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Herbal-Based Natural Polymers for Microsphere Formulation: *Piper longum* Linn

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Abstract: Piper longum Linn. has garnered significant attention in recent years due to its diverse applications in both traditional and modern medicine. The plant's active compounds have been shown to exhibit anti-inflammatory, antioxidant, and antimicrobial properties, making it a valuable resource in the development of new therapeutic agents. Research indicates that the alkaloids present in Piper longum, such as piperine, play a crucial role in enhancing bioavailability and efficacy of various drugs, thereby supporting its use in combination therapies. Furthermore, ongoing studies are exploring the potential of Piper longum in managing chronic diseases, including diabetes and cardiovascular disorders. Its adaptogenic properties may also contribute to stress relief and improved overall well-being. As interest in natural remedies continues to rise, Piper longum stands out as a promising candidate for further exploration in pharmacological research, with the potential to bridge the gap between traditional knowledge and contemporary scientific validation. In conclusion, the multifaceted uses of Piper longum highlight its importance not only as a culinary spice but also as a significant player in the realm of health and wellness. Continued research will undoubtedly unveil more of its secrets, paving the way for innovative applications in medicine and beyond. Novel drug delivery technology refers to the approaches, formulations, technologies, and systems for transporting a pharmaceutical compound in the body to safely achieve its desired therapeutic effects. Natural polymers are widely used in microspheres due to their biocompatibility, biodegradability, and ability to encapsulate drugs for sustained release. Starch Microspheres advantages are Abundant, low cost, and easily modifiable. Cellulose Microspheres' advantages are High stability and versatility in formulation. Dextran Microspheres advantages are low immunogenicity and tunable degradation. Natural polymers are increasingly vital in pharmaceutical formulations for targeted drug delivery and sustained/controlled-release microspheres, particularly for herbal drug formulations. Their biocompatibility, biodegradability, and ability to encapsulate bioactive herbal compounds make them ideal for delivering plant-derived drugs with improved efficacy and safety.

Keywords: *Natural Polymers, Microspheres Technology, Piper Longum Linn., Novel Drug Delivery Technology; Pharmacological and Therapeutic Activities.*

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I. INTRODUCTION

Medicinal plants have long been revered for their healing properties, forming the backbone of traditional medicinal systems worldwide. With over 3.3 billion people in developing countries relying on these natural remedies, the significance of plants like Piper longum cannot be overstated. Piper longum, commonly known as long pepper or pippalimool, has a rich history in herbal medicine. First documented by Hippocrates, this plant was recognized for its medicinal value rather than culinary use. The roots and fruits of Piper longum are the most utilized parts, celebrated for their therapeutic benefits. For nearly 2400 years, long pepper has been a significant export from India, highlighting its importance in trade and medicine.

In various traditional systems such as Ayurveda, Unani, Siddha, and Chinese medicine, Piper longum is employed to treat a range of ailments, including fever, asthma, hemorrhoids, bronchial stress, abdominal pain, inflammation, jaundice, diarrhea, and even as an antidote for snake bites. The primary active compound, piperine, is known for its

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diverse pharmacological properties, including CNS depressant, analgesic, antipyretic, antioxidant, anti-inflammatory, and hepatoprotective effects. In Ayurveda, Piper longum is classified under panchakola and Shudhashana, recognized for its effectiveness in enhancing digestion and appetite. Clinical studies have demonstrated its significant impact on bronchial asthma, particularly in children, showcasing its potential as a valuable therapeutic agent in modern medicine.

The enduring legacy of Piper longum underscores the importance of integrating traditional knowledge with contemporary scientific research, paving the way for innovative treatments derived from nature.

➢ *Formulation Techniques for Herbal Microspheres:*

- *Emulsion-Based Techniques:*

Involves creating water-in-oil (W/O) or oil-in-water (O/W) emulsions to encapsulate herbal actives. The polymer solution forms the dispersed phase, and the herbal compound is entrapped during emulsification. Process A polymer solution (chitosan in acetic acid) is mixed with the herbal extract. This aqueous phase is emulsified in an oil phase (vegetable oil) for W/O or an aqueous phase for O/W, using surfactants (Span 80, Tween 20). Cross-linking agents (glutaraldehyde for gelatin, calcium chloride for alginate) solidify the microspheres. Applications are suitable for both hydrophilic (green tea catechins) and lipophilic (curcumin, essential oils) herbal compounds. Used for chitosan or gelatin microspheres to deliver turmeric extract or silymarin. Advantages: High encapsulation efficiency, versatile for various herbal actives. Challenges: Residual solvents or cross-linkers may pose toxicity risks; requires careful washing.

