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Critical Review

Emulgel: A Promising Technology for Topical Delivery of Herbal Extracts

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ABSTRACT

Topical drug delivery is a remarkable but arduous task due to the inherent barrier system of the skin. More so, only a narrow range of drugs are available for topical use because most drugs are hydrophobic in nature and this restricts their permeation and absorption into the skin. Herbal remedies have been used in the treatment of various diseases including skin diseases for centuries and are gradually becoming acceptable as treatment options however, they are mostly hydrophobic. Growing interests in combating these issues have led formulating scientists to develop drug delivery systems like emulgels which are good carriers of hydrophobic drug molecules. Emulgels are a mixture of an emulsion and a gel, where drugs are incorporated into globules and solubilized, enhancing drug absorption from the skin. They are easily spread over the skin, easily removed from the skin, possess emollient properties, are non-greasy, cosmetically appealing and have good penetrating abilities. This review highlights the importance of emulgels in the delivery of herbal extracts/constituents, the methods of formulations and an overview of herbal emulgel formulations that have been exploited by different researchers. Emulgels have proven to be good prospects in enhancing the topical delivery of herbals and improving the treatment of skin infections.

INTRODUCTION

Topical drug delivery is the pharmaceutical system that allows delivery of drugs directly to the surface of the skin for the treatment of localized skin diseases (Bani and Bhardwaj, 2021). These systems can be classified based on their physical state into solids, liquid and semi-solids which are formulated as creams, ointments, gels, lotions, sprays, powders, aerosols and liniments (Sreevidya, 2019). Topical drug delivery systems are particularly beneficial because they are non-invasive, convenient to use/apply, makes self-medication possible, better patient compliance, avoids gastrointestinal effects and first pass metabolism. They provide larger areas of application than other drug delivery systems and can be easily terminated as soon as they are no longer required (Biswas, 2014).

Drug absorption through the skin

The skin is the largest organ of the human body, it is a vital organ that covers the entire outer body as a protective barrier against pathogens and injuries from the environment, it helps to regulate body temperature and maintains water and electrolyte imbalances (Abd et al., 2016). It serves as a reflector for the healthiness or otherwise of the internal organs of the body; where the skin barrier is broken, the possibility for infection by opportunistic organisms increases leading to various skin diseases. The skin is

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made up of three tissue layers called the epidermis, the dermis and hypodermis or subcutaneous layer.

Epidermis

This is the outer tissue layer of the skin and is made up of stratified squamous epithelial cells. It is a matrix of complex interlocking bridges which accounts for the distinctive integrity of the skin. The epidermis consists of a layer known as the stratum corneum which acts as the rate-limiting barrier for drug absorption into the skin, especially for hydrophilic drugs and macromolecules. Once a drug is able to penetrate the stratum corneum, then it can provide the intend action on the skin, however, the extent to which drug diffusion can take place is dependent on the integrity of the stratum corneum, the physicochemical properties of the drug itself and the type of vehicle that the drug is prepared in (Baibahav et al., 2011; Sahle et al., 2015).

Dermis

This is the deeper tissue layer beneath the epidermis containing numerous loose connective tissues. It is majorly composed of collagen which is responsible for the skin's strength and elasticity and serves as structural support for the skin. It also serves as protection for the body against injury, it regulates the body's temperature and binds water to the skin. The dermis is also a rate-limiting step to drug absorption in the skin (Sreevidya, 2019; Ingle et al., 2021).

Hypodermis

This is also known as the subcutaneous tissue; it is the depot of fat under the skin and is made up of loose connective tissues containing blood vessels, cutaneous nerves and secretory pores. The subcutaneous tissue is not often thought to be a barrier for drug absorption because the drug absorption could occur prior to passage through the subcutaneous tissues. However, the depot of fatty tissues has been observed to serve as a reservoir for drugs which it releases over time into the circulatory system (Gaur et al., 2009; Sah et al., 2017).

The complex but unique assembly of tissues in the skin makes delivery and absorption of drugs possible albeit difficult in some cases. Over the years, the development of topical drug delivery has gone from simple potions to revolutionary systems through advancements in drug delivery innovations and technologies whose major differences bother on the rate of drug absorption unto the skin.

Use of herbal therapy for topical diseases

Medicinal substances used to treat skin diseases have been in existence for many centuries and a number of synthetic drug molecules exist for this purpose. However, some drawbacks in the use of these synthetics include high cost, relatively high toxic profiles, environmental contamination and the propensity to be prone to resistance which ultimately makes them ineffective. The World Health Organization (WHO) has estimated that about 80 % of the African population utilize herbal medicines in one form or the other as a means of primary health care (WHO, 2002-2005). This is understandable because in developing climes like Africa with high poverty rate, access to and affordability of the conventional drugs is often a challenge.

The upsurge in the use of herbal plants for the treatment of various diseases including topical diseases can be attributed to the fact that they are organic and a part of the green revolution idea that is engulfing the world. Their use is growing into a global trend because they are readily available, easily accessible, cheap and prone to less side effects than the chemically synthesized. In addition, they tend to satisfy the desire for personalized health care and are being readily accepted due to its purported claim of relative safety (Bandaranayake, 2006). In recent years, herbal medicines have contributed greatly to the management of diseases including skin diseases and are considered an effective alternative their treatment (WHO, 2014-2023). For instance, the saps of *Hamamelis virginiana* popularly known as Witch hazel and *Solanum dulcamara* also known as Bittersweet nightshade have been applied for treatment of acne (Peirce et al., 1999; Flemming, 2000). Crushed flowers of *Matricaria recutita* has been used to reduce oedma and inflammation due to dermatitis (Blumenthal, 2000) while infusions of the whole plant has shown propensity to soothe ano-genital inflammation (Kyokong et al., 2002).

Others include the gel of *Aloe barbadensis* which is effective in treatment of minor wounds, skin irritations like bruises and burns and inflammatory skin disorders (Jia at el., 2008). The juice of the leaves

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of *Celosia argentae* and paste from the grounded seeds have been used in the treatment of rashes. The squeezed out juice from the leaves of *Ficus exasperata* has been shown to treat ringworm (Erhenhi et al., 2016). The leaf juice of the tree commonly called "tree of life" (*Newbouldia laevis*) has also demonstrated activity against septic wounds and various skin diseases when applied topically (Enebeli-Ekwutoziam et al., 2021). It has also been documented that traditionally, the seeds of *Trigonella foenum-graecum* (Fenugreek) are used as poultices on inflamed skin (ESCOP, 2003). Similarly, in some parts of South Africa, combined leaves of *Bryophyllum pinnata* and *Senecio serratuloides* are reported to be applied as poultices for the treatment of shingles ((De Wet et al., 2013). The juice of *Echinacea purpurea* (L.) applied to superficial wounds have shown anti-inflammatory activity (WHO, 1999) and the fruit sap of *Oxalis corniculata* has been used to cure several skin diseases while juice from its leaves have been used to cure snake bite wounds (Arshad et al., 2011). Traditionally, brews of *Violae tricoloris herba* have been used in the treatment of eczema ((Reuter et al., 2010) while extracts of the whole plant (*Alchornea cordifolia*) has been used in the treatment of ringworm (Enebeli-Ekwutoziam et al., 2021). Literature search and anecdotal evidence reveals that herbs are effective in the management and treatment of a wide range of skin diseases and their associated symptoms. However, the pharmaceutical use of natural bioactive principles from these herbal preparations is a challenge because of low solubility, poor permeability which could result in poor bioavailability. Nevertheless, formulation of these bioactive constituents as emulgels can combat these difficulties and improve bioavailability.

