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Spanlastics: Bridging Innovation and Efficacy in Drug Delivery

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Abstract: The novel drug delivery system 'spanlastics' has received prominence for its potential to enhance drug stability, targeted delivery, and bioavailability. Unlike traditional drug carriers, these surfactant-based nanovesicles have nonionic surfactants (Spans) incorporated with edge activators, giving them high permeability and high deformability. Moreover, spanlastic formulations overcome some of the most important limitations of traditional drug delivery systems, offering higher chemical stability and biocompatibility. Their ability to encapsulate hydrophilic and lipophilic drugs increases spanlastics' use for various administration routes like oral, ocular, transdermal, and nasal delivery. Furthermore, spanlastics enable controlled and sustained drug release, decreasing the frequency of dosage and improving patient compliance. This review comprehensively analyzes spanlastic technology covering its composition, preparation methods, mechanisms of drug penetration, and characterization, as well as major pharmaceutical applications, highlighting the technology's prospects in contemporary drug delivery and nanomedicine.

Keywords: *Nanovesicles; Spanlastics; Surfactants; Edge Activators; Drug Permeability.*

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I. INTRODUCTION

Vesicular drug delivery systems (VDDS) have become a promising way to improve controlled release, bioavailability, and drug stability while lowering side effects. Both hydrophilic and lipophilic medications can be effectively delivered by encapsulating them in vesicular structures made of self-assembled amphiphilic molecules. Numerous VDDS have been created, each with specific benefits for drug delivery such as liposomes, niosomes, transferosomes, phytosomes, virosomes, ethosomes, and spanlastics [1].

Spanlastics are a new type of elastic vesicular drug delivery system based on surfactants that trap the drug as a bilayer in the core cavity [2]. The word Spanlastic (Span + Elastic) was created by Kakkar and Kaur because they are made of nonionic surfactants based on sorbitan (Span) and have an edge activator that gives the vesicles their elastic properties [3]. Like transferosomes, these are extremely elastic and flexible carriers. The inclusion of edge activators in their composition is responsible for these vesicles' elastic properties. Compared to drug solutions, these deformable vesicular carrier systems exhibit better permeability.

A vesicle composed of nonionic surfactants encapsulates the drug in spanlastics, which are amphiphilic in nature. Spanlastics are little and extremely tiny. They are a unique kind of nanovesicle that overcomes the drawbacks of liposomes, namely their chemical instability. Liposomes' fluctuating purity of phospholipids and their susceptibility to oxidative destruction lead to chemical instability. Spanlastics are site-specific drug delivery systems that can be employed for topical, nasal, oral, ophthalmic, and transungual treatments. Numerous studies have shown that spanlastics can minimize side effects while increasing drug absorption, patient adherence, and treatment effectiveness.

II. SALIENT FEATURES OF SPANLASTICS

- Spanlastics are stable, osmotically active, and capable of entrapping solutes.
- Through its bilayer, they release medication in a regulated manner, allowing the encapsulated substance to be released over time.
- Since their structural characteristics are flexible, they can be altered to meet the specified requirements.
- Medication availability at the site is improved by spanlastics by shielding it from biological environments [4].

III. ADVANTAGES

- Target Specific: The medicated particles exhibit improved restorative function as they are protected from environmental factors and their action is limited at unintended sites.

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- Enhancement of Bioavailability: Compared to conventional methods, the vesicle's protective structure helps the drug reach its intended location intact, thereby improving bioavailability.
- Spanlastics decompose naturally and are not immunogenic.
- They enhance the stability of the encapsulated drug and are osmotically stable and active.
- There are no special requirements for the handling or storage of surfactants.
- They can be administered topically, parenterally, or orally to promote their delivery to the target site.
- In prolonged drug delivery, they are crucial in delaying the elimination of drug molecules from the systemic circulation.
- They have a low toxicity character and are very compatible with biological systems due to the presence of nonionic surfactants.
- These vesicular systems have superior ocular permeability compared to niosomal formulations because of their high degree of elasticity and deformability.
- The purpose of their design is to accomplish site-specific action. Since these vesicles are elastic, they can pass through the corneal membrane and target the retinal pigment epithelium, choroid, and vitreous cavity in both the posterior and anterior regions of eye.
- Surfactant irritancy follows the order: cationic > anionic > ampholytic > nonionic. Thus, spanlastics with nonionic surfactants are suitable for ocular use due to minimal irritation.
- Their chemical stability surpasses that of liposomes.
- Economical preparation technique.
- Raw materials are easy to obtain [5].

IV. DISADVANTAGES

- Vesicle size may increase as a result of drug entrapment, which occurs when the surfactant head group interacts with the drug molecule, thereby altering stability and release of drug.
- Long-term sonication can damage vesicle integrity, which could negatively impact the encapsulation efficiency of nanospanlastic vesicles.
- Spanlastics' encapsulation capacity is influenced by the surfactants' HLB value, thereby affecting drug loading and stability.
- Multi-Lamellar Vesicles (MLV) are most commonly prepared by extrusion and sonication, both of which require specialized equipment and are time-consuming.
- Over time, spanlastics are susceptible to aggregation, leakage, and degradation, which may compromise their therapeutic efficacy and shelf life [6].

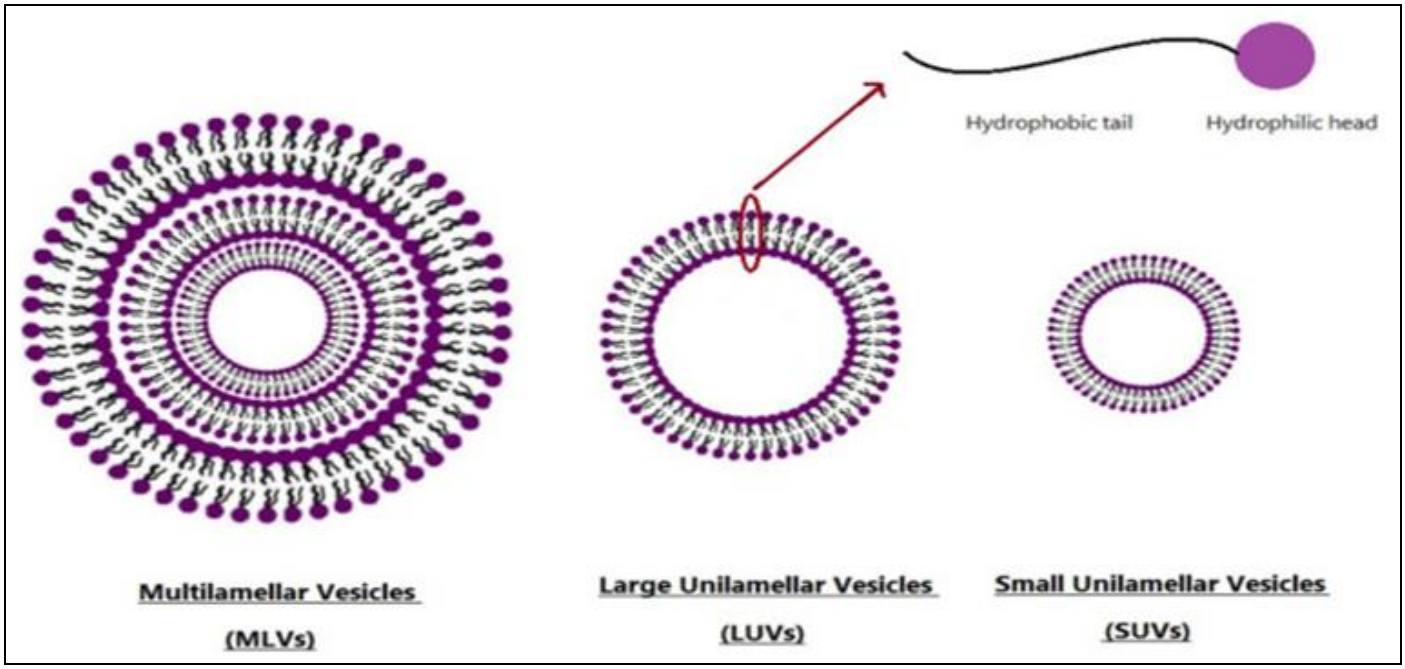

Fig 1 Classification of Spanlastics [8].