- *Spray-Drying:*

A solution of natural polymer and herbal active is atomised into a hot drying chamber, forming microspheres as the solvent evaporates. Process: Dissolve the polymer (starch, HPMC) and herbal extract (ashwagandha extract) in a suitable solvent. Spray the solution through a nozzle into a heated chamber (typically 100–200°C). Collect dried microspheres with encapsulated herbal actives. Applications: Ideal for heat-stable herbal compounds (e.g., berberine, piperine). Used for starch or cellulose derivative microspheres for oral delivery. Advantages: Scalable, produces uniform microspheres, suitable for volatile herbal oils. Challenges: High temperatures may degrade heat-sensitive herbal compounds (essential oils).

- *Coacervation (Phase Separation):*

Involves phase separation of a polymer solution to form coacervates that encapsulate the herbal active, followed by solidification. Process: Dissolve the polymer (gelatin, alginate) and the herbal active in an aqueous solution. Induce phase separation by adding a salt, pH change, or non-solvent (ethanol). Cross-link or harden the coacervates (with calcium ions for alginate) to form microspheres. Applications: Used for encapsulating sensitive herbal compounds like ginseng or aloe vera extracts. Suitable for gelatin or alginate microspheres for oral or topical delivery. Advantages: Gentle process, high encapsulation efficiency for hydrophilic actives. Challenges: Complex optimisation, potential for incomplete phase separation**.**

- *Ionic Gelation:*

Uses ionic interactions to form microspheres, particularly with polyelectrolyte polymers like alginate or chitosan. Process is a polymer solution (sodium alginate) containing the herbal active is extruded dropwise into a cross-linking solution (calcium chloride). Ionic cross-linking forms gelled microspheres that entrap the herbal compound. Applications: Widely used for alginate microspheres to deliver herbal extracts like berberine or curcumin for colon-targeted release. Suitable for chitosan microspheres with herbal actives like quercetin. Advantages: Simple, solvent-free, preserves the bioactivity of sensitive herbal compounds. Challenges: Limited to ionic polymers, may have low mechanical strength.

- *Solvent Evaporation:*

Involves emulsifying a polymer solution with the herbal active in an organic solvent, followed by solvent evaporation to form microspheres. Process is dissolving the polymer (cellulose derivatives) and the herbal active in a volatile solvent (dichloromethane). Emulsify in an aqueous phase with a surfactant, then evaporate the solvent under stirring or reduced pressure. Applications: Used for encapsulating lipophilic herbal compounds (resveratrol, essential oils) in HPMC or gelatin microspheres. Advantages: Effective for poorly soluble herbal actives, good control over particle size. Challenges: Residual solvents may remain, requiring thorough purification.

- *Electrospraying (Electrohydrodynamic Atomization):*

Uses an electric field to atomise a polymer solution containing the herbal active into fine droplets, forming microspheres upon solvent evaporation. Process is a polymer solution (hyaluronic acid, dextran) with the herbal active is passed through a needle under high voltage. Droplets solidify into microspheres as the solvent evaporates. Applications: Suitable for hyaluronic acid microspheres delivering herbal anticancer compounds (boswellic acids). Used for targeted delivery systems with precise particle size control. Advantages: produces uniform microspheres, suitable for sensitive herbal actives. challenges: requires specialised equipment, limited scalability.

- *Floating Drug Delivery System (FDDS) and Floating Microspheres:*

FDDS, or Floating Drug Delivery System, represents a significant advancement in pharmaceutical technology, particularly for medications that require prolonged gastric retention. This innovative approach enhances the bioavailability of drugs that are best absorbed in the stomach or those that are sensitive to the conditions of the intestines. The mechanism behind FDDS is its ability to maintain a lower density than gastric fluids, which allows the formulation to float. This floating capability not only prolongs the drug's presence in the stomach but also

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facilitates a controlled release, ensuring that therapeutic levels are maintained over an extended period.

Floating microspheres (also known as hollow microspheres or microballoons) are a specific subtype of non-effervescent FDDS. These are spherical, empty particles typically ranging from 1-1000 micrometers in size, made from polymers like polycarbonate, polystyrene, or polymethacrylates. They feature a hollow core that provides buoyancy, enabling them to float in gastric fluids for extended periods (often 3-12 hours or more). The drug is incorporated into the outer polymer shell, which controls release through diffusion or erosion.

