International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 22s, 2025
https://www.theaspd.com/ijes.php

Design Development And Evaluation Of Oral Suspension Of Antiemetic Drug

Dr. Mahesh M. Thakare[1*], Shilpa Dilip Gaikwad[2], Vaibhav Narwade[3], Dr. Vijaykumar Kale[4], Mamata M. Pavale[5], Anil B. Panchal[6], Mohini B. Yadav[7], Sonal V. Satav[8]

[1*]Associate Professor, Kasturi Shikshan Sanstha, College of Pharmacy, Shikrapur, Pune-412208 Maharashtra, India
[2]Student, Kasturi Shikshan Sanstha, College of Pharmacy, Shikrapur, Pune-412208 Maharashtra, India
[3, 5,7]Assistant Professor, Kasturi Shikshan Sanstha, College of Pharmacy, Shikrapur, Pune-412208 Maharashtra, India
[4]Principal, Kasturi Shikshan Sanstha, College of Pharmacy, Shikrapur, Pune-412208 Maharashtra, India
[6,8]Assistant Professor, Delight College of Pharmacy, Koregaon Bhima, Pune- 412216 Maharashtra, India

ABSTRACT

The present study aimed to design, develop, and evaluate an oral suspension of an antiemetic drug, Domperidone, to improve its dissolution behavior, stability, and patient compliance. Preformulation studies were conducted to evaluate organoleptic properties, melting point, solubility, and drug–excipient compatibility using UV spectroscopy, DSC, and FTIR analysis. Placebo batches were initially prepared using various polymers, including sodium alginate, Carbopol 934P, xanthan gum, methyl cellulose, HPMC K4M, and gum acacia, to identify suitable suspending agents based on sedimentation volume and redispersibility. Drug-loaded flocculated suspensions were subsequently formulated and evaluated for sedimentation behavior, redispersibility, conductivity, pH, particle size, in-vitro dissolution, viscosity, and assay. Among all formulations, HPMC K4M–based suspension (FF5) demonstrated optimal physical stability, excellent redispersibility, acceptable viscosity, stable pH, uniform drug content, and superior in-vitro drug release. The study concludes that a stable and patient-friendly oral suspension of Domperidone can be successfully developed using appropriate polymeric suspending agents.

KEYWORDS: *Domperidone; Oral suspension; Antiemetic; Preformulation study; Flocculated suspension; In-vitro dissolution; Suspension stability*

INTRODUCTION

The effectiveness of pharmacotherapy is not governed solely by the pharmacological activity of an active pharmaceutical ingredient (API), but is profoundly influenced by the manner in which the drug is delivered to the body. A drug delivery system encompasses the formulation approaches, routes of administration, and dosage forms employed to transport a drug to its site of action at an optimal rate and concentration. Traditional drug delivery systems continue to play a vital role in clinical practice owing to their simplicity, cost-effectiveness, and established safety profiles. These systems include oral, buccal or sublingual, rectal, intravenous, subcutaneous, and intramuscular routes, each possessing distinct advantages and limitations with respect to bioavailability, patient compliance, and therapeutic outcomes.[1]
Among these, the oral route of drug delivery remains the most preferred and widely accepted route for systemic therapy. The popularity of oral administration can be attributed to its non-invasive nature, ease of administration, accurate dose measurement, patient convenience, and high compliance. Oral dosage forms are economical to manufacture and administer, making them suitable for both acute and chronic therapies. However, oral drug delivery is often challenged by factors such as poor aqueous solubility of drugs, limited permeability across the gastrointestinal membrane, degradation by gastrointestinal enzymes or microflora, food–drug interactions, irregular absorption, and extensive first-pass hepatic metabolism. These limitations necessitate the development of optimized oral formulations to improve therapeutic efficacy.[2]
Alternative routes such as buccal and sublingual drug delivery systems have gained attention due to their ability to bypass first-pass metabolism and provide rapid onset of action. These systems utilize mucoadhesive polymers that adhere to the oral mucosa, allowing prolonged residence time and improved bioavailability. Nevertheless, discomfort, limited dose capacity, and the risk of accidental swallowing restrict their widespread use. Similarly, the rectal route serves as a valuable alternative when oral administration is impractical, particularly in pediatric patients and in conditions associated with nausea

and vomiting. Although rectal delivery partially avoids first-pass metabolism, erratic absorption and patient discomfort limit its acceptability.[3]

