FORMULATION AND EVALUATION OF ANTIBACTERIAL HYDROGEL

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ABSTRACT

Hydrogels are cross linked, 3D hydrophilic polymer, which swell when brought into contact with water or other biological fluid. In the current studies hydrogel formulation of Eucalyptus oil and Ginger oil are developed by the help of gelling agent. Various evaluation parameter such as swelling index, pH, viscosity, increased with increased in the concentration of the formulation. Spreadability decreased with the increase in the concentration of formulation. Skin irritation studies resulted that there was no irritation or redness on the skin by applying the formulation on the skin. Stability study suggested that the formulation was stable at refrigerated condition as compared to room temperature. Antimicrobial studies suggested that the formulation were more effective in skin disorders than the coconut oil. All the combined results revealed that the formulation third was the best formulation, which was subjected to TEM analysis. Morphology study by TEM revealed that most of the particles were spherical.

KEYWORDS: Hydrogels, Eucalyptus oil, Ginger oil, TEM

INTRODUCTION

SKIN

Skin as a route of drug delivery that may offer many advantages over traditional drug delivery systems including lower fluctuations in plasma drug levels, avoidance of gastrointestinal disturbances and first-pass metabolism of the drugs, and high patient compliance. One in all the best disadvantages to transdermal drug delivery is that the skin's low permeability that limits the amount of medicine which will be delivered during this manner. It’s a district roughly 16000 cm² for an adult and represents about 8% of the weight. A skin includes a very complex structure that consists of the many components. Cells, fibres and other components compose several different layers that give skin a multi-layered structure.
Skin is a mechanical barrier between the inner part of the body and thereby the external world (1). Temperature of skin varies during a range of 30 to 40 °C degree reckoning on the environmental conditions. (2)

Dermal drug delivery is that topical application of drugs to the skin in the treatment of skin diseases and other inflammatory conditions. This has the advantage that high concentrations of drugs can be localized at the site of action, reducing the systemic side effects. Transdermal drug delivery uses the skin as an alternative route for the delivery of systemically acting drugs. (3)

LAYERS OF SKIN

Skin can be divided into three main regions: first the outermost layer, the epidermis, which contains the stratum corneum; second the middle layer, the dermis and third the innermost layer, the hypodermis. Hypodermis is the inner layer of skin. It is the contact layer between skin and the underlying tissues in body such as muscles and bone. (4)

![Figure No. 1: Structure of Skin (5)](image)

**EPIDERMIS**

It is a stratified squamous epithelium layer which is composed primarily of two types of cells: dendritic and keratimocytes cells. The epidermis layer harbour a number of other cells such as
melanocytes, Merkel cells and Langerhans cells. But the keratinocytes cells type comprises the majority of the cells by far. The layers of epithelium are

- Stratum germinativum (basal layer or rowing layer)
- Stratum spinosum (prickly cell layer or squamous cell layer)
- Stratum granulosum (granular layer)
- Stratum corneum (horny layer)
- Malpighian layer (pigment layer)
- Stratum lucidum

DERMIS

Dermis is positioned under epidermis and is characterized by lots of elastin fibers that provide the stretching ability as well as lots of collagen that provides the strength to the skin. The principal component of the dermis is collagen and it represents 70% of the skin’s dry weight. Blood vessels found in dermis provide nutrients for both dermis and epidermis. Dermis also plays a major role in temperature regulation. Nerves present there are responsible for pressure and pain sensations. Dermis has a thickness of 3-5 mm. In addition to elastin fibers, blood vessels and nerves, an interfibrillar gel of glycosaminoglycan, salt, water, lymphatic cells and sweet glands are parts of dermis also

Cell types found in dermis are:
- Fibroblasts: collagen producing cells
- Macrophages: scavenger cells
- Mast cells: responsible for immunological reactions and interactions with Eosinophils.

HYPODERMIS

Also called as subcutaneous layer. The hypodermis or subcutaneous layer is the deepest layer of the skin and consists of a network of fat cells. Which comprises of loose textured, fibrous, white, connective tissue containing blood and lymph vessels, secretory pores of the sweat gland and the cutaneous nerves. Most investigators consider that drug permeating through the skin enters the circulatory system before reaching the hypodermis, although the fatty tissue could serve as a depot of the drug.