II. METHODOLOGY

- *Extraction Methods for Piper longum L.:*

Piper longum L. (long pepper) is extracted to isolate its bioactive compounds, such as piperine, piperlongumine, and essential oils, for medicinal, pharmacological, and industrial applications. Below are the common extraction methods used, based on available data

- *Solvent Extraction:*

The preparation of ethanolic extract from Piper longum L. involves several meticulous steps to ensure the extraction of beneficial compounds. First, 125 g of P. longum L. fruit powder is carefully packed in filter paper and placed in the thimble of a Soxhlet extractor. This method allows for the efficient extraction of active constituents through continuous solvent circulation. The extraction process utilizes ethanol (99.99%) as the solvent, maintained at a temperature range of 45 to 50°C for a duration of three days. This controlled environment facilitates the solubilization of phytochemicals present in the fruit powder. Once the extraction is complete, the resulting extract is separated and concentrated using a water bath. This step is crucial for removing excess solvent while retaining the valuable compounds extracted from the plant material. Following concentration, the extract undergoes phytochemical screening to identify the presence of various bioactive compounds. Meanwhile, the remaining extract is set aside for evaporation at a lower temperature of 40 to 45°C. This careful evaporation process ensures that the integrity of the phytochemicals is preserved. Finally, after complete evaporation of the solvent, the percentage yield of the extract is calculated. This yield provides insight into the efficiency of the extraction process and the concentration of active ingredients in the final product. Through these steps, the ethanolic extract of Piper longum L. is prepared, ready for further analysis and potential applications in various fields, including herbal medicine and pharmacology.

- *Preliminary phytochemical testing of Piper longum Linn.: Alkaloids (Dragendorff Test):*

In a test tube containing 10 mL of methanol, 200 mg of PLE was transferred and filtered through paper. This was then mixed with 1% HCl and 6 drops of Dragendorff's.

- *Flavonoids (Sodium hydroxide test):*

In order to prepare 200 mg of ethanolic extract of Piper longum L**.**, 10 mL of distilled water were heated with it for 5 minutes before being added to the mixture. One mL of the filtrate was treated with a few drops of NaOH (20% w/v) solution

- *Tannins (Ferric chloride test):*

For 5 minutes in a boiling water bath, 200 mg of ethanolic extract of Piper longum L**.** was combined with 20 mL of DW before being filtered through a fine mesh sieve. The solution was noted for its brownish-green or blue-black colour when around 1 mL of the cool filtrate was combined with 5 mL of distilled water and a few drops of ferric chloride.

- *Saponins (Froth test):*

For 10 minutes, 200 mg of ethanolic extract of Piper longum L**.** was heated in 10 mL of distilled water in the test tube. After cooling to room temperature (about 8–120 °C), the mixture was filtered while still hot (using filtered paper). After adding 10 mL of distilled water to 2.5 mL of the filtrate, sealing the tube, and shaking vigorously for 30 seconds, the filtrate was found to be clear. The solution was checked for steady froth after being left to stand vertically for 5 to 10 minutes.

- *Solubility test for ethanolic extract of Piper longum L.: Solvents:*

Test a range of solvents with varying polarities, such as water, ethanol, methanol, chloroform, dichloromethane, acetone, and hexane. *Procedure:* Weigh a small amount of the dried ethanolic extract (10 mg). Add the extract to a fixed volume of solvent (5 ml) in a test tube or vial. Stir or sonicate at room temperature (or a specific temperature, 25°C) for a set time (30 minutes). Observe visually for dissolution (clear solution indicates solubility; turbidity or residue indicates poor solubility). If quantitative data is needed, filter any undissolved residue, dry, and weigh to calculate the dissolved fraction. Alternatively, use analytical techniques like UV-Vis spectroscopy or HPLC to quantify piperine in the solution.