EMULGEL

This is a novel semisolid delivery system consisting of the mixture of an emulsion and a gel and is becoming very popular because of its effectiveness in the delivery of hydrophobic drugs than when other popular topical systems like creams, gels and ointments are used (Sahil et al., 2021). Practically, emulgels are formulations of either oil-in-water (o/w) or water-in-oil (w/o) emulsions which have been mixed with a gelling agent. They were developed to overcome the drawbacks of the gel and emulsion delivery systems.

Rationale for formulation of Emulgels

Emulgels are developed to overcome the drawbacks of the gel and emulsion delivery system. A gel is a cross-linked three-dimensional network composed of macromolecules which entraps solvent molecules. They are mucoadhesive as such, can modify the rate of drug delivery when applied unto the skin (Raj et al., 2016; Kulawik-Pióro and Małgorzata Miastkowska, 2021). Gels possess many favorable properties like good spreadability, easy drug penetrability, fast onset of action, being greaseless and thixotropic however, they lack ability to effectively deliver hydrophobic drug molecules to the skin except in the presence of a solubility or penetration enhancer. The poor/low solubility profile of hydrophobic drugs is a major barrier to drug release from gel systems.

Emulsions on the other hand, are systems consisting of an internal/dispersed phase and an external phase/dispersion medium which are made miscible by the addition of an emulsifying agent. They can be dispersions of aqueous phase in oily phase (w/o) or oily phase in aqueous phase (o/w). Similar to the gel systems, emulsions also possess good penetrability but they are thermodynamically unstable, lack prolonged contact time on the surface of the skin and have limited drug loading capacity. Nonetheless, they possess capability to release hydrophobic drug molecules trapped in the oily internal phase in a controlled manner (Patel et al., 2016; Sabalingam and Siriwardhene, 2022).

Therefore, to overcome the limitations of gels and emulsions, emulgels were developed, which consists of an emulsion gelled by a gelling agent and incorporates the advantages of both gels and emulsions. In addition, the problem of hydrophobic drugs is taken care of in emulgel formulations where the drug molecules are solubilized thus, providing larger surface area for drug action on the surface of the skin. This also suggests that lower doses of the drug could be used to elicit the required therapeutic action (Khullar et al., 2012; Peneva et al., 2014).

The advantages of emulgels are based on the different inherent properties they possess. Emulgels are easily spread over the skin, easily removed from the skin, possess emollient properties, are non-greasy therefore, are good for application unto hairy surfaces, transparent and non-residue producing,

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cosmetically appealing and have good cutaneous penetration. They are more stable over long periods of storage than other topical delivery systems like powders which could be hygroscopic and show caking or creams which show phase inversion or ointments which go rancid due to the oily base (Panwar et al., 2011; Suman et al., 2020). Of particular interest is the fact that they can be prepared with both aqueous and oleaginous ingredients making incorporation of hydrophobic drug molecules into the oily phase possible (Shahin et al., 2011a; Devi et al., 2021). In addition, emulgels provide controlled release for drugs with short biological half-life (t1/2). Other non-specific advantages of emulgels include convenient to apply which improves patient compliance, ease of terminating medication when needed and avoidance of first pass metabolism (Panwar et al., 2015; Prasad et al., 2020).

Ingredients used in formulation of emulgels

Emulgels basically consists of an oily component in an aqueous phase or an aqueous component in an oily phase interconnected by a gelling agent. Apart from the drug or active principle, the following are basic ingredients required for the formulation of emulgel.

Vehicles

These are classified as oily and aqueous vehicles which include the aqueous solvents like water, alcohols, other suitable solvents like rose water and oils. They are basically used in solubilizing the active and enhancing drug delivery to the skin. Ideal properties of these vehicles include ability to evenly distribute the drug on the skin, ability to deliver the drug to the target site and be aesthetically acceptable to the patient (Raj et al., 2016). The types of vehicles used in formulation of emulgels include the following;

Aqueous solvents

These form the aqueous phase of the emulsion and the most commonly used agent is water but alcohol is also used.

Oils

Different types of oils are used as the oily phase in the formulation of the emulsion, they include mineral oils like liquid paraffin which can be used alone or in combination with soft or hard paraffin wax in the preparation of oily phase for topical emulsion formulation. Other oils that have also been exploited for use include sesame oil (Jadhav et al., 2018; Nailwal et l., 2019), almond oil (Nawaz et l., 2013), Citrus sinensis oil (Ilomuanya and Oforkaja, 2020), olive oil (Negi and Kuma et al., 2019). Apart from being a component of the oily phase, some of these oils provide occlusive and local laxative effects (Panwar et al. 2011). Some others possess specific therapeutic activities have also been employed in the formulation of emulgels and provide synergism towards the desired function of the product. An example is Jojoba oil which is known to reduce inflammation associated with fungal infections (Habashy et al., 2005; Shahin et al., 2011b).

Emulsifiers

These are used to promote emulsification process during formulation and control stability during the shelf life of the product. Examples include surfactants like the sorbitan esters, polysorbates, polyethylene glycols, and others like stearic acid (Hyma et al., 2014; Sreevidya, 2019). These could be used alone in a formulation or in combination with each other.

Gelling agents

These are polymers that are used to prepare the gel base into which the emulsion is incorporated. They are also thickening agents which enhances the consistency of the formulation by swelling in the aqueous solvent and producing a gel-like formulation (Patel et al., 2009). Different classes of polymers are employed as gelling agents, they include natural polymers like guar gum, xanthan gum, acacia gum, starch, tragacanth, pectin, sodium alginate e.t.c. The synthetic polymers include different grades of carbomer (carbopol 940, 934), poloxamers (pluronics®), alkyl acrylates (Pemelum®) and polyvinyl alcohol (PVA) while the semi synthetic polymers include cellulose derivatives like hydroxypropyl methylcellulose (HPMC), sodium carboxyl methylcellulose (Na CMC), methylcellulose, Hydroxyethyl cellulose (HEC).