V. CLASSIFICATION OF SPANLASTICS

➢ *It is Categorized according to the Number of Layers it Comprises (Fig. 1):*

- *Multi-Lamellar Vesicles (MLV):*

The structure of MLVs is made up of many bilayers. MLVs have a diameter of around 0.5 to 1.0 microns. It is widely used, simple to prepare, and stable for a long time in storage.

- *Large Unilamellar Vesicles (LUV):*

LUVs are 100 nm to 1 µm in size. Due to their high aqueous/lipid component ratio, LUVs are able to capture a greater amount of medication inside their core.

- *Small Unilamellar Vesicles (SUV):*

SUVs typically range in size from 20 nm to 50 µm. The sonication process is used to prepare SUVs from Multi-Lamellar Vesicles [7].

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1435

VI. MORPHOLOGY

Spanlastics, as illustrated in Fig. 2, consist of concentric bilayers similar to those of liposomes. Spanlastics are spheroid structures made up of amphiphilic molecules that function as an appropriate matrix for bioencapsulation. Hydrophilic medications are found in the core region of the vesicle, while hydrophobic drugs are found in the hydrophobic tail. The number of vesicles in the core determines whether they are unilamellar or multilamellar (MLVs). These can be either Small Unilamellar Vesicles (10-100 nm) or Large Unilamellar Vesicles (100-3000 nm), depending on the size of the vesicles. MLVs exhibit longer retention time than SUVs with equivalent lipid content.

Usually, the spanlastic vesicle is between 180 and 450 nm in size [9].

VII. COMPONENTS OF SPANLASTICS

Nonionic surfactants and edge activators are two essential components that make up spanlastics. These vesicles have been termed Spanlastics since their main constituent is Spans, or surfactants.

- *Nonionic Surfactants:*

Surfactants, which are surface-active chemicals, work to lessen the interfacial tension between two liquids (the oily phase and the aqueous phase). Since nonionic surfactants are more stable, compatible, and non-toxic than their cationic, amphoteric, or anionic counterparts, they are the most often utilized surface-active agent in vesicle preparation. They serve as permeability enhancers, emulsifiers, wetting agents, and solubilizers, among other purposes. Both polar and nonpolar segments make up nonionic surfactants. The head of a nonionic surfactant is devoid of any charged groups.

One important type of nonionic surfactants are Spans, or Sorbitan alkyl esters. There are several varieties of Spans, including Span 80 (monooleate), Span 60 (monostearate), Span 40 (monopalmitate), and Span 20 (monolaurate), depending on the kind of fatty acid linked to the polyoxyethylene sorbitan portion of the molecule. Spans organize into concentric bilayers, forming the vesicular framework of spanlastics. Predicting the stability of the vesicular formulation is significantly influenced by the type of Span. Instability, aggregation and disruption are commonly observed in vesicles formulated with Span 40 and Span 80. Conversely, Span 60's saturated alkyl chains provide the formed vesicles more sustainability.

- *Edge Activators:*

These are a unique type of surfactants that exhibit strong hydrophilicity or a high HLB value. By reducing interfacial tension, these single-chain surfactants destabilize the vesicles and make the bilayer vesicles more deformable. Thus, they provide flexibility to these vesicles' lipid bilayer membranes.

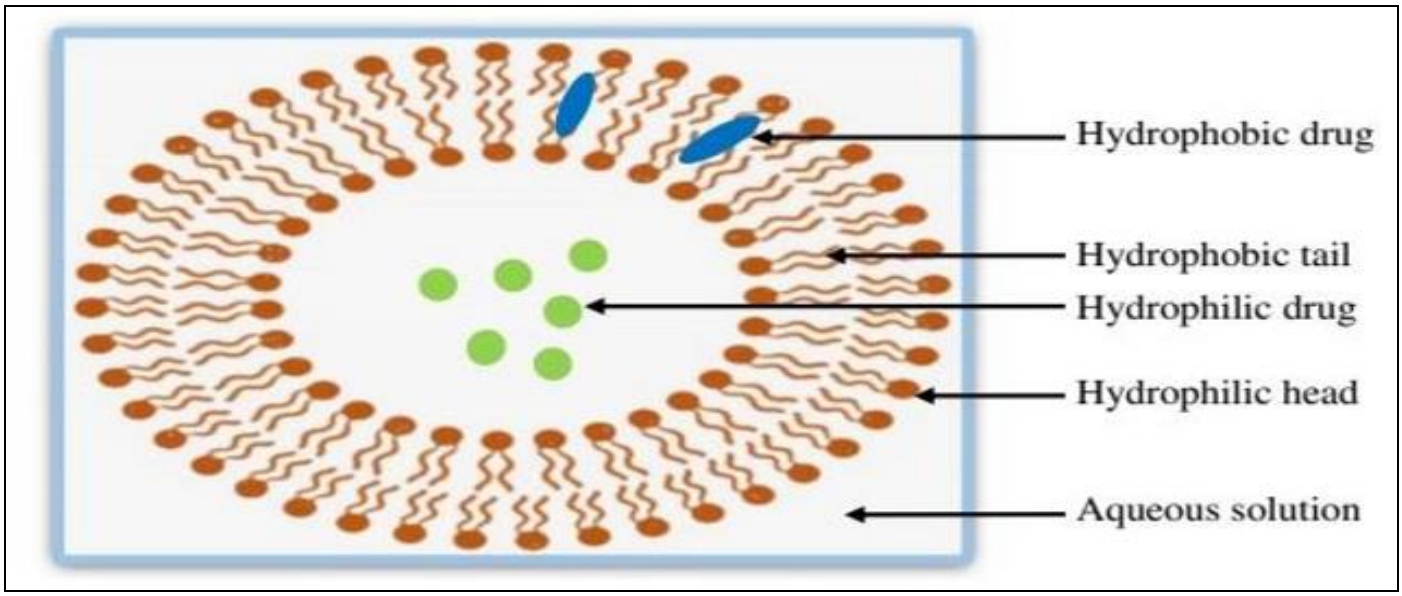

Fig 2 Structure of Spanlastic Vesicle [9].

EAs generally produce spherical vesicles with reduced particle size. The vesicles' elastic properties are enhanced by the use of an edge activator like Tween 80, enabling to temporarily expand the biological membranes' pore size so that slightly larger vesicles can pass through, improving drug penetration. Additionally, these hydrophilic surfactants have the capacity to destabilize vesicular membranes, improve deformability, and induce varying levels of packing disruption.