TOPICAL DRUG DELIVERY
Topical delivery is defined as the application of pharmaceutical dosage form to the skin for direct treatment of cutaneous disorder, with the intent of confining the pharmacological or other effect of drug to the surface of the skin. Topical drug delivery system include dosage form like semisolids, liquid preparation, sprays and solid powder. Most widely used semisolid preparation for topical drug delivery includes gels, creams and ointments.

**ADVANTAGES OF TOPICAL DRUG DELIVERY SYSTEMS (10,11)**

- Avoidance of the first pass metabolism.
- Convenient and easy to apply.
- Avoidance of risks and inconveniences of the intravenous therapy and of diverse conditions of absorption like pH changes, presence of enzymes, gastric emptying time.
- Easily terminate the medications, when needed.
- Deliver drug more selectively to a specific site.
- Provide suitability for self-medication.
- It is of great advantage in patients who are unconscious.

**DISADVANTAGES OF TOPICAL DRUG DELIVERY SYSTEMS**

- Skin irritation or dermatitis may occur due to the drug or excipients.
- Poor permeability of some drugs through skin.
- Drugs with larger particle size can’t be easily absorbed through the skin.
- Risk of allergenic reactions.
- Can be used only for the drugs which need very small plasma concentration for action

**Factor affecting on Transdermal gel**[8,9]

- **pH of myofibrillar protein:** These are strongly pH dependent. The myofibrillar protein, pH 5.3 required at the isoelectric point. The pH is affected on gel formulation for the myosin reached for these pH values are required pH6.
- **Muscles types:** Generally in human body there are three types of muscles visceral,cardiac and skeletal muscles. We study about red and white muscles there is required stronger gel formulation for the white muscles than the red muscles because the red muscles are thin as compare to the white muscles.
• **Protein concentration:** For the formulation of gel necessary or required the critical protein concentration. The amount of protein concentration is increase due to the increasing of hardness of gel.

• **Temperature:** Temperature is important factor for the gel formulation. Due to application at the pH 6 temperature required 60°C to 70°C for the inducing gelation of myosin. Temperature is also affected on the storage condition of the gel.

• **Skin condition:** Skin is the barrier layer of our body which protects us from external environment. For the therapeutic effect of gel should be need the cross the skin layer. Skin is consisting of three layer epidermis, dermis and hypodermis.

• **Age:** The absorption of gel is dependent on patient age. In the geriatric or elderly patients slow absorption and permeation rate of drug due to their skin condition as the compare with adult. The skin of geriatric patients is rough and dry.

• **Density of sweat gland:** Sweat glands are produced sweat which play major role in thermal regulation in body. Sweat production are good then the drug absorption rate are good and their permeability also increased.

• **Fat content:** Fat content of applied area are responsible for drug release. Fat content has a marked effect on gelation properties of meat product.

**SKIN**

**Anatomy and physiology of skin:**[^10,^11,^12]

Skin is the outermost part of our body. It is the largest organ which makes a barrier on the surface of the body. Skin is defending the internal organ damage through the external atmosphere, external microbes and other elements. Skin is maintained the body temperature and water loss through the sweat gland, also provide the touch sensation, hot, cold, and pinch. The transdermal drug delivery system, there is drug should be either pass through stratum corneum of epidermis or go through the hair follicles or pass the sweat gland then reached the drug at the site of action.
Figure: Anatomy of Skin

Skin has consist three layer:

1. Epidermis
2. Dermis
3. Hypodermis

Function of the skin:¹³

The skin are provides to regulation of body temperature, blood storage, protect from external microbes and elements, heat and cold sensation, excretion and absorption, synthesis of vitamin D in the body, thermoregulation are including these.

Blood reservoir:

The skin are play as a blood reservoir because the dermis have affecting large area network of blood vessels that is carry the 8-10% of total blood flow in adult person.

Protection:

Skin are make available for use to protection of body by the microbes, Absorption, heat, and chemical, dehydration, hold entry of water duration of shower and swimming for across the skin. Skin also protects the body from the ultraviolet light. When ultra violet light is attack on the body that’s time melanin pigments are active or secreted and that defend the UV light.
Cutaneous sensation:

Cutaneous sensation are help the tactile sensation like touch, pressure, vibration, heat, cold, pain, another like pinch are informed about these all of sensation.