Permeation enhancers

These are agents that partition into the skin layers to enhance drug permeability and promote drug

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absorption (Yadav et al., 2016). They act by interacting with the intercellular proteins of the skin, temporarily disrupting the structured lipid layer and increasing the fluidity of the lipid-protein portion of the stratum corneum. This improves drug partition into the stratum corneum and ultimately improves drug absorption (Raj et al., 2016). Changes to the skin barrier and impact of the formulated product are majorly influenced by the type of penetration enhancer used in the formulation. Different groups of penetration enhancers have been used and they include surfactants like cineol (Shokri et al., 2012), unsaturated fatty acids like oleic acid, linolenic acid, organic solvents, some organic constituents like essential oils like clove oil, menthe oil, cumin oil extracted from natural sources (Khullar et al., 2012; Morteza-Semnani et al., 2021). Others include derivatives of propylene glycols and urea. In spite of the type of permeability enhancers to be used, the agents are expected to be inert, non-allergenic, possess ability for rapid action, should possess target action to allow penetration of active agents without untoward effects. They are also required to be compatible with the active agent and other excipients that would be used in the formulation (Yadav et al., 2016).

pH adjusting agents

The skin is a very sensitive organ of the body; changes in diet, environment, products applied and intrinsic skin types contribute to how healthy or otherwise the skin becomes. The ideal pH of the skin is in the acidic region (between 4.5 and 6.5), products formulated for application on the skin are required to have pH close to that of the skin. pH adjusters like triethanolamine could be used to adjust pH of gel formulations especially when prepared with carbomers (Panwar et al., 2011).

Other ingredients that could be included in the formulation of emulgels include preservatives like methyl paraben, propyl paraben, humectants like glycerin and propylene glycol.

METHODS OF PREPARATION OF EMULGELS

Formulation of emulgels can be classified into the following basic steps;

Preparation of the gel base

This is done by mixing the gelling agent with sufficient quantity of water until a homogenous mixture free from bubbles is obtained. Where necessary, other ingredients like the permeation enhancers and humectants may be incorporated into the homogenous gel. The pH of the formulation is adjusted appropriately using the required adjusting agent.

Preparation of the emulsion

The dispersed and dispersion medium differ here depending on the type of emulsion to be prepared. An oil in water (o/w) emulsion would be prepared by dispersing the oily ingredients into the aqueous phase using an appropriate emulsifier to ensure a homogenous, one phase system is obtained. If a water in oil (w/o) emulsion is to be prepared, the aqueous portion is dispersed in the oily portions and emulsified by an emulsifier.

Preparation of the drug or active ingredient

The drug would be dispersed in a suitable solvent to solubilize it before it is incorporated into the emulsion. This step may not be necessary for active constituents that do not require solubilization; if the active ingredient in the formulation is an oil, it may be incorporated directly into the oily phase of the emulsion.

Incorporation of emulsion into the gel base

This final step entails incorporation of the prepared emulsion into the prepared gel base with continuous stirring to ensure a homogenous mixture is obtained.

A classic example of formulation of an emulgel containing herbal extracts would include preparation of the gel base using an appropriate gelling agent. The herbal extract would be dispersed in either the dispersion or dispersed phase depending on its solubility in either of these phases. Eventually, both phases would be mixed together in a ratio of 1:1 to obtain a homogenous product.

Below is a flowchart of the general method for preparation of emulgels

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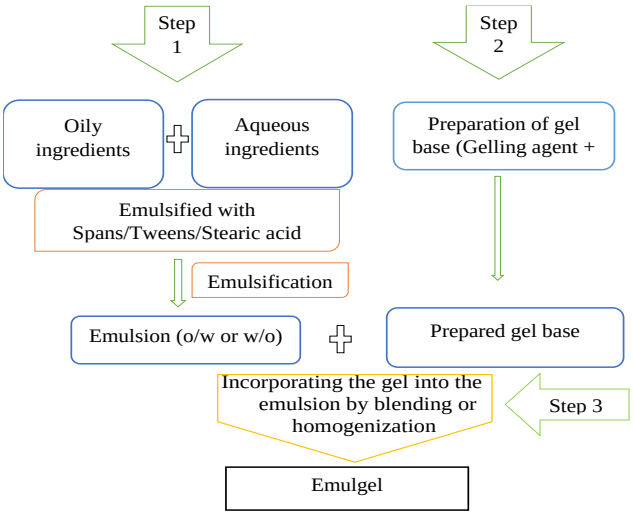

Fig. 1. *Flow chart showing steps involved in formulation of emulgel.*

Evaluation of emulgels

The various evaluations that can be carried out on an emulgel include;

Physical examination

This would entail visually examining the prepared emulgel to assess color, homogeneity and phase separation. These examinations are important because they influence the patient's acceptability.

Determination of pH

The pH of the prepared emulgel is determined using an appropriate pH meter. A topical product is required to be compatible with the skin, information about the pH of a product enables the formulating scientist ensures the product prepared is compatible with the skin. On the other hand, acidity or alkalinity of a product informs the patient about possible sensitivity upon application of the product since there are inherent differences in individual skin types.

Determination of viscosity

An appropriate viscometer is used to determine the viscosity of the prepared emulgel. The influence of shear and temperature on the viscosity could be determined by varying the rate of shear and storage temperature of the emulgel. Influence of shear provides insight into how the product can be applied; either with force or gently while different temperature shows the possible consistency of the product upon storage at different temperature.

Spreadability

Spreadability signifies the degree to which the emulgel can readily spread on the skin upon application. The capability of a product to spread on the skin also shows the extent to which the product will be bioavailable and therapeutically effective (Sulatana et al., 2016). The evaluation involves placing a known weight of the emulgel (2 g) on a glass slide with known dimensions, another glass slide also with known dimensions is placed on to sandwich the emulgel. A weight of 1 kg is placed on top of the slides for 5 minutes to provide uniform spread of the emulgel, excess emulgel is cleaned off the edges of the slides. At the appropriate time, the top slide is pulled off from the other slide and the time taken for this separation is noted. Spreadability (S) is calculated on the basis of "drag and slip" in Eq (1) below;

$$S = {MxL}/{T} \qquad (1)$$

Where M is the weight placed on the slides, L is the length of the glass slides and t is the time taken to separate the two slides.

Extrudability

This is an experimental test to determine the rate at which a known weight of emulgel can be squeezed out of a tube and is expressed in g/sec (Prajakta et al., 2019; Aremu et al., 2020). Extrudability demonstrates the ease with which a product is exuded from an orifice and connotes the ease or not of removal from the product's package.