- *Ethanol:*

Ethanol increases the efficacy of nanovesicular carriers by improving their size, zeta potential, and entrapment efficiency. It has the ability to condense membranes. It facilitates improved drug partitioning and entrapment within the vesicles. The thickness of the vesicular membrane is decreased, and the spanlastic system's capacity to encapsulate medications is improved. Ethanol's impact on nanovesicle stability during storage is one noteworthy feature. Nanovesicles based on ethanol have a negative surface charge

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and are stable due to their electrostatic repelling characteristics. Because of this characteristic, they are less likely to aggregate or fuse while being stored, guaranteeing a more stable formulation over time [10-12].

VIII. MECHANISM OF PENETRATION OF SPANLASTICS

The lipid bilayers are destabilized by edge activators, which makes the vesicles more deformable. These vesicles use a surfactant that disrupts lipid membranes, further encouraging breakdown (lysis) at elevated concentrations. Thus, elastic vesicles can deform and move through intercellular spaces due to a water gradient, with membrane bending energy influenced by their composition.

➢ *Drug Permeation Occurs through Two Mechanisms:*

- The elastic vesicles alter the intercellular lipid lamellae after interacting with the epithelial cell membrane and acting as penetration enhancers.
- Elastic vesicles function as carriers, in which intact vesicles containing medication can reach across biological membranes and pass through intercellular gaps.

➢ *The Effective Transport of these carriers is Influenced by Two Factors:*

- The vesicle bilayers' stress-dependent flexibility.
- The presence of an osmotic gradient.

➢ *The Process by which the Spanlastic System Penetrates the Lipid Bilayer and Epidermis is shown in Fig. 3.*

- Depicts the organ's layers and spanlastic system.
- Illustrates the interaction between the spanlastic system and the epidermis, resulting in pore formation within the organ's layers.
- Represents the penetration of the spanlastic system through the layers.
- Demonstrates drug release from the spanlastic system within the organ, allowing the entrapped drug to directly reach the infected area [13, 14].

IX. METHOD OF PREPARATION

➢ *Thin Film Hydration Method:*

A weighed amount of Span 80 or Span 60 is dissolved in chloroform in a round-bottom flask. Using a rotary evaporator under vacuum, the organic solvent is evaporated at an elevated temperature, forming a thin lipid layer on the flask's inner wall. The formed film is then hydrated by dissolving a specified amount of drug in the aqueous phase comprising the chosen edge activator and co-solvent, which is then introduced into the deposited thin film. The flask is then reattached to the evaporator and rotated at 90 rpm at 60°C under normal pressure for 30 min until all lipid film is stripped off the flask walls. After standing for an additional 2 h at room temperature for complete hydration, the resulting dispersion is stored at 4°C overnight [15,16].

➢ *Ether Injection Method:*

In this method, the surfactant dissolved in ether is injected into the continuously stirred aqueous phase containing edge activators, maintained at 60°C. The ethereal solution is injected using an 18-gauge needle at a rate of 25 mL/min. Using a rotary evaporator, the ether solution is evaporated. Once the organic solvent evaporates, single-layered vesicles are formed [17].

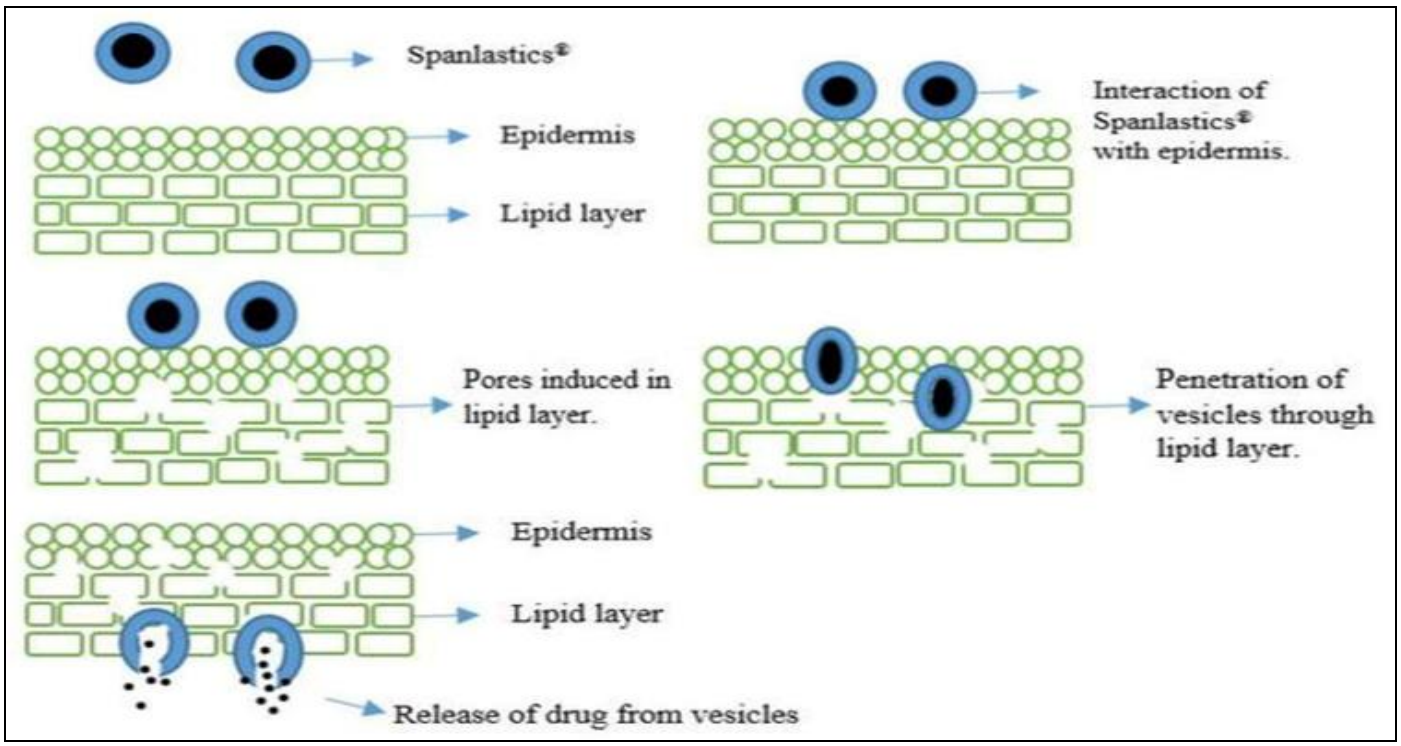

Fig 3 Mechanism of Penetration of Spanlastics [14].

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➢ *Sonication:*

In this technique, a 10 mL glass vial containing the surfactant combination is filled with an aliquot of medication in an appropriate buffer. A titanium probe is then used to sonicate the mixture.

➢ *Ethanol Injection Method:*

This method is used to produce spanlastics with a predetermined ratio of nonionic surfactant to edge activator. The nonionic surfactant and the drug to be encapsulated are dissolved in ethanol. After that, the lipid solution is sonicated for five minutes. A heated aqueous phase containing an edge activator, like Tween-80, is then gradually added to this lipid solution. Using a magnetic stirrer, the aqueous phase is continuously agitated at 800-1600 rpm and kept at 70-80°C for 30 min. Then, at a lower temperature, the mixture is stirred for another half hour. The final formulation is adjusted to 10 mL using distilled water.

