer disk containing the drug is affixed onto an occlusive base plate within a compartment formed by a drug-impermeable backing layer. Instead of being applied directly onto the drug reservoir, adhesive is spread around the perimeter to create an adhesive rim.[36,37]

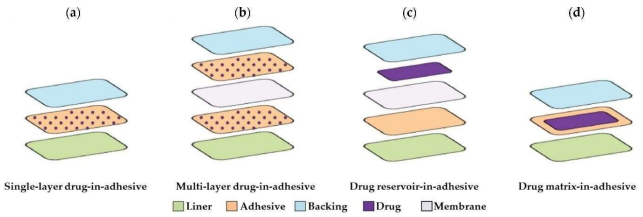

Figure 2: illustrates various types of transdermal delivery patches: (**a**) Single-layer drug-in-adhesive patch;(**b**) Multi-layer drug-in-adhesive patch; (**c**) Drug reservoir-in-adhesive patch; (**d**) Drug matrix-in- adhesive patch.[38]

5. Evaluation

5.1. Physical appearance[39]

Each of the formulated patches underwent visual inspection to assess factors such as color, clarity, opacity, transparency, flexibility, and smoothness.

5.2. Interaction atudies[39,40]

In various dosage forms, not limited to Transdermal Drug Delivery Systems (TDDS), excipients are utilized. These excipients must be compatible with the drug to prevent stability loss and decrease in bioavailability. Interaction studies are commonly conducted using thermal analysis, Fourier-transform infrared spectroscopy (FT-IR), ultraviolet (UV) spectroscopy, and chromatographic techniques. These studies involve comparing the physicochemical properties of the drug and excipients to ensure their compatibility.

5.3. Thickness[41,42]

The thickness of a transdermal patch is measured using instruments such as a traveling microscope, dial gauge, screw gauge, or micrometer. Measurements are taken at three different points on the patch, and the average of these three measurements is considered as the thickness of the patch. A uniformly thick patch will exhibit consistent thickness at every point measured.

5.4. Folding endurance[43]

Folding endurance is assessed by repetitively folding a strip of the patch or film at a specific area until it either breaks or is folded up to 300 times. The number of times the patch can be folded without breaking provides the folding endurance of the patch. This measurement indicates the flexibility of the patch.

5.5. Weight uniformity[44,45]

The patches are dried at 60°C before weighing. To assess weight uniformity, 1 cm^2 pieces are cut from three patches and weighed individually. The weight variation is calculated, ensuring that the individual weights do not significantly deviate from the average weight. The average weight of the three pieces is considered as the weight of the patch.

5.6. Percentage moisture content[46,47]

The individual patches are initially weighed and then placed in desiccators containing fused calcium chloride at a specific temperature for 24 hours. After this period, the patches are reweighed, and the percentage moisture content is calculated based on the difference in weight before and after the desiccation process. This method helps determine the moisture content present in the patches.

5.7. Percentage moisture uptake[46,48]

The weighed films are first placed in a desiccator for 24 hours and then exposed to 84% relative humidity, achieved by using potassium chloride in another desiccator. The films are reweighed periodically until they reach a constant weight. This process allows for the determination of how the films absorb and retain moisture under specific humidity conditions, providing valuable information about their stability and performance.

5.8. Percentage water vapour permeation (WVP test)[49,50]

Vials with equal diameters are employed as permeation cells. These vials are cleaned, dried, and then filled with 1 gram of fused calcium chloride. A patch with a surface area of 1 cm^2 is measured and affixed to the rim of the vial. The vials are weighed meticulously and then placed in a desiccator containing a saturated solution of potassium chloride to maintain the relative humidity at 63%. After a duration of 72 hours, the vials are removed, and their weight is measured once more. This process helps assess the permeation properties of the patch under specific humidity conditions.

5.9. Drug content[51,52]

The film, with a specific area and weight, is dissolved in an appropriate solvent like methanol or phosphate buffer at pH 7.4 and then filtered. After making suitable dilutions, the drug content is determined using UV or HPLC (High-Performance Liquid Chromatography) methods, employing a standard curve. This analytical process helps quantify the concentration of the drug in the film sample.