Skin irritation test

This is also known as the patch test; it assesses any dermal irritation or the degree of irritation of the emulgel upon application on the skin. Laboratory animals like rabbits, rats or mice are prepared by shaving off some part of the animal's skin (a pre-determined area of the skin). The product is applied unto the skin area and observed visually for adverse skin changes. Any change in skin color and appearance of erythema (redness) noted after a pre-determined period of time is recorded and the product is deemed to be prone to cause irritation (Nair et al., 2012; Vats et al., 2014).

In vitro diffusion study

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This test is used to evaluate in vitro drug permeation and the skin's permeability to the emulgel, it provides understanding of the relationship between the drug, the formulation and the skin (Ng et al., 2010). This evaluation is a useful tool for the formulating scientist in design and formulation of the product and also important for toxicity screening of a product. The formulation is applied unto an appropriate dialysis membrane, placed between the donor and receptor compartment of a diffusion cell. The rate of permeation or drug release is determined from samples withdrawn from the receptor chamber containing a suitable medium (Jelvehgari and Rashidi, 2007).

Stability studies

This assesses how the quality of the emulgel in its final packaging is influenced by environmental factors like temperature, humidity and light. This test establishes the type (physical, chemical, microbiological) and degree of change that affects the drug product and proposes adequate storage conditions to ensure efficiency of the drug product (Bajaj et al., 2012). The packaged emulgel is placed in a stability chamber at recommended temperature and relative humidity for specified period of time. Portions of the emulgel are withdrawn at pre-determined time intervals and evaluated accordingly.

Other tests include those that are specific for the action of the active constituent or drug incorporated into the emulgel; they include antimicrobial, anti-inflammatory tests e.t.c.

TOPICAL HERBAL EMULGEL FORMULATIONS

Literature search for studies reported on the formulation of herbal emulgels was carried out using PUBMED database and Google between the year 2010 and 2022. The search included these key search terms; 'emulgels', 'herbal emulgels', 'plant extracts', 'plant constituents', 'topical drug delivery', herbal medicine', 'formulation of herbal emulgels' or a combination of these terms. Eligibility criteria for this review included studies on the formulation/preparation and evaluation of emulgels containing plant extracts or plant parts or constituents from plants. Studies that discussed methods for evaluation of emulgels as well as reviews were included in this review. The search was limited to only studies reported in English language. Those not reported in English language, or not involving the formulation/preparation of emulgels containing plant extracts/parts/constituents were excluded. These have been summarized and listed below in Table 1.

Table 1. Overview of some topical emulgel formulations containing herbal extracts or plant constituents.

Plant materials/Part used	Gelling agents	Findings
Pothos scandens/Leaves	Carbopol 934 and Carbopol 940	Formulations prepared with Carbopol 934 (1.5 %) demonstrated significant acceleration of burn wound healing (Haneefa et al., 2010)
Combination of *Commiphora mukul* and *Psoralea corilyfolia*/Sap resin, Seed oil respectively	*Commiphora mukul* gum	Optimized formulation showed rapid onset and higher anti-inflammatory activity in comparison to a commercially available preparation (Marwaha and Bhise, 2013)
Combination of *Camellia sinensis* and *Rosa damascena* /Leaves and petal oil	Carbopol 934, Carbopol 1342	Formulations showed significantly high hydrating ability and good anti-aging protecting abilities in healthy participants (Yapar et al., 2013)
Combination of Tea tree oil, lemongrass oil, ginger oleoresin and Capsaicin/Both leaves, rhizome, seeds respectively	Carbopol 940	The polyherbal emulgel formulation showed significant anti-inflammatory activity in the presence of cow ghee as permeation enhancer and this activity was better than that of commercial diclofenac gel (Shrikhande, 2013)
Lantana camara/Leaves	Carbopol 934, Na CMC, HPMC, HPMC K15M, and HEC	Formulations prepared with Na CMC showed optimal physicochemical properties and significant

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		improvement in wound contraction (Sultana et al., 2016)
Combination of *Curcuma longa* and *Tinospora cordifolia*/Rhizome, leaves respectively	Carbopol 940	Optimized emulgel formulation produced sustained anti-arthritic activity for up to 18 h (Thakur et al., 2016)
Cardiospermum halicacabum/Leaves	Na CMC	Emulgel formulation demonstrated appreciable diffusion through animal skin and its anti-arthritic activity was comparable to that of commercially available diclofenac gel (Suganya et al., 2017)
Strawberry/Fruit	Carbopol 940	Formulation decreased skin melanin, improved skin hydration, and promoted skin whitening in healthy female human participants (Kausar and Akhtar, 2017)
Terminalia arjuna/Bark	Carbopol 934	Emulgel formulation for topical delivery of the extract was found be stable and possessed good release profile (Gaikwad and Jadhav, 2018)
Combination of *Ocimum tenuiflorum* and *Mentha arvensis*/Both leaves	Na CMC	The formulation exhibited significant and accelerated activity against acne (Susmitha and Devi, 2018)
Polycarpaea aurea/Whole plant	Carbopol 934	Formulation showed greater broad spectrum activity against the formulation of Ofloxacin (Jamal et al., 2018)
Coriandrum sativum/Seeds	Carbopol 940	Emulgel of the seed oil showed significant anti-inflammatory activity (Mohite and Salunkhe, 2019)
Coccinia grandis/Leaves	Carbopol 940, Carbopol 934	Formulation prepared with Carbopol 934 and liquid paraffin exhibited good antibacterial activity (Guntupalli et al., 2019)
Zingiber officinale/Roots	Na CMC	Formulation prepared with 1.5 % Na CMC showed highest release, better stability and significant inhibition of bacteria growth than formulations with less concentration of Na CMC (Desai and Mhaskar , 2019)
Combination of *Phyllanthus emblica*, *Centella asiatica*, *Wedelia calendulacea*, *Cucurbita pepo*/Fresh fruits, both leaves, seeds respectively	Carbopol 934	The hair emulgel was found to be economical, stable with significant hair promoting ability (Kumar et al., 2019)
Moringa oleifera/Leaves	Carbopol 940	The study showed that levels of purified Vitamin E extracted from *Moringa oleifera* were maintained in the emulgel formulation. It suggests that the emulgel could be used as a topical anti-oxidant formulation (Wuryandari et al., 2019)
Combination of *Curcuma longa, Datura metel*, *Aloe vera*/Rhizome, both leaves respectively	Carbopol 940	Formulation showed promising potential as a first-aid topical treatment of clinical mastitis by farmers (Kumar et al., 2020)
Camellia sinensis/Leaves	Aloe vera gel	The hair emulgel showed good physicochemical properties and produced no untoward skin sensitization or irritation in comparison to a commercial hair product (Avalaskar et al., 2020)
Ocimum basilicum/Leaves	Carbopol 934	Emulgel exhibited significant wound healing potential which was comparable to that of a commercial product (Khan et al., 2020)