Parenteral routes such as intravenous, subcutaneous, and intramuscular administration ensure rapid and complete drug availability and are indispensable in emergency and critical care settings. Intravenous administration provides immediate therapeutic levels with complete bioavailability, while subcutaneous and intramuscular routes allow sustained absorption of drugs. Despite these advantages, parenteral routes are invasive, require trained personnel, pose risks of infection and dosing errors, and are often associated with patient discomfort. These limitations further emphasize the preference for oral drug delivery whenever feasible.[4]

In recent decades, significant advancements have been made in oral drug delivery technologies to overcome physiological and formulation-related challenges. Conventional oral dosage forms such as tablets and capsules have been complemented by liquids, emulsions, and suspensions to improve drug administration in specific patient populations. Oral liquid formulations are particularly advantageous for pediatric, geriatric, and dysphagic patients, as well as in conditions involving nausea and vomiting. Among liquid dosage forms, oral suspensions are especially valuable for delivering poorly water-soluble drugs.

A pharmaceutical suspension is a biphasic system in which finely divided insoluble solid particles are uniformly dispersed in a liquid vehicle. Suspensions have been extensively used to enhance the dissolution rate of poorly soluble drugs by increasing surface area, thereby improving absorption and bioavailability. Oral suspensions allow flexible dosing from single formulation strength and can effectively mask the unpleasant taste of drugs. Additionally, suspensions may improve the chemical stability of certain drugs by maintaining them in a dispersed solid state rather than in solution.[5]

Despite these advantages, the formulation of a physically stable suspension remains a significant challenge. Problems such as sedimentation, caking, poor redispersibility, particle aggregation, and dose non-uniformity can compromise product quality and therapeutic performance. The physical stability of suspensions is influenced by particle size, particle size distribution, interfacial properties, zeta potential, viscosity of the dispersion medium, and the balance between flocculated and deflocculated systems. A well-designed suspension should sediment slowly, form loosely packed sediment that is easily redispersible, and maintain uniform drug distribution throughout its shelf life.[6]

The selection of appropriate excipients, particularly suspending and stabilizing agents, plays a crucial role in achieving a stable and acceptable oral suspension. Polymers such as sodium alginate, carbopol, xanthan gum, methyl cellulose, and hydroxypropyl methylcellulose are widely used to enhance viscosity, improve particle suspension, and prevent rapid sedimentation. These polymers also contribute to shear-thinning behavior, which is desirable for ease of pouring and administration while maintaining stability during storage. In addition, excipients such as surfactants, preservatives, buffers, antioxidants, and flavoring agents are incorporated to ensure wettability, microbial stability, pH control, and patient acceptability.

Antiemetic therapy represents an important area where oral suspensions offer distinct advantages. Domperidone, a dopamine D_2 and D_3 receptor antagonist, is widely used as an antiemetic and gastroprokinetic agent. It enhances gastric emptying, improves gastrointestinal motility, and suppresses nausea and vomiting by blocking dopamine receptors at the chemoreceptor trigger zone. However, domperidone exhibits low oral bioavailability due to extensive first-pass metabolism and limited aqueous solubility, which can lead to variability in therapeutic response. Formulating domperidone as an oral suspension provides an opportunity to improve its dissolution characteristics, ensure uniform dosing, and enhance patient compliance, particularly in pediatric and geriatric populations.[7,8]