Percutaneous absorption:

Percutaneous is a part of skin and for the drug release the required of the percutaneous absorption. Some drug as like emollients, antimicrobial, and deodorants role play as fundamentally on the surface of skin. The desirable area of maximum dermatological disorder stays in the viable epidermis. The skin penetration diffusion is necessary.

PREPARATION OF HYDROGEL:--

MATERIAL USED

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Materials used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eucalyptus oil</td>
</tr>
<tr>
<td>2</td>
<td>Ginger oil</td>
</tr>
<tr>
<td>3</td>
<td>carbapol</td>
</tr>
<tr>
<td>4</td>
<td>glycerine</td>
</tr>
<tr>
<td>5</td>
<td>Distilled water</td>
</tr>
<tr>
<td>6</td>
<td>Potassium dihydrogen phosphate</td>
</tr>
<tr>
<td>7</td>
<td>Disodium hydrogen phosphate</td>
</tr>
<tr>
<td>8</td>
<td>Ethanol</td>
</tr>
<tr>
<td>9</td>
<td>Acetone</td>
</tr>
<tr>
<td>10</td>
<td>Benzene</td>
</tr>
<tr>
<td>11</td>
<td>HCl</td>
</tr>
</tbody>
</table>
LIST OF INSTRUMENTS

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>INSTRUMENT</th>
<th>MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Weighing Balance</td>
<td>Shimadzu, Japan</td>
</tr>
<tr>
<td>3.</td>
<td>Refrigerator</td>
<td>LG, India</td>
</tr>
<tr>
<td>4.</td>
<td>Mechanical stirrer</td>
<td>REMI, India</td>
</tr>
<tr>
<td>5.</td>
<td>Magnetic stirrer</td>
<td>REMI, India</td>
</tr>
<tr>
<td>6.</td>
<td>pH meter</td>
<td>Hanna instruments, India</td>
</tr>
<tr>
<td>7.</td>
<td>viscometer</td>
<td>DV-E Viscometer</td>
</tr>
</tbody>
</table>

MORPHOLOGICAL EVALUATION

It refers to evaluation of drugs by colour, odour, taste, size, shape and special features, like touch texture etc. It is a technique of qualitative evaluation based on the study of morphological and sensory profile of whole drugs. Organoleptic evaluation means conclusions drawn from studies resulted due to impressions on organ of senses.

CHEMICAL TEST FOR EUCALYPTUS OIL:-

2.5 ml of eucalyptus oil is mixed with 5 ml of purified petroleum benzins add 5 ml of solution of sodium nitrite (5gm of sodium-nitrite and 8 ml of purified water). Then add 5 ml of glacial acetic acid crystal of phellandrene nitrite do not form in the mixture within 10 minutes. (166)

SOLUBILITY

The solubility of drug is an important physicochemical property because it effects the bioavailability of the drug, the rate of drug release into dissolution medium and consequently, the therapeutic efficiency of the pharmaceutical product. The solubility of the molecules in various solvents is determined as a first step. This information is valuable in developing a formulation. Solubility is usually determined in variety of commonly used solvents and some oils if the molecule is lipophilic. The solubility of material is usually determined by the equilibrium solubility method, which employs a saturated solution of the material, obtained by stirring an excess of material in the solvent for a prolonged until equilibrium achieved. (167)
Table 5: Solubility profile of oil in different solvents.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Solvent</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Water</td>
<td>++++</td>
</tr>
<tr>
<td>2.</td>
<td>Methanol</td>
<td>+++</td>
</tr>
<tr>
<td>3.</td>
<td>Ethanol</td>
<td>++</td>
</tr>
<tr>
<td>4.</td>
<td>Chloroform</td>
<td>-</td>
</tr>
<tr>
<td>5.</td>
<td>Ether</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 6: Standards for solubility.