- *Preparation of standard solution for calibration curve of piperine:*

The ethanolic extract is prepared by macerating or refluxing *Piper longum* (fruits, roots, or stems) with ethanol (typically 95% or absolute ethanol). The extract is filtered and concentrated (using a rotary evaporator) to obtain a crude extract. Dissolve the crude ethanolic extract in a UV-compatible solvent, such as ethanol or methanol, to prepare a stock solution. A stock solution of piperine was prepared by dissolving 10 mg of piperine in 100 ml of ethanol. Standard solutions of piperine were prepared from a stock solution in the concentration range of 2- 20µg/ml in 100 ml volumetric flask using ethanol as solvent. Set the wavelength scan range to 200–400 nm to capture the absorption peaks of piperine and other compounds. The absorbance of piperine standard solutions was measured at 340 - 345 nm (λmax for piperine) against ethanol as a blank. The calibration curve is plotted between absorbance and concentration. Plot absorbance vs. concentration to create a linear calibration curve ($R^2 > 0.99$).

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Use the equation of the line (y = mx + c) to calculate piperine concentration in the extract.

➢ *FTIR spectrum study:*

In 0.25 to 0.5 g of ethanolic extract of *Piper longum* Linn was used and was scanned over the 400 to 4,000 cm-1 and the spectrum was recorded and an attempt was made to find the presence of major functional groups of some phytoconstituents.

➢ *Method for Preparation of Floating Microsphere:*

Several techniques can be used to formulate microspheres incorporating *Piper longum* extract. The choice depends on the desired size, release profile, and polymer properties.

➢ *Emulsion Solvent Evaporation:*

Piperine, derived from long pepper (Piper longum), is the active ingredient here, serving as a bioenhancer and antioxidant. The design incorporates elements to make the microspheres buoyant in the stomach, extending drug release for improved absorption in the upper GI tract. This is a common approach in pharmaceutics for drugs with narrow absorption windows or to enhance bioavailability. The formulation uses an emulsion solvent evaporation technique (based on the solvents, emulsifier, and polymer matrix listed). The solids total approximately 9.2 g, but the % w/w values add up to 92%, suggesting they may be approximate or based on a targeted 10 g dry weight batch (with minor rounding or an unlisted filler). Liquids are not included in % w/w as they are processing aids that evaporate or are removed.

➢ *Active Ingredient:*

Piperine (P. longum fruit extract, ≥95%): 1.0 g (10% w/w). Acts as the primary therapeutic agent with bio-enhancing (increases absorption of other drugs) and antioxidant properties.

➢ *Polymer and Matrix Formers:*

Ethyl Cellulose (EC 7 cps): 5.0 g (50% w/w). Forms the buoyant shell/matrix for controlled release and floating properties due to its low density and hydrophobicity. Grade: USP. Povidone (PVP K30): 1.0 g (10% w/w). Serves as a binder and stabiliser, improving matrix integrity and drug dispersion.

➢ *Gas-Generating Agent:*

Sodium Bicarbonate ($NaHCO_3$): 2.0 g (20% w/w). Generates CO_2 gas in acidic gastric fluid, creating buoyancy for floating in the stomach.

➢ *Emulsifier:*

Span 80: 0.2 g (2.0% w/w). A non-ionic surfactant that stabilises the oil-in-oil emulsion during preparation.

➢ *Solvents:* Dichloromethane (DCM):

15 mL. Volatile organic solvent to dissolve polymers and drugs; evaporates during processing. Grade: AR. Liquid Paraffin: 50 mL. Acts as the external (continuous) phase in the emulsion. Grade: NF. n-Hexane: q.s. (quantum sufficit, as needed). Washing solvent to remove residual oils/solvents from the microspheres.

➢ *Preparation Method:*

Based on the ingredients and their functions, this is likely a solid-in-oil-in-oil (S/O/O) or oil-in-oil (O/O) emulsion solvent evaporation method for creating floating microspheres. Here's a step-by-step procedure (standard for such formulations; adapt with lab safety protocols like a fume hood for solvents):

➢ *Prepare the Internal Phase:*

Dissolve ethyl cellulose (5.0 g), povidone (1.0 g), and piperine (1.0 g) in dichloromethane (15 mL) with stirring until a clear solution forms. Finely disperse sodium bicarbonate (2.0 g) into this solution to create a uniform suspension ($NaHCO_3$ doesn't dissolve but gets entrapped).

➢ *Prepare the External Phase:*

Dissolve Span 80 (0.2 g) in liquid paraffin (50 mL) with gentle stirring to form the continuous oil phase.

➢ *Emulsification:*

Slowly add the internal phase to the external phase under high-speed stirring (e.g., 800-1500 rpm using a mechanical stirrer or homogeniser) to form an emulsion. Maintain stirring for 2-4 hours at room temperature to allow dichloromethane to evaporate, solidifying the microspheres.