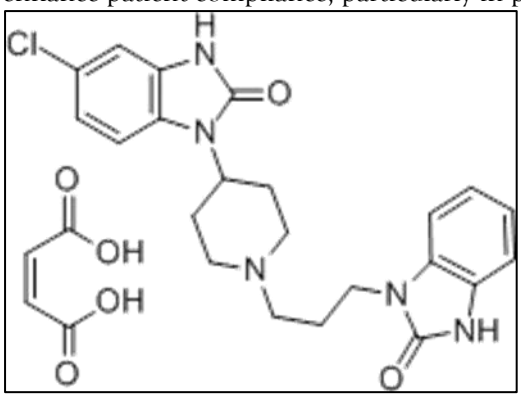

Figure 1: Structure of Domperidone

In this context, the present research focuses on the design, development, and evaluation of an oral suspension of domperidone using suitable polymeric combinations. The study aims to develop a suspension with desirable flocculated properties, improved physical stability, and acceptable rheological behavior, while ensuring effective antiemetic action. By optimizing formulation variables and evaluating critical quality attributes, the work seeks to provide a patient-friendly, stable, and therapeutically effective oral suspension capable of reducing nausea and preventing vomiting, especially in patients who have difficulty swallowing solid dosage forms.

MATERIALS AND MAETHODS:

MATERIALS:

Domperidone was obtained as a gift sample from Cipla Ltd., Mumbai, India. Sodium alginate, Carbopol 934P, xanthan gum, methyl cellulose, hydroxypropyl methylcellulose (HPMC), and gum acacia were procured from Loba Chemie Pvt. Ltd., Mumbai, India and used as suspending and stabilizing agents. Tween 80, glycerin, sorbitol, sucrose, citric acid, sodium citrate, methyl paraben, and propyl paraben were purchased from S.D. Fine-Chem Ltd., Mumbai, India. Purified water conforming to pharmacopoeial specifications was used as the dispersion medium. All chemicals and excipients employed in the study were of pharmaceutical or analytical reagent grade and were used without further purification.

METHODOLOGY:

Preformulation Studies

Preformulation studies were conducted to evaluate the physicochemical characteristics of Domperidone and its compatibility with selected excipients. These studies provide essential information required for rational formulation design and optimization of oral suspension dosage forms. The investigations focused on organoleptic properties, melting point, solubility behavior, analytical method development, and drug–excipient compatibility using thermal and spectroscopic techniques.[9,10]

Organoleptic Properties

Domperidone was examined visually and organoleptically for its appearance, color, odor, and taste to establish preliminary identification and acceptability parameters.

Melting Point Determination

The melting point of Domperidone was determined using the capillary method. A small quantity of the drug was filled into a capillary tube and placed in a melting point apparatus containing liquid paraffin as the heating medium. The temperature at which the drug completely melted was recorded, and the average of three determinations was reported.

Solubility Determination

The solubility of Domperidone was evaluated in distilled water, ethanol, and methanol. Excess drug was added to each solvent and agitated intermittently for 24 h to attain equilibrium. The solutions were filtered, suitably diluted, and analyzed using a UV–visible spectrophotometer at 286 nm to quantify drug solubility.

Standard Calibration Curve of Domperidone

A calibration curve of Domperidone was prepared in 0.1 N HCl using a UV–visible spectrophotometer (Shimadzu UV-1800). Domperidone (10 mg) was dissolved in 100 mL of 0.1 N HCl to obtain a stock solution. Aliquots (2–10 mL) were diluted to 10 mL with the same medium, and absorbance was measured at 290 nm. A linear relationship between concentration and absorbance confirmed adherence to Beer–Lambert's law.[11-14]

Differential Scanning Calorimetry (DSC)

DSC analysis was performed to study the thermal behavior of Domperidone and drug–excipient mixtures. Approximately 2 mg of sample was sealed in an aluminum pan and scanned between 50–400 °C at a heating rate of 10 °C/min under nitrogen purge using a DSC-60 (Shimadzu, Japan).[12]

Fourier Transform Infrared Spectroscopy (FTIR)

FTIR spectra of pure Domperidone and physical mixtures with excipients were recorded using the KBr pellet method. Spectra were obtained in the range of 4000–500 cm^{-1} to identify characteristic functional groups and assess drug–excipient compatibility.[15-18]

Formulation of Oral Suspension[19-38]

Preliminary Trials (Placebo Batches)

Preliminary formulation trials were conducted using individual polymers without drug to evaluate flocculation behaviour, sedimentation volume, and redispersibility. Required quantities of polymers were

dispersed in distilled water and allowed to hydrate overnight. Sorbitol was added as a wetting and sweetening agent, followed by preservatives. The final volume was adjusted with distilled water.