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Combination of *Helichrysum italicum* and *Cannabis sativa* oil/Whole plant, seeds respectively	Carbopol Ultrez 10	Emulgel formulations were assessed by healthy human volunteers as having better sensory properties and better hydrating capability than the corresponding cream formulations (Tadi´c et al., 2021)
Ficus benghalensis/Aerial roots	Carbopol 940, Carbopol 934, Xanthan gum	Herbal emulgel of the ethanol extract exhibited comparable anti-arthritic activity in comparison to diclofenac emulgel (Sonali et al., 2021)
Albizia lebbeck/Bark	Carbopol	Formulation was found to be stable upon storage in the refrigerator, room temperature and accelerated temperature for 8 weeks. It showed significant antioxidant effect on human skin (Tasneem et al., 2021)
Combination of *Piper nigrum* and *Curcuma longa*/Fruit and rhizomes respectively	Carbopol 934, Carbopol 940 and HPMC K4M	Formulation prepared with carbopol 934 showed optimum physicochemical characteristics, stability, improved skin permeability upon topical application and potential in treating vitiligo (Khanpure et al., 2021)
Leea indica/Leaves	Carbopol 940	Formulation demonstrated promising in vitro anti-inflammatory and antioxidant activates which could be investigated in animal models (Srilal and Hettihewa, 2021)
Curcuma longa/Rhizome	Carbopol 934	Formulation demonstrated good physicochemical characteristics and anti-inflammatory activity (Shah, 2021)
Pongamia pinnata/Seeds	Carbopol 934	Emulgel formulation showed good physicochemical characteristics, significant drug release and good stability (Wadher et al., 2101)
Linum usitatissimum oil/Seeds	Chitosan FG90	Emulgel exhibited remarkable inhibitory activity against *S. aureus*, *P. aeruginosa*, *S. pyogenes*, *E. coli*, and *K. pneumoniae* growth which are known to be responsible for diabetic-foot infection (Pagano et al., 2021)
Vitis *Vinifera* oil/Seeds	HPMC	The emulgel was deemed a good candidate for topical anti-aging peel-off mask (Nursal et al., 2021)
Combination of *Syzygium aromaticum* and *Cinnamomum verum*/Buds and Barks respectively	Almond gum	Emulgel containing the combined extracts exhibited significant alleviation of denture-stomatitis related inflammation and better clinical cure rates in infected patients than when commercially marketed gel was used (Iyer et al., 2022)
Spilanthes acmella/Whole plant	Carbopol 934	The formulation demonstrated significantly higher activity against *E. coli* than a standard drug; Meropenem. The herbal emulgel was proposed as an alternative formulation in the treatment of deep skin tissue Infections (Afzal et al., 2022)

CMC: Carboxymethyl cellulose, HPMC: Hydroxypropyl methylcellulose, HEC: Hydroxyethyl cellulose, Na CMC: Sodium Carboxymethyl cellulose, *E. coli*: *Escherichia coli, S. aureus*: *Staphylococcus aureus, P. aeruginosa*: *Pseudomonas aeruginosa, S. pyogenes*: *Streptococcus pyogenes, K. pneumonia*: *Klebsiella pneumoniae.*

According to the literature search, most studies employed extracts from plant leaves or whole dried leaves as main therapeutic agents in their formulation. Other parts investigated include seed oil, whole seed,

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fruit, rhizome, bark, sap/resin from the stem bark, roots and whole plant. Carbopol was found to be the most commonly used gelling agent for preparation of herbal emulgels followed by Hydroxypropyl methylcellulose (HPMC), Sodium carboxymethyl cellulose (Na CMC), and some natural gums like xanthan gum. Evaluation of the formulations focused on determination of effectiveness of the incorporated active plant material, however, other parameters like appearance, spreadability, pH and formulation stability were also evaluated.

The search returned studies that reported herbal formulations with significant acceleration in wound healing due to chemical burn (61, 53, 78, 84), some demonstrates higher anti-inflammatory than those elicited by commercially available agents (62, 88) and enhanced antibacterial activity over ofloxacin; a commercial antibiotic (70). Some clinical studies revealed good cosmetic value of herbal emulgels with report of improved skin hydration (63, 67, 79). The presence of permeation enhancers improved skin permeation and anti-inflammatory activity (64) while another study reported potential action in treating vitiligo (82). Anti-arthritic activity of some emulgel formulations were found to be comparable to that of diclofenac emulgel (68, 80). Another study reported the potential for first-aid treatment of clinical mastitis (76). Different studies showed the good potential for hair growth (74, 77) while some demonstrated the ability to be used as topical antioxidant (75, 81, 83). Stability study of a formulation showed no significant change in physical properties upon storage (68).

CONCLUSIONS

This literature review has attempted to collate studies in which plant extracts or plant constituents were formulated into emulgels. It features the different plants, plant parts, plant extracts/constituents that have been developed into emulgels and their outcomes. In addition, it showcases emulgels as a suitable delivery system for plant extracts/constituents since these constituents have poor solubility or are majorly hydrophobic in nature. This literature purports a number of benefits of using emulgels, for instance; wound healing, antibacterial, anti-arthritic, anti-acne, anti-oxidant and anti-aging activities, and even for herbal extracts employed in promotion of hair growth. Therefore, emulgels have invaluable prospects in improving topical delivery of herbal extracts.

REFERENCES

Abd, E., Yousef, S.A., Pastore, M.N., Telaprolu, K., Mohammed, Y.H., Namjoshi, S., Grice, J.E., Roberts, M.S., 2016. Skin models for the testing of transdermal drugs. Clin Pharmacol, 8(163), 163-176.

Afzal, A., Shah, N.H., Hussain, I., Munawar, S.H., Mumtaz, A., Quresh, N., 2022. Preparation of spilanthes acmella based emulgel: Antimicrobial study and evaluation. Pak J Pharm Sci, 35(1), 287-295.

Ajazuddin, Alexander, A., Khichariya, A., Gupta, S., Patel, R.J., Giri, T.K., Tripathi, D.K., 2013. Recent expansions in an emergent novel drug delivery technology: Emulgel. J Control Release, 171(2), 122-132.

Aremu, O., Olayemi, O., Ajala, T., Isimi, Y., Oladosu, P., Ekere, K., John, J., Emeje, M., 2020. Antibacterial evaluation of Acacia nilotica Lam (Mimosaceae) seed extract in dermatological preparations. J Res Pharm, 24(1), 170-181.