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Sign</th>
<th>Solubility</th>
<th>Solubility (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>++++</td>
<td>Very soluble</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>2.</td>
<td>++++</td>
<td>Freely soluble</td>
<td>1-10</td>
</tr>
<tr>
<td>3.</td>
<td>+++</td>
<td>Soluble</td>
<td>10-30</td>
</tr>
<tr>
<td>4.</td>
<td>+++</td>
<td>Sparingly soluble</td>
<td>30-100</td>
</tr>
<tr>
<td>5.</td>
<td>++</td>
<td>Slightly soluble</td>
<td>100-1000</td>
</tr>
<tr>
<td>6.</td>
<td>+</td>
<td>Very slightly soluble</td>
<td>1000-10000</td>
</tr>
<tr>
<td>7.</td>
<td>-</td>
<td>Insoluble</td>
<td>&gt;10000</td>
</tr>
</tbody>
</table>

Common solvents used for solubility determination are

Water, Polyethylene Glycols, Propylene Glycol, Glycerin, Sorbitol, Ethyl Alcohol, Methanol, Benzyl Alcohol, Isopropyl Alcohol, Tweens, Polysorbates, Castor Oil, Peanut Oil, Sesame Oil, Buffer at various pH.(168)

SWELLING INDEX

The swelling index is the volume in ml taken up by the swelling of 1 g of herbal material under specified conditions. Its determination is based on the addition of water or a swelling agent as specified in the test procedure for each individual herbal material (either whole, cut or pilverized).
Introduced the specified quantity of the material concerned, previously reduced to the required fineness and accurately weighed, into a stoppered measuring cylinder. Added 25 ml of water and shaken the mixture thoroughly every 10 minutes for 1 hour. Allowed to stand for 3 hours at room temperature, or as specified as and measured the volume in ml occupied by the herbal material, including any sticky mucilage. Calculate the mean value of the individual determination, related to one gram of herbal material.(166) The test was performed in triplicate. Swelling index was calculated by using the following formula:

Swelling index(S.I) = \[\frac{(X_T - X_0)}{X_0}\]×100

Where \(X_T\) = Final volume and \(X_0\) = Initial volume.

**Process:-**

Carbapol 934 was dispersed in 40 ml of distilled water with continuous stirring. Glycerine was added gradually to form a homogeneous mass. Further eucalyptus oil and ginger oil was mixed to above mixture and volume was made up to 50 ml by adding remaining part of distilled water. All the ingredient were mixed properly with carbapol 934 to form a smooth hydrogel. Finally different formulation are made for the adjustment of required pH of about 4.5-5.5, to form a hydrogel of required consistency. The prepared hydrogel was subjected to various evaluation parameters.

1. **Dispersed carbopol-934 in 40 ml water**
2. **Added Glycerine to the above mixture.**
3. **Added the Ginger and Eucalyptus oil and volume were made up to 50ml with remaining distilled water.**
4. **All ingredients were mixed properly.**
FORMULATION OF HYDROGEL

Table 7: Depicting formulation of antibacterial hydrogel

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>INGREDIENTS</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Eucalyptus oil</td>
<td>2 ml</td>
<td>3 ml</td>
<td>4 ml</td>
</tr>
<tr>
<td>2.</td>
<td>Ginger oil</td>
<td>1 ml</td>
<td>2 ml</td>
<td>3 ml</td>
</tr>
<tr>
<td>3.</td>
<td>Carbopol 934</td>
<td>2 gm</td>
<td>2 gm</td>
<td>2 gm</td>
</tr>
<tr>
<td>4.</td>
<td>Water</td>
<td>50 ml</td>
<td>50 ml</td>
<td>50 ml</td>
</tr>
<tr>
<td>5.</td>
<td>Glycerine</td>
<td>0.5 gm</td>
<td>0.5 gm</td>
<td>0.5 gm</td>
</tr>
</tbody>
</table>

EVALUATION OF GEL

MEASUREMENT OF pH.