Table 1. Placebo batches of sodium alginate oral suspension

Ingredient	SF1 (%)	SF2 (%)	SF3 (%)	SF4 (%)	SF5 (%)
Sodium alginate	0.10	0.25	0.50	0.75	1.00
Methyl paraben	0.15	0.15	0.15	0.15	0.15
Propyl paraben	0.05	0.05	0.05	0.05	0.05
Sorbitol	10	10	10	10	10
Calcium chloride	0.10	0.10	0.10	0.10	0.10
Distilled water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

Table 2. Placebo batches of Carbopol 934P oral suspension

Ingredient	CF1 (%)	CF2 (%)	CF3 (%)	CF4 (%)	CF5 (%)
Carbopol 934P	0.10	0.25	0.50	0.75	1.00
Methyl paraben	0.15	0.15	0.15	0.15	0.15
Propyl paraben	0.05	0.05	0.05	0.05	0.05
Sorbitol	10	10	10	10	10
Calcium chloride	0.10	0.10	0.10	0.10	0.10
Distilled water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

Table 3. Placebo batches of xanthan gum oral suspension

Ingredient	XF1 (%)	XF2 (%)	XF3 (%)	XF4 (%)	XF5 (%)
Xanthan gum	0.10	0.25	0.50	0.75	1.00
Methyl paraben	0.15	0.15	0.15	0.15	0.15
Propyl paraben	0.05	0.05	0.05	0.05	0.05
Sorbitol	10	10	10	10	10
Calcium chloride	0.10	0.10	0.10	0.10	0.10
Distilled water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

Table 4. Placebo batches of methyl cellulose oral suspension

Ingredient	MF1 (%)	MF2 (%)	MF3 (%)	MF4 (%)	MF5 (%)
Methyl cellulose	0.10	0.25	0.50	0.75	1.00
Methyl paraben	0.15	0.15	0.15	0.15	0.15
Propyl paraben	0.05	0.05	0.05	0.05	0.05
Sorbitol	10	10	10	10	10
Calcium chloride	0.10	0.10	0.10	0.10	0.10
Distilled water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

Table 5. Placebo batches of HPMC K4M oral suspension

Ingredient	HF1 (%)	HF2 (%)	HF3 (%)	HF4 (%)	HF5 (%)
HPMC K4M	0.10	0.25	0.50	0.75	1.00
Methyl paraben	0.15	0.15	0.15	0.15	0.15
Propyl paraben	0.05	0.05	0.05	0.05	0.05
Sorbitol	10	10	10	10	10
Calcium chloride	0.10	0.10	0.10	0.10	0.10
Distilled water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

Table 6. Placebo batches of gum acacia oral suspension

Ingredient	AF1 (%)	AF2 (%)	AF3 (%)	AF4 (%)	AF5 (%)
Gum acacia	0.10	0.25	0.50	0.75	1.00
Methyl paraben	0.15	0.15	0.15	0.15	0.15
Propyl paraben	0.05	0.05	0.05	0.05	0.05
Sorbitol	10	10	10	10	10

Calcium chloride	0.10	0.10	0.10	0.10	0.10
Distilled water	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

Formulation of Domperidone Flocculated Oral Suspension:
Domperidone suspensions were prepared using selected polymers based on preliminary trials. Polymers were hydrated overnight in purified water to form the vehicle. Accurately weighed Domperidone was dispersed uniformly, followed by addition of sorbitol, calcium chloride, and preservatives. The suspension was homogenized and volume was adjusted to 100 mL.