The formation of a heterogeneous population (between 30 and 110 nm) is the primary disadvantage of this technique. Additionally, very dilute spanlastics are formed as ethanol forms azeotrope with water thus it is difficult to remove all ethanol and the presence of even low amount of ethanol can lead to inactivation of various biologically active molecules [18, 19].

➢ *Microfluidization Method:*

In this method, two fluidized streams—one containing the drug and the other containing the surfactant—interact at ultrahigh velocity within strictly defined microchannels inside the interaction chamber. The energy supplied to the system remains confined to the spanlastic formulation area. This is known as the submerged jet principle, which enhances uniformity, reduces particle size, and improves formulation reproducibility [20].

➢ *Extrusion Method:*

This method involves preparing a solution of diacetyl phosphate and surfactant, then employing a rotary vacuum evaporator to evaporate the mixture, leaving behind a thin layer. The thin film is rehydrated with aqueous drug solution, and the obtained mixture is extruded through a polycarbonate membrane (mean pore size of 0.1 microns). The mixture is passed through the membrane in series for up to eight passages to obtain a uniform result [21].

X. FACTORS AFFECTING THE PHYSICO-CHEMICAL PROPERTIES OF SPANLASTICS

➢ *Membrane Additives:*

In addition to drugs and surfactants, several additives may be used to create stable spanlastics. The spanlastics formed have a number of morphologies and their permeability and stability properties can be altered by manipulating membrane characteristics by different additives. For example, Tweens enhance the flexibility of the formed vesicles to easily enter into targeted area. The composition of the membrane affects the average spanlastic size.

➢ *Characteristics of Drugs:*

The drugs entrapment efficiency can be influenced by a number of factors, including its chemical structure, molecular weight, lipophilicity and hydrophilicity as well as the value of its hydrophilic-lipophilic balance. The trapping of pharmaceuticals may result in an increase in the size of the vesicle. The drug interacts with the head groups of surfactants and generates a charge that causes the bilayers of surfactants to repel one another, increasing the size of the vesicles.

➢ *Temperature of Hydration:*

The spanlastics' size and form are influenced by the temperature at which they are hydrated. In an ideal situation, it should be higher than the system's gel-to-liquid phase transition temperature. Temperature changes in the spanlastic system can affect the assembly of surfactants into vesicles. In addition to this, the amount of hydration medium and the duration of hydration are other important variables. Improper selection of these factors may impact vesicle formation and drug retention.

➢ *Content and Surfactant Type:*

Since the surface free energy of surfactants lowers as their hydrophobicity rises, the mean size of spanlastics increases proportionately with an increase in the hydrophilic-lipophilic balance (HLB) of surfactants. Depending on the temperature, the kind of lipid or surfactant, and the presence of other additives such edge activators, spanlastic bilayers can exist in either a liquid or gel form. Alkyl chains are present in a well-organized form in the gel state, while the bilayers' structure is more disorganized in the liquid state. The gel-liquid phase transition temperature (TC) is used to characterize the lipids and surfactants. Entrapment efficiency is also influenced by the phase transition temperature (TC) of surfactants; for example, Span 60 with a higher TC offers greater entrapment. The entrapment efficiency of the spanlastics is affected by the HLB value; for example, spanlastics have high entrapment efficiency at HLB value 8.6 but HLB value 14 to 17 is not suitable for their formulation.

➢ *Resistance to Osmotic Stress:*

When a hypertonic salt solution is added to a spanlastic formulation, the diameter decreases. The vesicles in a hypotonic salt solution first release slowly and slightly swell, most likely as a result of the eluting fluid being inhibited. This is followed by a quicker release, which might be the result of the vesicles' structure mechanically loosening under osmotic stress [22, 23].

➢ *Structure of Surfactants:*

The vesicle geometry formed by surfactants is influenced by their structure, which is determined by the critical packing parameter (CPP). The CPP can be calculated using (1):

$$\text{Critical packing parameter (CPP)} = v/lc \times a_0$$

Where,

v = hydrophobic group volume,

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lc = critical hydrophobic group length,

a_0 = area of hydrophilic head group.

➢ *In the following ways, CPP aids in Vesicle Structure Prediction:*

- If CPP<1/2, spherical micelles are generated.
- If ½<CPP<1, bilayer micelles are created.
- If CPP>1, inverted micelles are created [24].

➢ *Method of Preparation:*

The final formulation properties are significantly hampered by spanlastic preparation techniques such handshaking, ether injection, or sonication. In contrast to vesicles created by the handshaking approach, ether injection-made vesicles are smaller. Thus, hydrating the mixture and subsequently vortexing will aid in the reduction of the vesicles produced by the hand-shaken approach.

➢ *In-Vivo Behaviour of Spanlastics:*

It has been observed that *in-vivo* spanlastics are equivalent to nanovesicles, and their dispersion resembles that of colloidal drug delivery systems. Due to the natural vectoring process, these components have a notably high level of disposition in body. Since bigger vesicles become stuck in the lungs' alveolar part due to retention or maybe phagocytic activity, changes in size also impacts pattern of drug elimination from circulation. However, tiny vesicles will have easier access to the spleen since they may readily pass through the sinusoidal epithelium [4].

XI. CHARACTERIZATION OF SPANLASTICS

➢ *Vesicle Size and PDI:*

Dynamic light scattering is used to determine the particle size (PS) and polydispersity index (PDI) at 25°C using a Zetasizer. Formulations are diluted with distilled water to ensure proper scattering intensity. PDI indicates the degree of homogeneity of vesicle size, where a small value implies homogeneously sized vesicle and vice versa. The measurement is conducted three times for each sample, with each measured twice.

➢ *Zeta Potential:*

Zeta potential of the Spanlastic formulation is determined using a Zetasizer by measuring the electrophoretic mobility of charged vesicles in an applied electrical field. The measurements are performed at 25°C in triplicate after suitable dilution with double-distilled water. Due to strong electrostatic repulsion, stability is ensured by a high zeta potential, whether positive or negative; aggregation is more likely when the value is low. A zeta potential of about ±30 mV indicates that the system is stable [25-27].

➢ *Number of Vesicles Per Cubic Millimetre [28]:*

Vesicles are suitably diluted with water, and the number of vesicles per cubic millimetre is counted using a hemocytometer. The vesicles in 80 small squares are counted, and the number of vesicles per cubic millimetre is calculated using (2):

➢ *Entrapment Efficiency [29, 30]:*

Encapsulation efficiency is estimated by the indirect method using ultracentrifugation to separate the unentrapped drug**.** A 1 mL sample is centrifuged at 15,000 rpm for 1 h at 4°C using a cooling centrifuge. The supernatant is separated and diluted with a suitable solvent. The amount of free drug is measured using an appropriate method as described in the monograph of that particular drug. Encapsulation efficiency is determined using (3):

$$\text{Total no. of vesicles per mm}^3 = \frac{\text{Total no. of vesicles counted} \times \text{dilution factor} \times 4000}{\text{Total no. of squares counted}} \quad (2)$$

$$\%EE = \frac{\text{Total amount of drug} - \text{Free drug in the supernatant}}{\text{Total amount of drug}} \times 100 \quad (3)$$

➢ *Elasticity Measurement:*

The elasticity of spanlastics is determined by the deformability index (DI). DI is characterized via the extrusion technique. Under continuous vacuum pressure, the mixture is extruded for ten minutes through a polycarbonate membrane (100 nm pore size). Following extrusion, the mean particle size and the weight of the extruded sample are determined. DI is computed using (4):

$$DI = J\left(\frac{r_v}{r_p}\right)$$

Where

J = sample weight (g) extruded by the membrane filter in 10 minutes,

r_v = size of the spanlastic vesicles following extrusion (nm),

r_p = pore size of the membrane filter (nm) [31].