➢ *Collection and Washing:*

Filter or centrifuge the microspheres from the liquid paraffin. Wash them multiple times with n-hexane (q.s.) to remove residual paraffin and Span 80.

➢ *Drying:*

Air-dry the microspheres at room temperature or in a desiccator for 24-48 hours to obtain free-flowing powder.

➢ *Characterisation (Optional but Typical):*

Evaluate for size (e.g., 100-500 µm), buoyancy (floating time >12 hours in simulated gastric fluid), drug entrapment efficiency, and in vitro release. This system promotes prolonged gastric retention: the ethyl cellulose matrix provides buoyancy, while $NaHCO_3$ generates CO_2 in acidic conditions for additional floating. Piperine's bioenhancing properties could make this useful for co-administration with other drugs, but consult pharmacopeial standards (USP/NF/AR grades indicate pharmaceutical quality). If this is for a lab experiment or scaling, ensure proper safety (DCM and n-hexane are volatile/toxic) and validate with tests like dissolution studies.

III.RESULTS AND DISCUSSION

➢ *Percentage yield of Extracts of Piper longum L:*

- Weight of Powder sample = 125g
- Weight of extract with container = 30.5g
- Weight of empty container = 10.5g
- Actual weight of extract = Weight of extract with container - Weight of empty container = 30.5-10.5= 20g
- Percentage yield (%) =20/125x100 = 80%

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The percentage yield of ethanolic extract of Piper longum L, ethanol as solvent. The ethanolic extract gave the highest yield (80%).

➢ *Major Phyto-Constituents Detected in the Ethanolic Extract of Piper Longum L:*

Preliminary phytochemical testing of ethanolic extract of piper longum L, Major Phyto-Constituents Detected: presence of Alkaloids, Flavonoids, Tannins, Saponins, Phenol.

➢ *Solubility test for ethanolic extract of Piper longum L.:*

The solubility test for ethanolic extract of Piper longum L. is more soluble in Ethanol, Methanol, and acetone.

➢ *UV Absorption Spectra Calibration Curve of Ethanolic Extract of Piper Longum L (Piperine):*

With piperine concentrations ranging from 1 to 20 µg/ml, ethanol was used to generate the calibration curve for piperine. At 342 nm, the absorbance was determined. The regression equation is given by $y = 0.0758x$, and the R^2 value is 0.9981, indicating good linearity.