Table 7. Final formulation of Domperidone oral suspensions

Ingredient	FF1	FF2	FF3	FF4	FF5
Sodium alginate (%)	10	–	–	–	–
Carbopol 934P (%)	–	10	–	–	–
Xanthan gum (%)	–	–	10	–	–
Methyl cellulose (%)	–	–	–	10	–
HPMC K4M (%)	–	–	–	–	10
Domperidone (mg)	500	500	500	500	500
Methyl paraben (mg)	150	150	150	150	150
Propyl paraben (mg)	50	50	50	50	50
Sorbitol (%)	10	10	10	10	10
Calcium chloride (mg)	100	100	100	100	100
Distilled water (mL)	Up to 100	Up to 100	Up to 100	Up to 100	Up to 100

EVALUATION OF ORAL SUSPENSION
The prepared Domperidone oral suspension formulations were subjected to comprehensive evaluation studies to assess their physical stability, rheological behavior, uniformity, and drug release characteristics. These parameters are critical in determining the quality, performance, and patient acceptability of oral suspension dosage forms.

Sedimentation Volume
Sedimentation volume was determined to evaluate the physical stability of the suspension formulations and the degree of flocculation. Each suspension was shaken thoroughly to ensure uniform dispersion and immediately transferred into a 100 mL graduated cylinder. The cylinders were securely stoppered and stored undisturbed at room temperature. The volume of sediment formed was recorded at predetermined time intervals. Sedimentation volume (F) was calculated using the equation:

F = Vu / Vo

where *Vu* represents the ultimate volume of sediment and *Vo* represents the original volume of the suspension before settling. A higher sedimentation volume indicates better suspension stability and ease of redispersion.

Redispersibility
Redispersibility studies were carried out to assess the ease with which the sedimented particles could be uniformly re-dispersed upon agitation. Suspension bottles were held vertically and inverted through 180° repeatedly in a clockwise and anticlockwise direction. The number of inversion cycles required to completely redisperse the sediment without visible lumps was recorded. Fewer inversion cycles indicated good redispersibility and acceptable physical stability of the suspension.

Conductivity
Electrical conductivity of the oral suspension formulations was measured using a calibrated digital conductivity meter. This study was performed to evaluate the influence of electrolyte concentration on the stability and flocculation behavior of the suspensions. Conductivity measurements provided insight into the ionic environment of the formulation, which plays a significant role in particle interaction and zeta potential.

pH Measurement
The pH of each oral suspension formulation was measured using a digital pH meter previously calibrated with standard buffer solutions. The pH measurement was performed at room temperature to ensure compatibility with oral administration and to compare the formulation pH with that of marketed products. Maintaining an appropriate pH is essential for drug stability, palatability, and patient safety.

Particle Size Analysis

Particle size analysis was conducted to determine the average particle size and uniformity of drug dispersion within the suspension. A small quantity of the suspension was placed on a clean glass slide, diluted with distilled water, and covered with a coverslip. The samples were examined under a calibrated optical microscope at 100× magnification. The diameters of 100 randomly selected particles were measured, and the mean particle size was calculated. Uniform and smaller particle size contributes to improved stability, dissolution, and bioavailability.

In-vitro Dissolution Study

In-vitro dissolution studies were performed to evaluate the drug release profile from the oral suspension formulations. A diffusion cell assembly fitted with a nitrocellulose membrane was used. The donor compartment contained a measured volume of the suspension, while the receptor compartment was filled with 0.1 N HCl maintained at 37 ± 0.5 °C. The system was stirred at a constant speed using a magnetic stirrer. Samples were withdrawn at specified time intervals, and the drug content was analyzed using a UV-visible spectrophotometer. The cumulative percentage of drug released was calculated to assess dissolution behavior.

Viscosity Measurement

Viscosity of the oral suspension formulations was determined using a Brookfield CAP-2000 viscometer fitted with spindle S-61 at 100 rpm. Measurements were carried out at controlled temperature conditions. Viscosity evaluation was performed to understand the flow behavior of the suspensions, as it directly influences sedimentation rate, redispersibility, pourability, and patient acceptability. An increase in viscosity with higher polymer concentration was expected and evaluated.

Assay of Domperidone

The assay of Domperidone in the oral suspension formulations was performed to determine drug content uniformity. A measured volume of suspension was transferred to a volumetric flask and diluted with 0.1 N HCl. The solution was sonicated to ensure complete drug extraction and then filtered. Suitable dilutions were prepared, and absorbance was measured at 286 nm using a UV-visible spectrophotometer. The drug content was calculated using the previously established calibration curve, and results were expressed as a percentage of the labeled claim.