➢ *Differential Scanning Calorimetry (DSC):*

DSC is used to analyze the thermal properties of a sample. The sample is accurately weighed (2mg), and sealed in an aluminum pan. The analysis is performed at a heating rate of 10°C/min over a temperature range of 20°C to 200°C under a nitrogen atmosphere (50 mL/min). The thermograms generated are examined for any shifts, disappearance, or appearance of new peaks [32].

➢ *Morphology Examination:*

To determine the lamellarity, size homogeneity, shape, and physical stability of spanlastics, morphological examination is performed using a transmission electron microscope. A single drop of the diluted spanlastic sample is placed on a copper grid coated with carbon and allowed to dry at room temperature. After applying 1% phosphotungstic acid as a negative stain, the sample is allowed to dry at room temperature for 20 min prior to visualization.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1435

➢ *In-Vitro Drug Release Studies:*

The *in-vitro* drug release study is carried out using the dialysis membrane diffusion method. The sample is introduced into the dialysis bag, previously hydrated with the receptor medium for 24 h. The dialysis bag is immersed in phosphate buffer solution and rotated at a specified rpm at 37±0.5°C. Samples are withdrawn at fixed time intervals and replenished with an equal volume of fresh buffer to preserve sink conditions. The samples are then spectrophotometrically analyzed for drug concentration [33, 34].

➢ *Stability Studies:*

For three months, spanlastic formulations are stored in amber-colored, airtight glass vials at 4 ± 1°C in order to carry out stability studies. At specified intervals of one, two, and three months, samples are taken out and assessed for zeta potential (ZP), drug content, particle size (PS), polydispersity index (PDI), and entrapment efficiency (%EE). Significant changes in these parameters suggest that the formulation may be unstable [35].

XII. APPLICATIONS OF SPANLASTICS

Nanovesicles initially emerged in cosmetics and are now gaining attention for their applications in vesicle-based drug delivery systems. Spanlastics can be a perfect medication delivery device as they can capture both hydrophobic (lipophilic) as well as hydrophilic (lipophobic) drugs. For numerous applications, nanovesicles have previously been developed for drugs such as doxorubicin, siRNA, insulin, vaccines, etc. Features of these vesicles' formulation include high stability, ease of storage, biodegradability, biocompatibility, affordability, and low toxicity. They are easy to deliver by a variety of routes, including transdermal, oral, and intravenous. The following are some applications for this nanovesicular drug delivery system:

➢ *Oral Delivery:*

The oral route is the most preferred for drug administration, although it has disadvantages such as low solubility, systemic adverse effects, first-pass metabolism, and unpredictable absorption, leading to lower bioavailability. These issues make it difficult to deliver many medications effectively, particularly those with low permeability and water solubility. The surfactant-based nanocarrier drug delivery system called spanlastics has become a potent technique for enhancing bioavailability, drug solubility, and drug delivery to the intended site. They follow a biphasic release pattern, providing both rapid onset and prolonged drug action. An edge activator improves drug penetration across biological membranes by increasing the flexibility and deformability of the bilayer. By encasing both hydrophilic and lipophilic medications, these nanovesicular structures can improve stability and prevent degradation. Additionally, spanlastics provide controlled and sustained drug release, improving therapeutic effectiveness. Their ability to overcome solubility and permeability barriers makes them a valuable approach for oral drug delivery [10, 31].

➢ *Nasal Delivery:*

Bypassing hepatic metabolism, blood-cerebrospinal fluid barrier, and blood-brain barrier (BBB), the intranasal route is one of the most effective ways to deliver drugs directly to the brain through the olfactory neuron and trigeminal pathway. The highly vascularized nasal mucosa facilitates rapid drug absorption, lowers systemic adverse effects, reduces degradation by gastric fluids, and eliminates first-pass metabolism. However, obstacles including restricted epithelial permeability and fast mucociliary clearance make it difficult for drugs to be absorbed. Spanlastics improve medication penetration through the BBB and nasal epithelium, hence overcoming these restrictions. Efficient nose-to-brain drug delivery is made possible by their elasticity, which improves permeation, and penetration enhancers in their structure, which facilitate fluidization. Because of these characteristics, spanlastics exhibit significant potential as carriers for nasal drug delivery, guaranteeing improved therapeutic results, particularly for medications that target the central nervous system [36-38].

➢ *Ocular Delivery:*

Ocular drug delivery presents distinct obstacles due to eye's complex physiological and anatomical barriers. Due to intricate structure and highly selective physiological corneal barriers that prevent exogenous materials from entering the ocular tissues, traditional ocular drug delivery methods, including eye drops and ointments, often have low drug bioavailability. Furthermore, nasolacrimal drainage and high tear fluid turnover may cause excessive and quick drug loss, which might decrease ocular absorption by shortening the duration the instilled drug remains at the action site. Spanlastics, an elastic vesicular system based on nonionic surfactants, have emerged as a promising delivery vehicle capable of overcoming the limitations of traditional ocular drug delivery systems. Their high elasticity, achieved by incorporating an edge activator with a nonionic surfactant, improves penetration across the cornea for loaded drugs, highlighting spanlastics' promise as effective carrier in ocular delivery. They provide good patient compliance, ease, target specificity, and chemical stability. Spanlastics decrease systemic adverse effects, increase retention time, increase drug absorption, and shield medications from tear dilution and enzymatic breakdown. Because of these characteristics, spanlastics are a useful method for improving the therapeutic effectiveness and ocular medication delivery [39, 40].

➢ *Transdermal Delivery:*

The transdermal route is a suitable alternative to oral administration as it avoids hepatic first-pass metabolism and reduces gastrointestinal side effects. It reduces the need for frequent dosing, enables prolonged drug release, and enhances overall patient adherence. But the main obstacle to transdermal medication delivery is stratum corneum's barrier function, which restricts drug penetration. Because of their ultra-deformability, spanlastics can better absorb drugs by penetrating deeper into dermal tissues and squeezing through the stratum corneum's intracellular gaps. Since spanlastics are more stable and non-irritating than formulations based on cationic surfactants, they are a good choice for transdermal medication administration [41, 42].

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➢ *Transungual Delivery:*

Onychomycosis, a fungal infection mostly caused by Trichophyton rubrum, causes pain, irritation, and deformity in the nail apparatus. Despite being widely used, oral antifungal medications can have unintended side effects such gastrointestinal problems, drug interactions, and a high recurrence rate. The barrier characteristics of the nail prevent topically administered antifungal medicines from penetrating, which makes transungual administration difficult. New topical treatments such as spanlastics, which are self-assembling nanovesicles derived from surfactants, have been created to address this. By encapsulating poorly water-soluble medications, these ultra-deformable carriers can improve their transungual penetration and therapeutic effectiveness [43].