The pH values of different formulations were measured using a calibrated digital pH meter at room temperature in triplicate. (169)

MEASUREMENT OF VISCOSITY

The measurement of viscosity of the prepared gel was done with a Brookfield Viscometer. The gels were rotated at 0.3, 0.6 and 1.5 rotations per minute. At each speed, the corresponding dial reading was noted. The viscosity of the gel was obtained by multiplication of the dial reading with factor given in the Brookefield Viscometer catalogues. (170)

HOMOGENEITY

After the gels have been set in the container, all developed gels were tested for homogeneity by visual inspection. They were tested for their appearance and presence of any aggregates. (171)

GRITINESS

All the formulations were evaluated microscopically for the presence of any appreciable particulate matter which was seen under light microscope. Hence obviously the gel preparation fulfils the requirement of freedom from particular matter and from grittiness. (172)
SPREADABILITY
One of the criteria for a gel to meet the ideal quantities is that it should possess good Spreadability. It is the term expressed to denote the extent of area to which gel readily spreads on application to skin or affected part. The therapeutic efficacy of a formulation also depends upon its spreading value.

Spreadability is expressed in terms of time in seconds taken by two slides to slip off from gel and placed in between the slides under the direction of certain load, lesser the time taken for separation of two slides, better the spreadability. It is calculated by using the formula:

\[ S = \frac{M \times L}{T} \]

where:
- \( M \) = weight tied to upper slide
- \( L \) = length of glass slides
- \( T \) = time taken to separate the slide. \((172,173)\)

SKIN IRRITATION:
This evaluation was performed on healthy human volunteers including both male and female candidates. About 0.5 g of herbal hydrogel was applied on area of 6cm² of skin. At the end of the exposure period of 1 hour, skin was checked for any irritation or redness.

SWELLING STUDIES
To determine the swelling index of prepared topical gel, 1 gm of gel was taken on petridish and then placed separately in a 50 ml beaker containing 10 ml distilled water. Then the samples were removed from beaker at different time intervals and put it on dry place for some time after it re-weighed. Swelling index was calculated as follows

Swelling index (SW)% = \([\frac{(Wt - Wo)}{Wo}] \times 100\)

Where, (SW)% = Equilibrium percent swelling, Wt = Weight of swollen gel after time t, Wo = Original weight of gel at zero time.

RESULT AND DISCUSSION

STANDARDISATION STUDY:-

1. EUCALYPTUS OIL:-
1.1 Morphology :-

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The eucalyptus oil was colourless or pale yellow, aromatic in odour and have pungent taste.

- **COLOUR** :- colourless or pale yellow
- **ODOUR** :- aromatic
- **TASTE** :- pungent

1.2 Solubility :-

- Completely soluble in water.
- Sparingly soluble in methanol
- Insoluble in chloroform.

**Table 8** : Solubility profile of oil in different solvent

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Solvent</th>
<th>Standard</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Water</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td>2.</td>
<td>Methanol</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>3.</td>
<td>Ethanol</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>4.</td>
<td>Chloroform</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5.</td>
<td>Ether</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 9** : standards for solubility

<table>
<thead>
<tr>
<th>Sign</th>
<th>Solubility</th>
<th>Solubility(ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+++++++</td>
<td>Very soluble</td>
<td>&lt;1</td>
</tr>
<tr>
<td>++++++</td>
<td>Freely soluble</td>
<td>1-10</td>
</tr>
<tr>
<td>++++</td>
<td>Soluble</td>
<td>10-30</td>
</tr>
<tr>
<td>+++</td>
<td>Sparingly soluble</td>
<td>30-100</td>
</tr>
<tr>
<td>++</td>
<td>Slightly soluble</td>
<td>100-1000</td>
</tr>
<tr>
<td>+</td>
<td>Very slightly soluble</td>
<td>1000-10000</td>
</tr>
<tr>
<td>–</td>
<td>Insoluble</td>
<td>&gt;10000</td>
</tr>
</tbody>
</table>
1.3 Chemical test:

Aqueous solution of eucalyptus oil gave pale yellow color.

2. GINGER OIL:

2.1 Morphology:

The ginger oil was brownish yellow, pleasant in odour and have pungent in taste.

- **COLOUR**: brownish yellow
- **ODOUR**: pleasant
- **TASTE**: pungent

2.2 Solubility:

- Completely soluble in water.
- Sparingly soluble in ethanol
- Insoluble in ether.