RESULTS AND DISCUSSSIONS:

Preformulation Study of Oral Suspension

Preformulation studies were carried out to evaluate the fundamental physicochemical properties of Domperidone required for the rational design of a stable and effective oral suspension. These studies provided critical information regarding the drug's identity, purity, solubility behavior, thermal characteristics, and compatibility, which collectively influence formulation selection and performance.

Organoleptic Properties

Organoleptic evaluation of Domperidone revealed that the drug appeared as a white, amorphous powder with no characteristic odor. The drug exhibited a distinctly bitter taste, which necessitates formulation approaches such as suspension dosage forms to improve palatability and patient compliance, particularly in pediatric and geriatric populations. These properties are consistent with the reported characteristics of Domperidone and confirm the suitability of the drug for further formulation development.

Melting Point Determination

The melting point of Domperidone was found to be in the range of 242–250 °C, which closely corresponds with reported literature values. This narrow melting range indicates the crystalline nature and purity of the drug substance. The high melting point also suggests good thermal stability, which is advantageous during formulation processing and storage.

Solubility Studies

Solubility analysis demonstrated that Domperidone is freely soluble in organic solvents such as ethanol and methanol, with solubility values of 99.9% and 99.7%, respectively. In contrast, the drug showed limited solubility in distilled water (76.4%) and very low solubility in ether (12.1%). The poor aqueous solubility justifies the selection of an oral suspension dosage form, as suspensions are particularly suitable for delivering poorly water-soluble drugs by enhancing dissolution through increased surface area.

Standard Calibration Curve of Domperidone

A UV spectrophotometric method for the quantitative estimation of Domperidone was developed using 0.1 N HCl as the dissolution medium. The maximum absorbance (λmax) was observed at 290 nm. The calibration curve showed a linear relationship between concentration and absorbance over the range of

2–10 µg/mL, confirming compliance with Beer–Lambert's law. This validated analytical method was subsequently used for drug content analysis, dissolution studies, and assay determination.

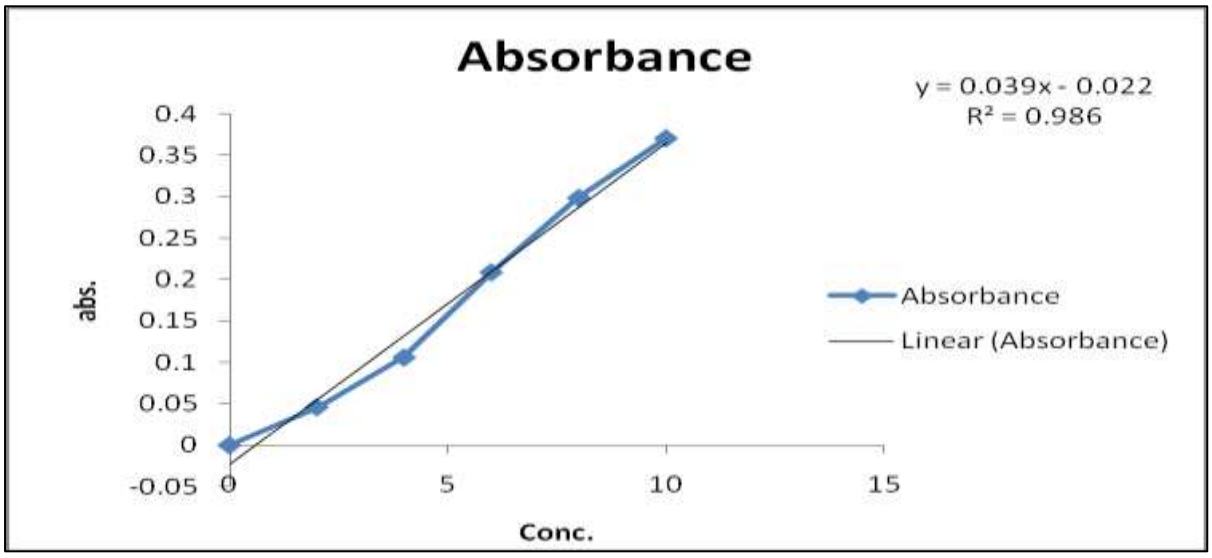

Figure 2: Standard calibration curve of Domperidone in 0.1N HCL

The linearity of the calibration curve confirms the suitability of the developed method for accurate quantitative estimation of Domperidone in oral suspension formulations.