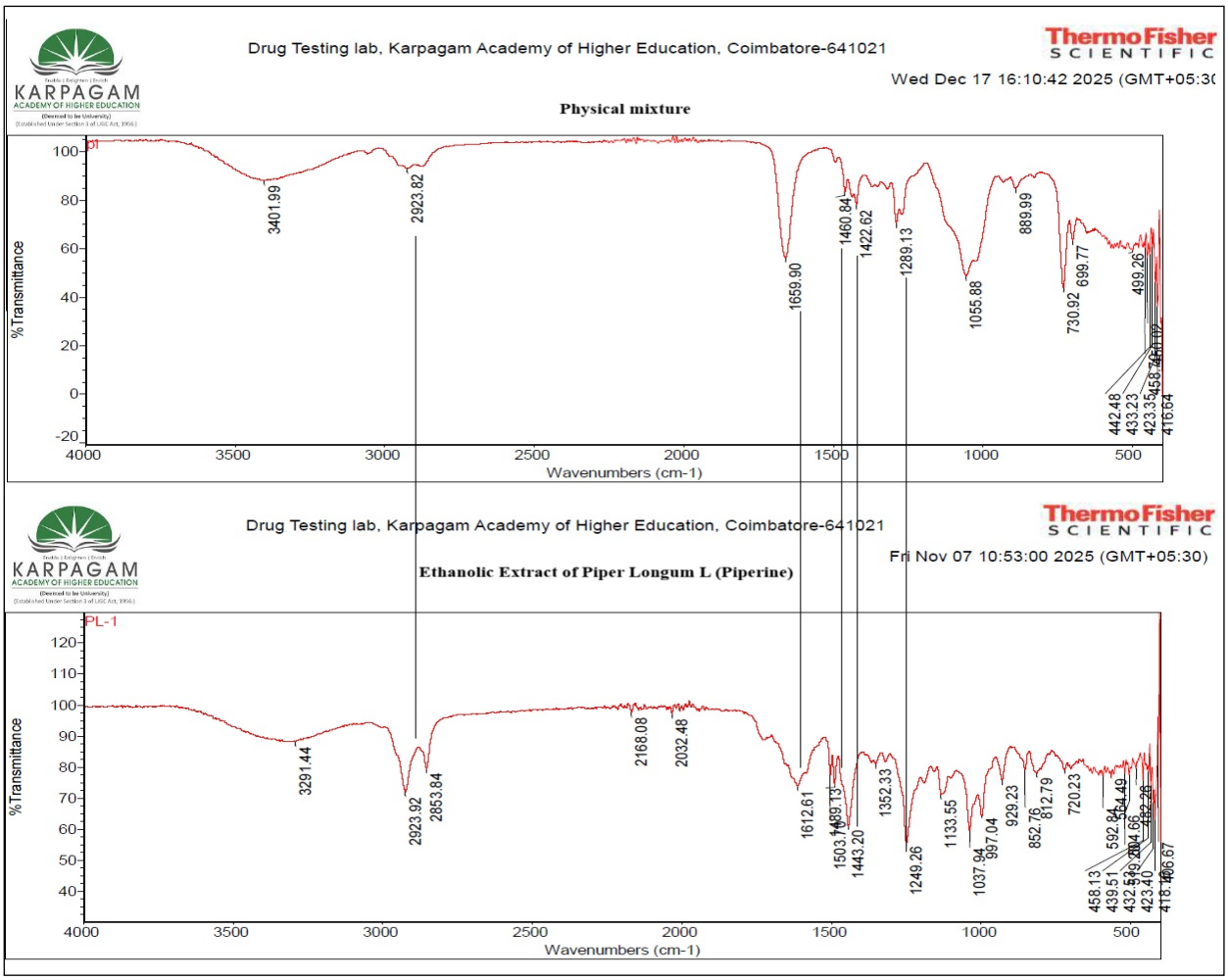

Fig 1 FTIR Spectrum of Ethanolic Extract of Piper Longum L (Piperine)

In order to ascertain the likelihood of an interaction between the drug and the excipients utilised with the analytical method of drug evaluation, the physical mixture was exposed to FTIR analysis. The presence of the excipient peaks and their associated drug peaks in the spectra above was proven by all of the spectrum's peaks. There was no interaction in this composition as a result.

➢ *Formulation of Ethanolic Extract of Piper Longum L Floating Microspheres:*

It is well known that the success of formulation depends upon, its percentage yield as well as percentage floating of microspheres, drug content and drug release study.

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Table 1 Formulation of Floating Microspheres

Ingredient	F1	F2	F3
Piperine (*P.longum* extract, ≥ 95% purity)	1 gms	1 gms	1 gms
Ethyl Cellulose (EC 7 cps)	2.5 gms	5 gms	7.5 gms
Sodium Bicarbonate ($NaHCO_3$)	1.5 gms	2 gms	2.5 gms
Povidone (PVP K30)	2 gms	2 gms	2 gms
Dichloromethane (DCM)	5 ml	10 ml	15 ml
Liquid Paraffin	50 ml	50 ml	50 ml
Span 80	0.2 ml	0.2 ml	0.2 ml
n-Hexane	Q. S	Q. S	Q. S

Floating microspheres represent a significant advancement in drug delivery systems, offering controlled release and enhanced bioavailability. The preparation of these microspheres through the emulsion solvent diffusion technique and oil-in-water emulsion solvent evaporation method has shown promising results, particularly when utilizing organic solvents like dichloromethane. In the preformulation studies, it was evident that the oil-in-water emulsion solvent evaporation method yielded free-flowing, smooth, and uniformly sized microspheres. The choice of polymers, specifically ethyl cellulose and Povidone K30, in varying ratios (1:1, 1:2, 1:3) was crucial. Notably, microspheres formulated with Povidone K30 demonstrated superior characteristics, indicating its effectiveness in achieving the desired microsphere properties. Agitation speed emerged as a pivotal factor influencing microsphere formation. An increase in agitation speed correlated with a decrease in mean particle size, likely due to enhanced frothing and reduced adhesion of microspheres to the beaker walls. Conversely, lower agitation speeds resulted in unstable emulsion droplets, leading to the formation of larger particles. The optimal agitation speed was determined to be 1000 rpm/min, which facilitated the ideal conditions for microsphere formation. Temperature also played a critical role, with an optimal range of 35-40ºC identified for the formation of microspheres.