Table 1 Overview of Drug Formulations Developed using Spanlastics.

Sr. no	Drug (Type)	Composition	Method of Preparation	Characterization	Outcome	Reference
1.	Lacidipine (Antihypertensive)	Span 60, Tween 80	Modified ethanol injection method	EE: 86.84% In-vitro release: 92.96%	Enhanced barrier permeation profile and increased drug permeability	[3]
2.	Lamotrigine (Antiepileptic)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 174.2 nm PDI: 0.563 ZP: -39.35 mV EE: 92.75% In-vitro release: 80.44%	Improved solubility, enhanced drug absorption and high brain targeting efficiency for maximizing the antiepileptic effect	[22]
3.	Miconazole nitrate (Antifungal)	Span 60, Tween 60, Ethanol	Ethanol injection method	VS: 210 ± 0.28 nm EE: 90 ± 3.6% In-vitro release: 75%	Improved skin permeability, enhanced antifungal activity, prolonged drug release, deeper skin deposition and reduced cytotoxicity	[25]
4.	Clotrimazole (Antifungal)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 206.20 ± 4.95 nm PDI: 0.39 ± 0.00 ZP: -29.60 ± 0.99 mV EE: 66.54 ± 7.57%	Higher drug permeation, sustained release, high antifungal activity and non-irritant to the cornea.	[26]
5.	Dorzolamide (Carbonic anhydrase inhibitor, antiglaucoma agent)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS:150.6 nm PDI: 0.735 ZP: -17.2 mV Deformability: 24.8	Sustained drug release, enhanced intraocular penetration and increased bioavailability	[27]
6.	Ketoconazole (Antifungal)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 126 ± 4.7 nm EE: 68.82 ± 0.42%	Enhanced corneal permeation compared to prepared niosomal formulation, improved posterior eye delivery and prolonged retention	[28]
7.	3-acetyl-11-keto-β-boswellic acid (Anti-inflammatory)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 255.8 ± 2.67 nm ZP: -49.56 mV EE: 90.04 ± 0.58%	High entrapment efficiency, enhanced skin permeability, and improved topical delivery.	[29]
8.	Miconazole nitrate (Antifungal)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 242.8 nm ZP: -28.3 mV EE: 82.00%	Enhanced permeability compared to control niosomes	[30]
9.	Famotidine (Prokinetic and H2 receptor antagonist)	Span 60, Tween 60, Ethanol	Ethanol injection method	VS: 170.58 ± 4.48 nm PDI: 0.368 ± 0.04 ZP: −30.93 mV EE: 68.91 ± 0.48 % DL: 6.07 ± 0.04% DI: 8.26 ± 0.18	Improved dissolution, drug release characteristics, membrane permeation and pharmacokinetic behavior	[31]
10.	Simvastatin (Anti-cancer)	Span 20, Tween 80	Ethanol injection	VS: 128.50 nm PDI: 0.329	Improved cytotoxicity, enhanced anti-cancer activity	[33]

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			method	ZP: -29.11 mV	against MCF-7, HCT-116 and HepG2 cancer cells	
11.	Benzalkonium chloride (Antimicrobial)	Span 60, Tween 80	Thin film hydration method	VS: 152.53 ± 17.11 nm PDI: 0.76 ZP: 49.50 ± 6.77 EE: 97.29 ± 0.34%	Enhanced drug encapsulation, superior antimicrobial activity, and significantly better wound healing efficacy compared to conventional niosomes	[34]
12.	Caffiene (Hair growth stimulant and dermatological agent)	Span 60, Tween 80	Thin film hydration method	VS: 372.63 ± 3.58 nm PDI: 0.529 ± 0.10 ZP: -39.10 ± 0.79 mV EE: 60.77 ± 2.45%	Improved deep skin penetration, prolonged drug release, higher skin retention and potential follicular targeting for hair growth stimulation	[35]
13.	Filbanserin (5-HT1A agonist and 5-HT2A antagonist)	Span 60, Sodium deoxycholate, Ethanol	Ethanol injection method	VS: 129.70 nm ZP: -33.17 mV EE: 80.4 ± 6.8%	Enhanced bioavailability and faster drug absorption for efficient trans-nasal brain delivery	[37]
14.	Celecoxib (Anti-inflammatory)	Span 60, Tween 80, Ethanol	Spraying technique/ modified injection method	VS: 112.5 ± 3.6 nm PDI: 0.126 to 0.321 ZP: -13.6 to -17.5 mV EE: 83.6 ± 2.3%	Displayed highest transdermal flux and permeability coefficient. Marked suppression of COX-2, NF-kB and TNF-α levels, along with significant reduction in edema circumference. Offer enhanced site-targeted therapy for treating chronic inflammation such as rheumatoid arthritis, outperforming both commercial and conventional therapies.	[42]
15.	Piperine (Anti-epileptic)	Phospholipon 90G, Span 60, Sodium cholate	Thin film hydration method	VS: 152.4 nm PDI: 0.1118 ZP: -36.83 mV EE: 72.93% In-vitro release: 82.32%	Enhanced permeation across nasal mucosa, higher brain distribution, improved anticonvulsant effect and nasal safety	[44]
16.	Oxiconazole nitrate (Antifungal)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 452.56 nm ZP: -5.74 mV EE: 94.67 ± 0.89% In-vitro release: 82.74 ± 1.34%	Biphasic release, higher entrapment efficiency, improved solubility and enhanced topical delivery.	[45]
17.	5-flucytosine (Antifungal)	Span 60, Tween 80	Ethanol injection method	VS: 464.57 nm PDI: 0.14 ZP: -34.5 mV EE: 96.379%	Enhanced skin permeation, sustained drug release and improved antifungal activity	[46]
18.	Repaglinide (Anti-diabetic)	Span 60, Tween 80, Ethanol	Thin film hydration method	VS: 126.162 nm PDI: 0.416 ZP: -43.257 mV EE: 77.753%	Improved solubility, enhanced stability and better drug delivery efficiency.	[47]
19.	Zolmitriptan (Antimigraine)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 117.5 nm PDI: 0.685 ZP: -28.0 mV EE: 45.65%	Enhanced nasal membrane permeation, faster drug absorption, higher steady-state flux and potential for effective brain delivery	[48]
20.	L-ascorbic acid (Antioxidant)	Span 60, Tween 60, Ethanol	Ethanol injection method	VS: 642.6 ± 16.54 nm PDI: 0.533 ± 0.12 ZP: -23.5 ± 1.34 mV DI: 11.13 ± 1.145 EE: 89.77 ± 3.61%	Enhanced antioxidant protection against skin photodamage, improved skin permeation, LAA stability, better suppression pf MMP2 and MMP9 and effective prevention of UV-induced skin	[49]