Differential Scanning Calorimetry (DSC)

The DSC thermogram of Domperidone exhibited a sharp endothermic peak corresponding to its melting point, confirming the crystalline nature of the drug. The absence of additional peaks indicated the purity of the drug substance and the absence of polymorphic transitions or thermal degradation within the studied temperature range. These results support the stability of Domperidone under formulation and processing conditions.

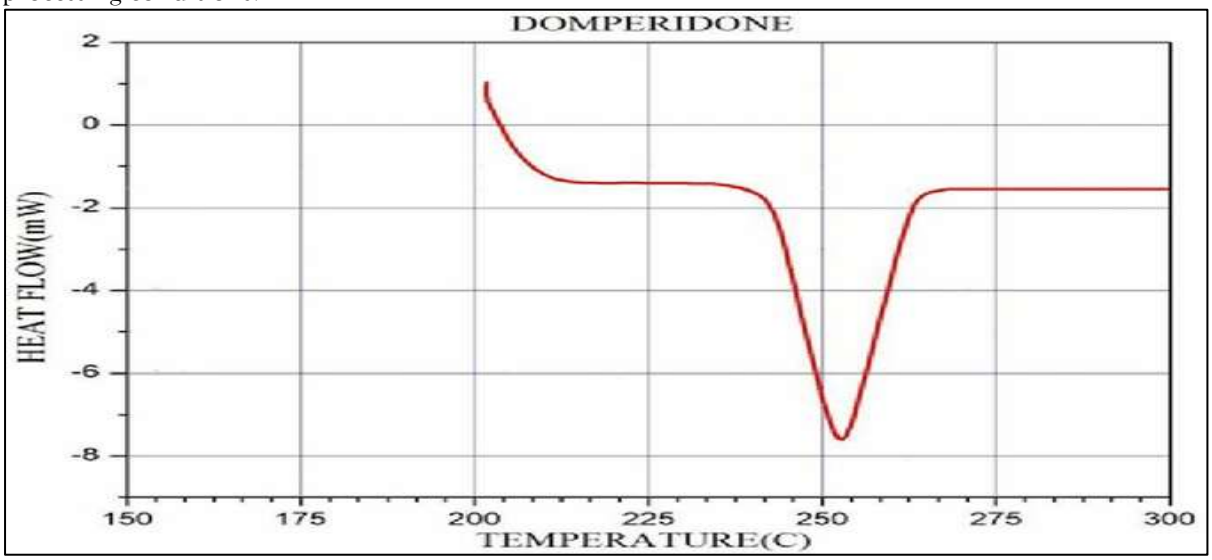

Figure 3: DSC thermogram of Domperidone

Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectroscopy was employed to identify the functional groups present in Domperidone and to confirm its chemical integrity. The characteristic absorption peaks observed corresponded to functional groups such as C–H stretching, O–H deformation, and C=N stretching. The presence of these peaks confirms the structural identity of Domperidone and indicates no chemical modification during sample preparation.