Arshad, M., Nisar, M.F., Ismail, A.S., Ahmad, M., 2011. Ethnomedicinal Flora in District Sialkot, Punjab, Pakistan. Middle East J Sci Res, 9(2), 209-214.

Avalaskar, A.N., Choudhari, L.S., Punmiya, A.H., Ranvare, S.S., Polawar, R.A., Honkalas, K.G., 2020. Formulation and evaluation of herbal hair emulgel. J Emerg Tech Innov Res, 7(2), 161-166.

Baibhav, J., Gurpreet, S., Rana, A.C., Seema, S., Vikas, S., 2011. Emulgel, a comprehensive review on the recent advances in topical drug delivery. Int Res J Pharm, 2(11), 66-70.

Bajaj, S., Singla, D., Sakhuja, N., 2012. Stability Testing of Pharmaceutical Products. J App Pharm Sci, 2(3),129-138.

Bandaranayake, W.M., 2006. Quality control, screening, toxicity, and regulation of herbal drugs, in Modern Phytomedicine; Turning Medicinal Plants into Drugs eds Ahmad I., Aqil F., Owais M. (Weinheim:Wiley-VCH GmbH & Co. KGaA;) pp 25-57.

Bani, K.S., Bhardwaj, K., 2021. Topical drug delivery therapeutics, drug absorption and penetration enhancement techniques. J Drug Deliv Ther, 11(4), 105-110.

Baynes, R.E., Hodgson, E., 2004. Absorption and distribution of toxicants. in Chapter 6 of A Textbook of Modern Toxicology. 3rd edition; John Wiley & Sons, Inc.

Biswas, M., 2014. Topical route of drug administration and dosage forms. Retrieved March 10, 2022, from https://www.slideshare.net/doctormansij/topical-route-mansij.

Blumenthal, M., Goldberg, A., Brinckann, J., 2000. Herbal medicine. Expanded Commission E Monographs. German. Newton: Chamomile flower, American Botanical Council, pp. 57-61.

De Wet, H., Nciki, S., van Vuuren, S.F., 2013. Medicinal plants used for the treatment of various skin disorders by

http://doi.org/10.5920/bjpharm.1046

a rural community in Northern Maputaland, South Africa. J Ethnobiol Ethnomed, 9(51), 1-9

Desai, P., Mhaskar, G.M., 2019. Formulation and evaluation of zingiber officinale emulgel. Res J Pharm Tech, 12(3),1294-1300.

Devi, A., Chaurasia, H., Singh, R., 2021. Design and characterization of emulgel for the treatment of antifungal infection. Hunan Daxue Xuebao/ J Hunan Univ Nat Sci, CN 43-1061, 20-37.

Enebeli-Ekwutoziam, K.C., Aruah, C.B., Ogbonna, B.O., Eze, U.J., Egedeye-Fubura, F.S., Nwankwo, C.F., Oliseyenum, I.N., Udoha, N.W., Afuye, T.N., Asogwa, G.N., Chinweokwu, K.A., Anenih, F.O., Iyamu, J.E.., Oboti, I.D., Nwaizu, N., Ajabor, J.I., Ozadibe, O.Y., Otunla, R.A., Francis, O.B., Orji, C.M., 2021. Ethnomedicinal survey of plants used in the treatment of skin-related ailments in the Northern Delta State of Nigeria. Asian J Ethnobio, 4(2), 76-85.

Erhenhi, A.H., Lemy, E.E., Okunbor, R.A., 2016. Medicinal plant used for the treatment of skin diseases in Edo State, Nigeria. J Med Plant Herb Ther Res, 4, 25-29.

ESCOP Monographs, 2003. Matricariae flos. 2nd ed. New York: Thieme; European Scientific Cooperative on Phytotherapy; pp. 312-319.

Fleming. T., 2000. PDR® for Herbal Medicines™. Second edition. Edited by Fleming T. New Jersey, Medical Economics Company, 224-225.

Gaikwad, DT., Jadhav, N.R., 2018. Formulation design and evaluation of an emulgel containing *terminalia arjuna* bark extract for transdermal delivery. Pharmacog Mag, 14(Suppl S1), 249-255.

Gaur, P.K., Mishra, S., Purohit, S., Dave, K., 2009. Transdermal drug delivery system: A review. Asian J Pharm Clin Res, 2, 14-20.

Guntupalli, G., Rani, G.M., Nori, L.P., Manikira, S.S., 2019. Studies on the development of promising herbal emulgel of *coccinia grandis* leaf extract for dermatalogical complications. J Pharm Sci Res, 11(8), 2915-2920.

Habashy, R., Abdel-Naim, A., Khalifa, A., Al-Azizi, M., 2005. Anti-inflammatory effects of jojoba liquid wax in experimental models. Pharmacol Res, 51(2), 95-105.

Haneefa, M., Mohanta, G.P., Nayar, C.R., 2010. Formulation and evaluation of herbal emulgel of *pothos scandens* linn for burn wound healing activity. Asian Pac J Trop Med, 3(12), 988-992.

Hardenia, A., Jayronia, S., Jain, S., 2014. Emulgel: An emergent tool in topical drug delivery. Int J Pharm Sci Res, 5(5),1653-1660.

Hyma, P., Raheemunnisa, N., Sreelekha, G., Babu, K., 2014. Emulgel: A review. Int J Pharm Sci, 3,1-11.

Ilomuanya, M.O., Oforkaja, C.A., 2020. Formulation and characterization of palm olein/caprylic triglycerides ester based emulgel for topical use. Afr J Pharm Res Dev, 12(2), 172-180.

Ingle, S., Tegeli, V., Chandakavate, B., Matole, V., Kirdak, O., Gophane, G., Tonape, S., Birajdar, A., Nangare, S., Adlinge, S., Ramanshetti, S., Yadav, K., Patil, A., Khare, A., Ubale, S., Dulange, V., Habib, B., Mittha, J., 2021. A brief review on emulgel – A novel topical drug delivery system. Res J Pharm Dosage Forms Tech, 13(1), 25-30.

Iyer, M.S., Gujjari, A.K., Paranthaman, S., Abu Lila, A.S., Almansour, K., Alshammari, F., Khafagy, E.S., Arab, H.H., Gowda, D.V., 2022. Development and evaluation of clove and cinnamon supercritical fluid extracts-loaded emulgel for antifungal activity in denture stomatitis. Gels, 8(33), 1-20.

Jadhav, R., Yadav, G., Jadhav, V., Jain, A., 2018. Formulation and evaluation of black sesame seed oil sunscreen emulgel using natural gelling agent. Int Res J Pharm, 9(6), 197-201.