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					damage.	
21.	Vanillic acid (Anti-inflammatory)	Span 60, Tween 80	Ethanol injection method	VS: 299.8 ± 9.97 nm PDI: 0.386 ± 0.047	Improved ocular permeability, absorption and superior anti-inflammatory efficacy compared to VA suspension	[50]
22.	Irbesartan (Antihypertensive)	Span 60, Tween 80, Labrafil	Ethanol injection method	VS: 311.6 ± 2.45nm PDI: 0.536 ± 0.044 EE: 90.06 ± 1.44% In-vitro release: 58.2 ± 1.87%	Enhanced skin permeation, improved bioavailability and superior antihypertensive efficacy compared to oral suspension	[51]
23.	Bimatoprost (F2α analog)	Span 60, Tween 80, Ethanol	Ethanol injection method	VS: 364.2 ± 15.8 nm DI: 10.48 ± 1.6 ZP: -19.9 ± 2.1 EE: 83.1 ± 2.1% In-vitro release: 71.3 ± 5.3%	Enhanced dermal accumulation, superior drug deposition and significantly improved hair regrowth compared to naïve BIM gel and commercial minoxidil	[52]

XIII. CONCLUSION

Spanlastics have gained significant attention as a next-generation drug delivery system, addressing key challenges in traditional formulations, such as low permeability, instability, and poor bioavailability. The unique composition, combining nonionic surfactants and edge activators, provides exceptional flexibility, facilitating efficient drug transport across biological membranes. Recent advancements in nanotechnology and pharmaceutical sciences have optimized spanlastic formulations, leading to better drug targeting, minimized side effects, and enhanced therapeutic efficacy. As current studies explore their potential in diverse medical applications, including cancer treatment, neurological conditions, and transdermal therapies, spanlastics are set to play a central role in the future of precision medicine and patient-specific drug delivery.

REFERENCES

[1]. Alhammid SN, Kassab HJ, Hussein LS, Haiss MA, Alkufi HK. Spanlastics nanovesicles: an emerging and innovative approach for drug delivery. Maaen J Med Sci. 2023;2(3):100-7.

[2]. Vindhya VS, Kamath KK, Shripathy D, Shabaraya AR. Formulation of oxiconazole nitrate spanlastic gel. Int J of Pharm Sci. 2024;2(4):539-46.

[3]. DCruz CEM, Bhide PJ, Kumar L, Shirodkar RK. Novel nano spanlastic carrier system for buccal delivery of lacidipine. J Drug Deliv Sci Technol. 2022;68:103061.

[4]. Sharma A, Pahwa S, Bhati S, Kudeshia P. Spanlastics: a modern approach for nanovesicular drug delivery system. Int J Pharm Sci & Res. 2020;11(3):1057-65.

[5]. Chauhan MK, Verma A. Spanlatics-future of drug delivery and targeting. World J Pharm Res. 2017;6(12): 429-46.

[6]. Ratnam MA, Sirisha R, Indu I, Valli RH, Sravani I, Raju VB, et al. Spanlastics as innovative drug delivery system. Int J Innov Res Technol. 2024;11(7):3290-5.

[7]. Imam SS. The future of non-invasive ways to treat cancer. Int J Pharm Sci Res. 2021;12(9):4684-96.

[8]. Shinde AK, Sufi B, Deolekar RS, Bihade VD, Kale AA. Review on niosome-a future of targeted drug delivery system. Int J Adv Res Sci Commun Technol. 2023;3(2):716-24.

[9]. Alwan LA, Abd Alhammid SN. A modern method for the delivery of nanovesicular drugs, spanlastics. IAR J Pharm. 2023;4(6):1-11.

[10]. Vindhya VS, Kamath KK, Jain SK, Shabaraya AR. Spanlastics: a modern formulation approach in drug delivery. Eur J Pharm Med Res. 2023;10(4):96-102.

[11]. Kumar GP, Rajeshwarrao P. Nonionic surfactant vesicular systems for effective drug delivery-an overview. Acta Pharm Sin B. 2011;1(4):208-19.

[12]. Subramaniyan G, Rubina S, Ramana BV, Stanley AM, Srinivasan D. Nano-revolution in transdermal drug delivery: a bibliographic compilation of vesicular system. Int J Pharm Investig. 2024;14(2):317-26.

[13]. Alva NR, Vineetha K, Kamath KK. Exploring spanlastic: an advanced vesicular drug delivery system. Eur J Biomed Pharm Sci. 2024;11(6):420-7.

[14]. Mousa SAA, Qelliny MR, Ibrahem RA, Hadiya S, Sarhan HA, Mady FM. Spanlastics: a unique formulation strategy in the delivery of pharmaceuticals-carbapenems as a model. J Adv Biomed & Pharm Sci. 2024;7(4):117-25.

[15]. El Menshawe SF, Nafady MM, Aboud HM, Kharshoum RM, Elkelawy AMH, Hamad DS. Transdermal delivery of fluvastatin sodium via tailored spanlastic nanovesicles: mitigated Freund's adjuvant-induced rheumatoid arthritis in rats through suppressing p38 MAPK signaling pathway. Drug Deliv. 2019;26(1):1140-54.

[16]. Farghaly DA, Aboelwafa AA, Hamza MY, Mohamed MI. Topical delivery of fenoprofen calcium via elastic nano-vesicular spanlastics: optimization using experimental design and in vivo evaluation. AAPS Pharm Sci Tech. 2017;18(8):2898-909.

[17]. Kaur IP, Rana C, Singh M, Bhushan S, Singh H, Kakkar S. Development and evaluation of novel surfactant-based elastic vesicular system for ocular delivery of fluconazole. J Ocul Pharmacol Ther. 2012;28(5):484-96.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1435