5.10. Polariscopic examination[53]

This test is performed to identify the physical state of the drug, distinguishing between its crystalline or amorphous form. A segment of the patch is positioned on a slide and examined under a microscope objective to assess the physical characteristics of the drug particles.

5.11. Flatness[39]

In the flatness test for a transdermal patch, strips are cut from the center and both right and left sides of the patch. The length of each strip is measured, and the variation in length is calculated as percentage constriction using the following formula:

% Constriction = (Initial Length - Final Length)/Initial Length x100

If the percentage constriction is 0%, it indicates 100% flatness, meaning that the patch maintains its smooth surface without any constriction over time.

5.12. Tensile strength

A modified pulley system is utilized to study the tensile strength of the film. The system measures the force needed to break the film, providing valuable information about its tensile strength.

5.13. Shear adhesion test[54]

This test is conducted to assess the cohesive strength of the adhesive polymer. In this method, the adhesive-coated patch is applied over a smooth surface, and a specific weight is hung from the patch parallel to the surface. The duration taken to pull off the patch from the surface measures its shear adhesion property, indicating the strength of the adhesive bond.

5.14. Peel adhesion test[55]

In this test, the force required to remove the patch from a surface is determined. The patch is applied to a steel plate, and then it is pulled away at a 180-degree angle from the surface. The force needed to detach the patch is measured, providing information about its adhesive strength.

5.15. Rolling ball tack test[56]

In this test, a steel ball with a diameter of 7/16 inch is rolled down an inclined plane with the horizontally placed patch facing upward, adhesive surface exposed. The ball rolls down and travels a specific horizontal distance on the patch. The distance covered by the ball provides information about the tackiness or tack property of the adhesive patch. Tackiness is a measure of the adhesive's ability to quickly adhere to a surface upon contact.

5.16. Thumb tack test[56]

Tackiness is determined by the force needed to separate a thumb or any object from an adhesive surface.

5.17. Quick stick (Or) peel tack test[55]

This method is employed to measure the peel force required to break the bond between the adhesive and the substrate. It involves pulling the tape (with the adhesive layer) away from the substrate, typically a stainless-steel plate, at a speed of 12 inches per minute.

5.18. Probe tack test[57]

Tack is determined by measuring the force required to pull a probe away from an adhesive at a consistent rate.

5.19. In vitro release study[58]

In the in vitro release test, a USP dissolution apparatus is employed at 50 rpm and 37°C. A transdermal film is affixed to a glass slide using an adhesive and submerged in a dissolution medium containing 900 ml of phosphate buffer at pH 7.4. Samples of 5 ml are withdrawn at hourly intervals over 24 hours, and an equal volume of buffer is replenished in the dissolution medium. These samples are then analyzed spectrophotometrically, and the cumulative drug release is calculated based on the collected data.

5.20. Stability studies[38]

The stability testing is conducted in accordance with ICH (International Council for Harmonisation) guidelines. The formulated transdermal patches are stored at a temperature of 40°C ± 0.5°C and a relative humidity of 75% ± 5% for a period of six months. Samples are withdrawn at specific intervals, namely 0, 30, 60, 90, and 180 days, and are analyzed appropriately to determine drug content. This testing ensures the stability and quality of the transdermal patches over an extended period under specified storage conditions.

6. Conclusion

The transdermal drug delivery route is considered both safe and effective when compared to other administration

methods. Numerous drugs, including hormonal therapies, a broad spectrum of analgesics, and medications for heart diseases, are formulated in Transdermal Drug Delivery System (TDDS) to mitigate gastrointestinal effects and first-pass metabolism. Given the multitude of advantages and the growing popularity of transdermal drug delivery systems, researchers are increasingly focusing on introducing new drugs in this delivery format. Despite its advantages, it is crucial to acknowledge that the skin primarily functions as a protective barrier for internal organs. When designing a transdermal drug delivery system, one must strive to minimize alterations to the skin's natural functions. The application of drugs through the transdermal route has the potential to influence skin physiology, underscoring the importance of maintaining such alterations to a minimum. A comprehensive understanding of skin physiology and anatomy is essential for further advancements in this field. However, achieving optimal transdermal delivery requires extensive knowledge and comprehension of the interactions between various polymers and skin components. This knowledge is pivotal in designing and optimizing transdermal drug delivery systems.

7. Source of Funding

None.

8. Conflict of Interest

None.

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