Jamal, B.D., Srinivas, M.B.R., Prakash, P., Anuradha, K.C., 2018. Preliminary phytochemical investigation and in vitro anti-bacterial studies of Polycarpaea aurea wight and arn (Caryophyllaceae) emulgel. Asian J Pharm Res, 8(3), 151-157.

Jelvehgari, M., Rashidi, M.R., 2007. Adhesive and spreading properties of pharmaceutical gel composed of cellulose polymer. Jundishapur J Nat Pharm Prod, 2(1), 45-58.

Jia, Y., Zhao, G., Jia, J., 2008. Preliminary evaluation: The effects of Aloe ferox Miller and Aloe arborescens Miller on wound healing. J Ethnopharmacol, 120(2), 181-189.

Kausar, R., Akhtar, N., 2017. Formulation of an emulgel containing strawberry fruit extract and in-vivo evaluation for different skin parameter. Ind J Pharm Educ Res, 51(4), 679-683.

Khan, B.A., Ullah, S., Khan, M.K., Alshahrani, S.M., Braga, V.A., 2020. Formulation and evaluation of ocimum basilicum-based emulgel for wound healing using animal model. Saudi Pharm J, 28(12), 1842-1850.

Khanpure, M.K., Bhosale, D.S., Kalyani, N., Hotkar, K., 2021. Formulation and evaluation of emulgel containing *piper nigrum* and *curcuma longa* extract for vitiligo. J Glob Trends Pharm, 12(2), 9283-9293.

Khullar, R., Kumar, D., Seth, N., Saini, S., 2012. Formulation and evaluation of mefenamic acid emulgel for topical delivery. Saudi Pharm J, 20(1), 63-67.

Kulawik-Pióro, A., Miastkowska, M., 2021. Polymeric gels and their application in the treatment of psoriasis vulgaris: A Review. Int J Mol Sci, 22(10), 5124.

Kumar, M.R., Teelavath, M., Yellanki, S.K., 2019. Development and evaluation of polyherbal emulgel formulation (A preventive hair care preparation). Int J Herb Med, 7(1), 8-10.

Kumar, P.S., Ranganathan, V., Vijayakaran, K., Elamaran, A., Priyadharshini, R., 2020. Preparation and evaluation of herbo-mineral topical emulgel formulation in bovine clinical mastitis. J Pharmacog Phytochem, 9(4), 1575-1584.

Kyokong, O., Charuluxananan, S., Muangmingsuk, V., Rodanant, O., Subornsug, K., Punyasang, W., 2002. Efficacy of chamomile-extract spray for prevention of post-operative sore throat. J Med Assoc Thai, 85(1), 180-185.

Marwaha, T.K., Bhise, K., 2013. Formulation, design and evaluation of herbal anti psoriatic emulgel. J Pharm Sci Innov, 2(3), 30-42.

http://doi.org/10.5920/bjpharm.1046

Mohite, S., Salunkhe, A., 2019. Formulation and evaluation of emulgel containing *coriandrum sativum* seeds oil for anti-inflammatory activity, J Drug Del Therap, 9(3-s), 124-130.

Morteza Semnani, K., Saeedi, M., Akbari, J., Eghbali, M., Babaei, A., Mohammad, S., Hashemi, H., Nokhodchi, A., 2021. Development of a novel nanoemulgel formulation containing cumin essential oil as skin permeation enhancer. Drug Deliv Transl Res, https://doi.org/10.1007/s13346-021-01025-1

Nailwal, D., Chopra, H., Shrivastav, A., Ahmad, Y., 2019. Formulation and evaluation of vegetable oil based emulgel of Fluconazole. J Drug Deliv Ther, 9(4), 415-418.

Nair, S.S., Mathew, M., Sreena, K., 2012. Evaluation of skin irritation of herbal antioxidant cream. Asian J Biochem Pharm Res, 2, 184-189.

Nawaz, A., Jan, S.U., Khan, N.R., Hussain, A., Khan, G.M., 2013. Formulation and in vitro evaluation of clotrimazole gel containing almond oil and Tween 80 as penetration enhancer for topical application. Pak J Pharm Sci, 26(3), 617-622.

Negi, A., Kuma, P., 2019. Formulation and characterization of etoricoxib olive oil emulgel by using different gelling agents. IOSR J Pharm Biol Sci, 14(6), 26-36.

Ng, S.F., Rouse, J., Sanderson, D., Eccleston, G., 2010. A Comparative study of transmembrane diffusion and permeation of ibuprofen across synthetic membranes using Franz diffusion cells. Pharmaceutics, 2(2), 209-223.

Nursal, F.K., Nining, Rahmah, A.S., 2021. Formulation and development of grape seed oil (*vitis vinifera* L) emulgel peel-off mask using gelling agent Hydroxy propyl methyl cellulose (HPMC). In IOP Conference Series: Earth and Environ Sci, 755(1), 012046).

Pagano, C., Baiocchi, C., Beccari, T., Blasi, F., Cossignani, L., Ceccarini, M.R., Orabona, C., Orecchini, E., Di Raimo, E., Primavilla, S., Laura, S., Michele, A.D., Perioli, L., Ricci, M., 2021. Emulgel loaded with flaxseed extracts as new therapeutic approach in wound treatment. Pharmaceutics, 13, 1107, 1-21.

Panwar, A.S., Upadhyay, N., Bairagi, M., Gujar, S., Darwhekar, G.N., Jain, D.K., 2011. Emulgel: A Review. Asian J Pharm Life Sci, 1(3), 333-343.

Patel, R.P., Patel, G., Patel, H., Baria, A., 2009. Formulation and evaluation of transdermal patch of aceclofenac. Res J Pharm Dosage Forms Tech, 1(2), 108-115.

Patel, S., Aundhia, C., Seth, A., Shah, N., Pandya, K., 2016. Emulgel: A novel approach for topical drug delivery system. European J Biomed Pharm Sci, 3(9), 501-506.

Peirce, A., Fargi,s P., Scordato, E., 1999, Editors, The American Pharmaceutical Association Practical Guide to Natural Medicines. New York: Stonesong Press Inc.

Peneva, P., Andonova, V., Pilicheva, B., Kassarova, M., 2014. In vitro survey of Ketoprofen release from emulgels. Sci Tech, 4, 118-121.

Prajakta, K.K., Gilhotra, R.M., Nitalikar, M.N., Vrunal, V., 2019. Formulation and Evaluation of Itraconazole Emulgel for Various Fungal Infections. Asian J Pharms, 13(1), 19- 22.

Prasad, B., Tyagi, Y., Raghavendra, N.O.R., 2020. A review on emulgel: the topical drug delivery system World J Pharm Life Sci, 6(6), 47-55.