Lower temperatures resulted in reduced yield, while higher temperatures adversely affected the buoyancy of the microspheres. Furthermore, the type and concentration of emulsifiers were found to significantly impact the preparation process. Insufficient emulsifier concentration led to increased particle aggregation and size. The study identified a 0.2% v/v emulsifier concentration as optimal for achieving the desired particle size, highlighting the delicate balance required in formulation development. In conclusion, the careful selection of preparation methods, polymer types, agitation speeds, temperatures, and emulsifier concentrations is essential for the successful development of floating microspheres, paving the way for more effective drug delivery systems.

- *Evaluation of Characteristics of floating microspheres:*

Physical Characteristics was determined as per procedure given in material and method part. The results of micromeritic properties were showed in table. The tapped density values obtained in the range from0.116-0.121 gm/cm^3 and bulk density values obtained in the range from 0.106-0.108 gm/cm^3. for all the formulations. For the prepared formulations angle of repose ranged between (25º- 26º), the compressibility index ranged between 6.89 %-10.74 % and Hausner's ratio ranged between (1.07-1.12), confirmed good flow properties of the microspheres. Thus, the floating microspheres showed better flow property and were non-aggregated.

Excellent buoyancy was shown by prepared microspheres because of their hollow nature, which can be retained for a longer period of time in the upper part of gastrointestinal tract (GIT) in order to increase gastric residence time of the drug, Buoyancy of prepared microspheres was investigated by in-vitro buoyancy test and the buoyancy of all the formulations were found to be in the range of 70 - 84%, F2 showed highest buoyancy of 84%.Formulation F2 gave the best floating ability (84%) in Simulated Gastric Fluid . Smaller the microspheres lesser was the floating ability, while larger the size, floating ability was found to be more and sustained was the release of drug.

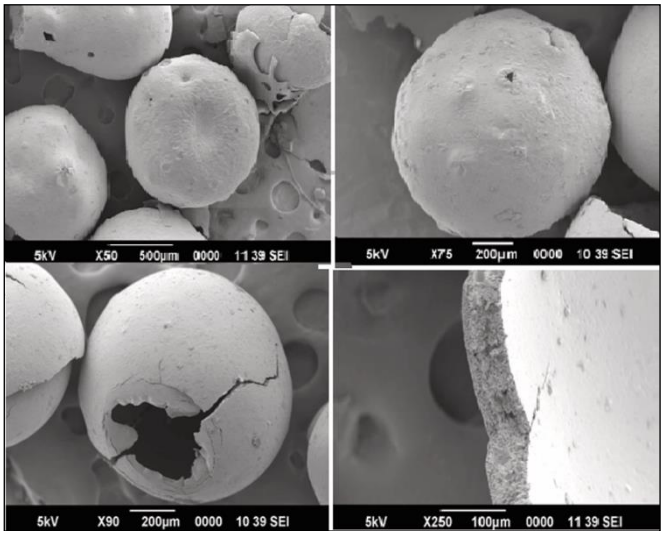

Fig 2 Surface Morphology using Scanning Electron Microscope.

Morphology of floating microspheres was examined by scanning electron microscopy. The SEM images of prepared formulations were showed by figure. SEM analysis showed that the prepared floating microspheres were having size in micrometers and the particles were nearly spherical.