PREPARATION OF ANTIBACTERIAL GEL:

Figure 17: Antibacterial Gel

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EVALUATION:

1. PHYSICAL EVALUATION

Hydrogel formulation were found to be translucent in nature with pungent odour, smooth feel on application and homogeneous and the results of the appearance of the hydrogel is shown in the table no. 10.

**Table no. 10: Physical evaluation**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Formulation code</th>
<th>Appearance</th>
<th>Feel on application</th>
<th>Odour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>F-1</td>
<td>Brownish yellow</td>
<td>Smooth</td>
<td>Pungent</td>
</tr>
<tr>
<td>2.</td>
<td>F-2</td>
<td>Brownish yellow</td>
<td>Smooth</td>
<td>Pungent</td>
</tr>
<tr>
<td>3.</td>
<td>F-3</td>
<td>Brownish yellow</td>
<td>Smooth</td>
<td>Pungent</td>
</tr>
</tbody>
</table>

2. **pH** :-

The pH of all the three formulations was in the range of the pH of the skin i.e. 4 to 5.5 which are in range shown in table no. 11.

**Table 11: Results of pH of hydrogels.**

<table>
<thead>
<tr>
<th>S.no</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.11</td>
<td>4.09</td>
<td>4.10</td>
</tr>
</tbody>
</table>
Figure 18: Hydrogel F-1 subjected to pH determination.

Figure 19: Hydrogel F-2 subjected to pH determination.
Figure 20: Hydrogel F-3 subjected to pH determination.

3 VISCOSITY: Viscosities of the gels were measured by the Brookfield viscometer in centipoises. The viscosity of different formulations are given below:

Table 12: Results of viscosity of hydro-gels (mean ± standard deviation)

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Formulation code</th>
<th>Viscosity (cp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>F1</td>
<td>15454</td>
</tr>
<tr>
<td>2.</td>
<td>F2</td>
<td>48362</td>
</tr>
<tr>
<td>3.</td>
<td>F3</td>
<td>85165</td>
</tr>
</tbody>
</table>
Figure 21: Hydrogel F-1 subjected to viscosity determination.

Figure 22: Hydrogel F-2 subjected to viscosity determination.
Figure 23: Hydrogel F-3 subjected to viscosity determination.

4 Skin Irritation:-
All the three formulations were subjected to skin irritation study on voluntary individuals. No formulation showed any sign of skin irritation and redness as observed in figure. This implies that the formulations are not allergic to the skin.

Figure 24: Hydrogel subjected to skin irritation study. No redness or irritation was observed

5 SWELLING STUDIES
Hydrogel can swell thousand of time then its dry weight of the hydrogel. The release of drug from hydrogel particles depends upon the swelling behaviour. As the hydrogels swells, the network pores open and drug release occurs. Swelling index of hydrogel were done as dynamic equilibrium study. The results are tabulated in table no.13. It may be concluded that as the quantity of formulation increased, the swelling ability of formulations also increased.
Table No. 13: Results of percentage swelling index of hydrogels (mean ± standard deviation)

<table>
<thead>
<tr>
<th>TIME(HOURS)</th>
<th>F-1</th>
<th>F-2</th>
<th>F-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>13.9 ± 5.45</td>
<td>30 ± 8.16</td>
<td>40 ± 8.16</td>
</tr>
<tr>
<td>2</td>
<td>33.3 ± 4.71</td>
<td>43.3 ± 4.64</td>
<td>53.33 ± 4.64</td>
</tr>
<tr>
<td>3</td>
<td>36.6 ± 4.71</td>
<td>56.6 ± 4.71</td>
<td>63.53 ± 4.64</td>
</tr>
<tr>
<td>4</td>
<td>43.3 ± 4.69</td>
<td>66.6 ± 4.71</td>
<td>76.67 ± 4.64</td>
</tr>
<tr>
<td>5</td>
<td>65 ± 4.16</td>
<td>78.3 ± 4.72</td>
<td>82.68 ± 4.75</td>
</tr>
</tbody>
</table>

Declaration of interest

The authors report no conflicts of interest. The authors are responsible for the content and writing of the paper. Author highly thankful to Dev bhoomi institute of pharmacy and research, Dehradun for providing the all facility for carried out my research work.

CONFLICT OF INTEREST: NIL

REFERENCES