Raj, S., Prakash, E.L., Balakrishnan, S., 2016. Short review - Emulgel. J Compr Pharm, 3(1), 34-37.

Reuter, J., Wölfle, U., Weckesser, S., Schempp, C., 2010. Which plant for which skin disease? Part 1: Atopic dermatitis, psoriasis, acne, condyloma and herpes simplex. J Dtsch Dermatol Ges, 8(10), 788-796.

Sabalingam, S., Siriwardhene, M.A., 2022. A review on emerging applications of emulgel as topical drug delivery system. W J Adv Res, 13(01), 452-463.

Sah, S.K., Badola, A., Nayak, B.K., 2017. Emulgel: Magnifying the application of topical drug delivery. Indian J Pharm Biol Res, 5(1), 25-33.

Sahil, H., Bhandari, S., Sharma, A., Garg, P., 2021. Emulgel: A Review. Asian J Pharm Pharm Res,11(4), 263-268.

Sahle, F.F., Gebre-Mariam, T., Dobner, B., Wohlrab, J., Neubert, R.H.H., 2015. Skin diseases associated with the depletion of stratum corneum lipids and stratum corneum lipid substitution therapy. Skin Pharmacol Physiol, 28(1), 42-55.

Shah, R.S., 2021. Formulation and evaluation of Turmeric emulgel. Asian J Pharm Tech, 11(3), 213-219.

Shahin, M., Abdel, H.S., Hammad, M., Mortada, N., 2011a. Drug Development and Ind Pharm,37(5), 559-568.

Shahin, M., Hady, S.A., Hammad, M., Mortada, N., 2011b. Novel jojoba oil-based emulsion gel formulations for clotrimazole delivery. AAPS Pharm Sci Tech, 12(1), 239-247.

Sharma, S., 2008. Topical preparations are used for the localized effects at the site of their application by virtue of drug penetration into the underlying layers of skin or mucous membranes. Pharm. Rev, 6(1), 26-39.

Shokri, J., Azarmi, S.H., Fasihi, Z., Hallaj-Nezhadi, S., Nokhodchi, A., Javadzadeh, Y., 2012. Effects of various penetration enhancers on percutaneous absorption of piroxicam from emulgels. Res Pharm Sci, 7(4), 225-234.

Shrikhande, P.V., 2013. Formulation and evaluation of polyherbal topical anti-inflammatory emulgel. Res J Pharm Tech, 6(1), 118-122.

Sonali, M., Siddiqui, A., Gupta, A., Singh, A., Kumar, N., 2021. Formulation and evaluation of *ficus benghalensis* emulgel for its anti-rheumatoid arthritis effect. J Innov App Pharm Sci, 6(3), 31-36.

Sreevidya, V.S., 2019. An Overview on Emulgel. Int J Pharm Phytopharmacological Res, 9(1), 92-97.

Srilal, T.L.I., Hettihewa, S.K., 2021. Development and evaluation of a novel herbal emulgel for potential anti-inflammatory and antioxidant activities in vitro. CINEC Academic J, 5(1), 46-53.

Suganya, K., Grace, X.F., Shanmuganathan, S., 2017. Formulation and evaluation of herbal emulgel using *cardiospermum halicacabum* leaf extract for anti-arthritic activity. Int J Pharm Tech, 9(2), 29648-29654.

Sultana, S.S., Swapna, G., Lakshmi, G.S., Swathi, S., Jyothi, G.N., Devi, A.S., Shaheda, S., 2016. Formulation and evaluation of herbal emulgel of *lantana camara* leaves

http://doi.org/10.5920/bjpharm.1046

extract for wound healing activity in diabetic rats. Indo Am J Pharm Res, 6(8), 6404-6408.

Suman, D., Sangeeta, Beena, K., 2020. Emugel for topical drug delivery: A novel approach GSC Biol Pharm Sci, 11(03), 104-114.

Susmitha, A., Devi, A.S., 2018. Formulation and evaluation of herbal emulgel of *ocimum tenuiflorum* and *mentha arevensis* leaves extract for anti-acne activity. Indo Am Jo Pharm Res, 8(11), 1347-1384.

Tadi´c, V.M., Žugi´c, A., Martinovi´c, M., Stankovi´c, M., Maksimovi´c, S., Frank, A., Neši´c, I., 2021. Enhanced skin performance of emulgel vs. cream as systems for topical delivery of herbal actives (immortelle extract and hemp oil). Pharmaceutics, 13(11), 1919.

Tasneem, R., Khan, H.M., Zaka, H.S., Khan, P., 2021. Development and cosmeceutical evaluation of topical emulgel containing *albizia lebbeck* bark extract. J Cosmet Derm, DOI:10.1111/jocd.14244Corpus ID: 235093341

Thakur, S., Thakur, N., Ghosh, N.S., 2016. Formulation and in-vitro evaluation of polyherbal micro-emulgel containing *tinospora cordifolia* and curcumin for treatment of arthritis. Int J Pharm Sci Drug Res, 8(5), 259-264.

Vats, S., Saxena, C., Easwari, T., Shukla, V., 2014. Emulsion based gel technique: Novel approach for enhancing topical drug delivery of hydrophobic drugs. Int J Pharm Sci Res, 3(2), 649-660.

Wadher, K., Dabre, S., Supare, V., Ghaywat, S., Umekar, M., 2021. Design and development of emulgel containing *pongamia pinnata* extract. Int J Pharm Sci Rev Res, 66(2), 68-73.

World Health Organization; WHO., 1999. WHO Monographs on selected medicinal plants. Vol. 1. Herba Echinaceae Purpureae. World Health Organization, Geneva; pp 136-44.

World Health Organization; WHO (2002-2005). Traditional Medicine Strategy 2002 (WHO/EDM/TRM/2002.1). Geneva, Switzerland: World Health Organization.

WHO Traditional Medicine Strategy.2014–2023.Geneva, World Health Organization, 2014 (WHO/EDM/TRM/2002.1). Available at https://apps.who.int/iris/bitstream/handle/10665/92455/9789241506090_eng.pdf (accessed 25 October 2022).

Wuryandari, T., Sugihartini, N., Kintoko, K., 2019. Emulgel formulation of purified extract of moringa (*Moringa oleifera* L.) Leaf. Folia Medica Indonesiana, 55(1), 17-24.

Yadav, S.M., Mishra, M.K., Tiwari, A., Shukla, A., 2016. Emulgel: A new approach for enhanced topical drug delivery. Int J Curr Pharm Res, 9(1), 15-19.

Yapar, E.A., Ýnal, O., Erdal, M.S., 2013. Design and in vivo evaluation of emulgel formulations including green tea extract and rose oil. Acta Pharm, 63, 531-543.