[18]. Singh S, Walia MK, Pryanka, Kumari A. Spanlastic advanced approach as nanovesicular drug delivery system. Int J Sci Dev Res. 2023;8(9):422-6.
[19]. Wasankar SR, Deshmukh AD, Ughade MA, Burghat RM, Gandech DP, Meghwani RR, *et al*., Liposome as a drug delivery system- A review. Res J Pharma Dosage Forms Tech. 2012;4(2):104-12.
[20]. Mallikarjun DP, Pooja VM, Rajarajan S, Baby B, Rao V. A systematic review on non-invasive drug delivery on spanlastics. Int J Novel Res Dev. 2024;9(5):317-29.
[21]. Kumar KA, Sathyanarayanam S, Gomathi J. Nano spanlastics; a new formulation approach in novel drug delivery system. Int J Res Trends Innov. 2024;9(6):559-68.
[22]. Karim KM, Mandal AS, Biswas N, Guha A, Chatterjee S, Behera M, *et al*., Niosome: a future of targeted drug delivery systems. J Adv Pharm Tech Res. 2010;1(4):374-80.
[23]. Khan A, Varshney C, Chaudhary T, Singh B, Nagarajan K. Spanlastics: an innovative formulation strategy in pharmaceutical drug delivery. World J Pharm Res. 2023;12(20):219-34.
[24]. Ashutosh L, Suman R, Sidhyartha S, Altaf bhai S, Vandana YM. A novel drug delivery system: niosomes review. J Drug Deliv Ther. 2012;2(5):129-35.
[25]. Ibrahim MS, Elkady OA, Amer MA, Noshi SH. Exploiting response surface D-optimal design study for preparation and optimization of spanlastics loaded with miconazole nitrate as a model antifungal drug for topical application. J Pharm Innov. 2023;18:2402-18.
[26]. Abdelbari MA, El-mancy SS, Elshafeey AH, Abdelbary AA. Implementing spanlastics for improving the ocular delivery of clotrimazole: in vitro characterization, ex vivo permeability, microbiological assessment and in vivo safety study. Int J Nanomedicine. 2021;16:6249-61.
[27]. Sharma A, Pahwa S, Bhati S, Kudeshia P. Formulation and evaluation of dorzolamide spanlastics. Int J Pharm Sci & Res. 2020;11(8):3930-5.
[28]. Kakkar S, Kaur IP. Spanlastics-a novel nanovesicular carrier system for ocular delivery. Int J Pharm. 2011;413(1-2):202-10.
[29]. Badria F, Mazyed E. Formulation of nanospanlastics as a promising approach for improving the topical delivery of a natural leukotriene inhibitor (3-acetyl-11-keto-β-boswellic acid): statistical optimization, in vitro characterization, and ex vivo permeation study. Drug Des Devel Ther. 2020;14:3697-721.
[30]. Mohanta P, Pandey NK, Kapoor DN, Singh SK, Sarvi Y, Sharma P. Development of surfactant-based nanocarrier system for delivery of an antifungal drug. J Pharm Res. 2017;11(9):1153-8.
[31]. Almohamady HI, Mortagi Y, Gad S, Zaitone S, Alshaman R, Alattar A, *et al.*, Spanlastic nano-vesicles: a novel approach to improve the dissolution, bioavailability, and pharmacokinetic behavior of famotidine. Pharmaceuticals. 2024;17(12):1-25.
[32]. Zaki RM, Ibrahim MA, Alshora DH, El Ela AESA. Formulation and evaluation of transdermal gel containing tacrolimus-loaded spanlastics: *in vitro*, *ex vivo* and *in vivo* studies. Polymers. 2022;14(8):1-15.
[33]. Badr-Eldin SM, Aldawsari HM, Alhakamy NA, Fahmy UA, Ahmed OAA, Neamatallah T, *et al*., Merging experimental design and nanotechnology for the development of optimized simvastatin spanlastics: a promising combined strategy for augmenting the suppression of various human cancer cells. Pharmaceutics. 2022;14(5):1-16.
[34]. Wagdi MA, Salama A, El-Liethy MA, Shalaby ES. Comparative study of niosomes and spanlastics as a promising approach for enhancing benzalkonium chloride topical wound healing: *in-vitro* and *in-vivo* studies. J Drug Deliv Sci Technol. 2023;84(5):1-35.
[35]. Ghozzy OM, Abdelghani GM, Elsabbagh HM. Formulation, characterization, and ex vivo skin permeation of caffeine loaded spanlastic nanovesicles. IOSR J Pharm. 2020;10(2):1-15.
[36]. Abdelmonem R, Abo El-Enin HA, Abdelkader G, Abdel-Hakeem M. Formulation and characterization of lamotrigine nasal insert targeted brain for enhanced epilepsy treatment. Drug Deliv. 2023;30(1):1-11.
[37]. Alharbi WS, Hareeri RH, Bazuhair M, Alfaleh MA, Alhakamy NA, Fahmy UA, *et al*., Spanlastics as a potential platform for enhancing the brain delivery of flibanserin: in vitro response-surface optimization and in vivo pharmacokinetics assessment. Pharmaceutics. 2022;14(12):1-16.
[38]. Salamah M, Budai-Szűcs M, Sipos B, Volk B, Katona G, Balogh GT, *et al*., Development and characterization of in situ gelling nasal cilostazol spanlastics. Gels. 2025;11(2):1-24.
[39]. Batur E, Özdemir S, Durgun ME, Özsoy Y. Vesicular drug delivery systems: promising approaches in ocular drug delivery. Pharmaceuticals. 2024;17(4):1-27.
[40]. Almutairy BK, Khafagy ES, Abu Lila AS. Development of carvedilol nanoformulation-loaded poloxamer-based in situ gel for the management of glaucoma. Gels. 2023;9(12):1-15.
[41]. Fahmy AM, El-Setouhy DA, Ibrahim AB, Habib BA, Tayel SA, Bayoumi NA. Penetration enhancer-containing spanlastics (PECSs) for transdermal delivery of haloperidol: *in vitro* characterization, *ex vivo* permeation, and *in vivo* biodistribution studies. Drug Deliv. 2018;25(1):12–22.
[42]. Alaaeldin E, Abou-Taleb HA, Mohamad SA, Elrehany M, Gaber SS, Mansour HF. Topical nano-vesicular spanlastics of celecoxib: enhanced anti-inflammatory effect and down-regulation of TNF-α, NF-κB and COX-2 in complete Freund's adjuvant-induced arthritis model in rats. Int J Nanomedicine. 2021;16:133–145.
[43]. Almuqbil RM, Sreeharsha N, Nair AB. Formulation-by-design of efinaconazole spanlastic nanovesicles for transungual delivery using statistical risk management and multivariate analytical techniques. Pharmaceutics. 2022;14(7):1-19.
[44]. Gupta I, Adin SN, Rashid MA, Alhamhoom Y, Aqil M, Mujeeb M. Spanlastics as a potential approach for

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr1435

enhancing the nose-to-brain delivery of piperine: in vitro prospect and in vivo therapeutic efficacy for the management of epilepsy. Pharmaceutics. 2023;15(2):1-19.

[45]. Kamath KK, Vindhya VS, Shripathy D, Shabaraya AR. Development of spanlastics: nanovesicular drug delivery of oxiconazole nitrate. Int J of Pharm Sci. 2024;2(3):483-93.

[46]. Safhi AY, Naveen NR, Rolla KJ, Bhavani PD, Kurakula M, Hosny KM, *et al*., Enhancement of antifungal activity and transdermal delivery of 5-flucytosine via tailored spanlastic nanovesicles: statistical optimization, *in-vitro* characterization, and *in-vivo* biodistribution study. Front Pharmacol. 2023;14:1-13.

[47]. Seary H, Barakat EH, Raslan MA, Samy AM. Development, characterization, and optimization of repaglinide loaded spanlastics along with investigation of drug solubility in various media. Univ J Pharm Res. 2024;9(5):105-112.

[48]. Saleh A, Khalifa M, Shawky S, Bani-Ali A, Eassa H. Zolmitriptan intranasal spanlastics for enhanced migraine treatment; formulation parameters optimized via quality by design approach. Sci Pharm. 2021;89(2):1-10.

[49]. Elhabak M, Ibrahim S, Abouelatta SM. Topical delivery of L-ascorbic acid spanlastics for stability enhancement and treatment of UVB induced damaged skin. Drug Deliv. 2021;28(1):445-453.

[50]. Ibrahim SS, Abd-allah H. Spanlastic nanovesicles for enhanced ocular delivery of vanillic acid: design, in vitro characterization, and in vivo anti-inflammatory evaluation. Int J Pharm. 2022;625(1-2):122068.

[51]. Mohamed NW, Sabry SA, Mahdy MA, Faisal MM. Tailoring of spanlastics for promoting transdermal delivery of irbesartan: In vitro characterization, ex vivo permeation, and in vivo assessment. J Drug Deliv Sci Technol. 2024;100:106088.

[52]. Almutairy BK, Khafagy ES, Aldawsari MF, Alshetaili A, Alotaibi HF, Abu Lila AS. Spanlastic-laden nanogel as a plausible platform for dermal delivery of bimatoprost with superior cutaneous deposition and hair regrowth efficiency in androgenic alopecia. Int J Pharm X. 2024;7:136-41.