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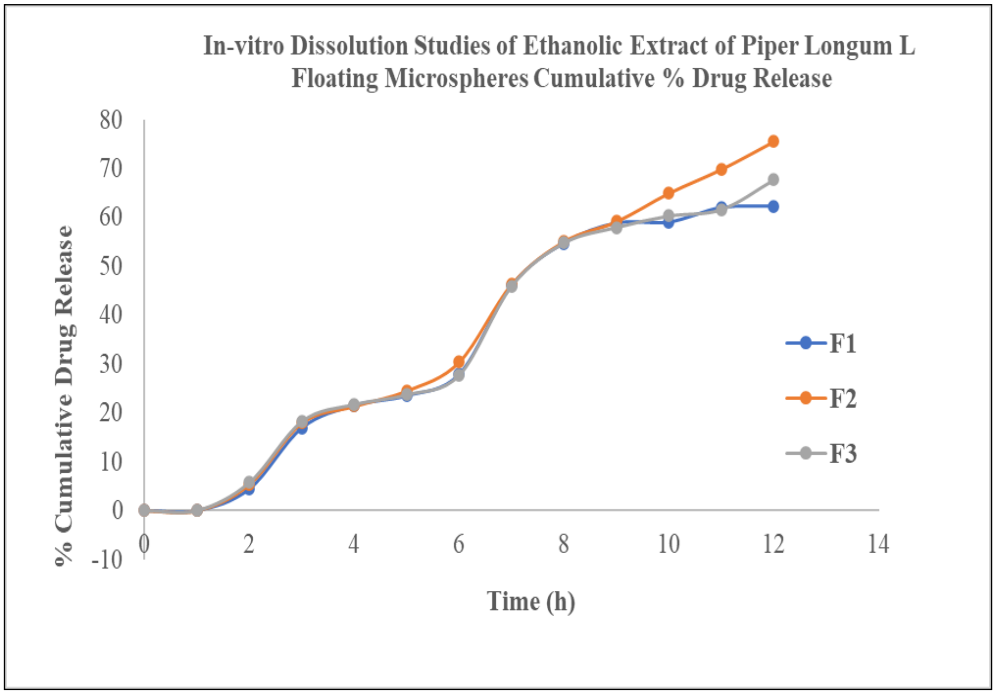

Fig 3 Comparative Dissolution Profile for Ethanolic Extract of Piper Longum L. Floating Microspheres

For comparison of the release rate of formulations prepared using different polymer ratios, an in vitro release study was conducted. In-vitro drug release studies were performed in 0.1 N HCl for 2 h and in a pH 6.8 buffer for 10 h. The cumulative release of the drug significantly decreased with an increase in polymer concentration. The increased density of the polymer matrix at higher concentration resulted in an increased diffusion path length. This may decrease the overall drug release from the polymer matrix. And it was found that as the polymer concentration was increased, the release rate decreased. The selected formulation percentage of drug released was found to be initially 5.39% at 1 h and 80.67% up to 12 h.

Table 2 Release kinetic study

Formulation	Zero order (r^2)	First order (r^2)	Higuchi (r^2)	Korsmeyer-Peppas	
				(r^2)	n value
F1	0.747	0.830	0.897	0.856	0.703
F2	0.827	0.947	0.944	0.904	0.713
F3	0.754	0.837	0.905	0.881	0.659

In order to determine the release model which best describes the pattern of drug release, the in-vitro release data were substituted in various models such as zero order, first order, Higuchi plot and Korsmeyer-Peppas kinetics models. The highest regression (0.947) was obtained for the Higuchi equation. To explain the mechanism of drug release, korsmeyer-peppas equation was used. Value of slope (n) was calculated and found to be (0.713), which is less than 0.89, which indicates anomalous non-Fickian diffusion, i.e. coupling of diffusion and erosion, which indicates that the drug release is sustained by more than one process. From the above parameters, the best selected formulation was found to be F2 having, 88.2% yield, 88% buoyancy, 85.2% drug content, 91.2% entrapment efficiency and 80.67% drug release.

IV. CONCLUSION

Floating microspheres of Piper Longum L were developed using an innovative oil-in-water emulsion solvent evaporation method, incorporating various biodegradable polymers like ethyl cellulose and Povidone K-30 to enhance the drug's retention in the body. The ethanolic extract of Piper Longum L (Piperine) has low water solubility, necessitating a novel gastroprotective drug delivery system that ensures prolonged gastric presence and improved oral bioavailability. The floating microspheres were evaluated for their floating capacity, compatibility, particle size and morphology, drug content, in vitro drug release, and entrapment efficiency. These multi-particulate drug delivery systems, characterized by low density, demonstrated excellent floating properties, remaining in the gastric environment for over 12 hours. Microspheres based on ethyl cellulose and Povidone K-30 exhibited buoyancy for more than 15 hours, essential for sustained therapeutic effects. Key benefits of this system include straightforward preparation, effective floating ability, high encapsulation efficiency, and prolonged drug release over several hours. The study concluded that the formulation of floating microspheres of Piper Longum L (Piperine) provides extended gastric residence time and continuous medication release. The kinetics of drug loading and release are vital for the effective delivery of Piper Longum L

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(Piperine) bioactive compounds. Piper Longum L (Piperine) is characterized by its biocompatibility, biodegradability, and low toxicity, making it suitable for long-term applications.

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