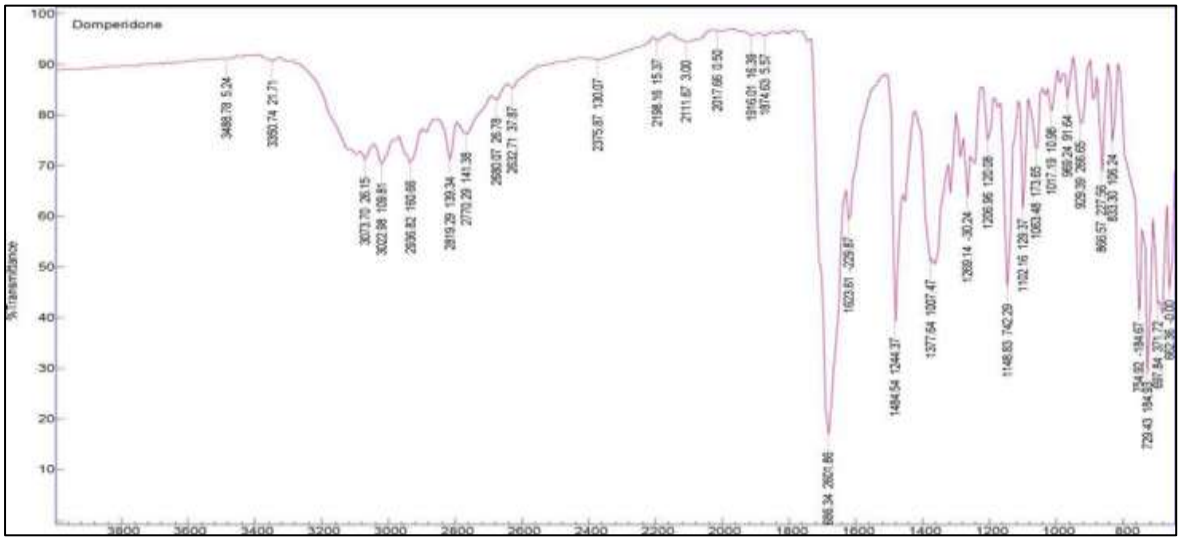

Figure 4: FTIR Spectra of pure Domperidone

The FTIR results confirm the chemical stability of Domperidone and validate its suitability for further formulation development.

The preformulation studies confirmed that Domperidone possesses suitable physicochemical properties for formulation as an oral suspension. The poor aqueous solubility, high melting point, and bitter taste justify the selection of a suspension dosage form with appropriate suspending agents to improve dissolution, stability, and patient acceptability. The analytical methods developed were found to be accurate and reliable, providing a strong foundation for subsequent formulation and evaluation studies.

Formulation Study of Oral Suspension

Preliminary formulation studies were conducted using different polymers to evaluate their suitability as suspending and flocculating agents in the development of an oral suspension. Placebo batches were prepared to study sedimentation behavior and redispersibility, which are critical parameters influencing physical stability, pourability, and dose uniformity. The effect of increasing polymer concentration on sedimentation volume and ease of redispersion was systematically investigated.

Preliminary Trials for Sodium Alginate (SF) Formulation Batches

Sedimentation Volume

The sedimentation volume of sodium alginate–based placebo formulations (SF1–SF5) was evaluated to assess the degree of flocculation and suspension stability. The sedimentation volume values ranged from 0.33 to 0.78. Lower polymer concentrations (SF1–SF4) resulted in compact and clumpy sediment formation, which adversely affected flowability and pourability. In contrast, formulation SF5 containing 1.0% sodium alginate exhibited the highest sedimentation volume, indicating the formation of a loosely packed sediment with improved stability and flow characteristics.

Table 8. Sedimentation volume of SF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd	Avg ± SD
1	SF1	0.329	0.347	0.327	0.334 ± 0.011
2	SF2	0.446	0.455	0.440	0.447 ± 0.007
3	SF3	0.567	0.571	0.574	0.570 ± 0.003
4	SF4	0.631	0.635	0.642	0.647 ± 0.005
5	SF5	0.781	0.778	0.772	0.777 ± 0.004

Redispersibility

Redispersibility studies demonstrated that formulations SF1–SF4 formed hard, clumpy masses that could not be readily redispersed. SF5 showed excellent redispersibility, requiring only 5–6 inversion cycles, indicating optimal flocculation and minimal sediment compaction.

Table 9. Redispersibility of SF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd
1	SF1	–	–	–

2	SF2	–	–	–
3	SF3	–	13	–
4	SF4	9	8	8
5	SF5	5	6	5

Preliminary Trials for Carbopol 934P (CF) Formulation Batches

Sedimentation Volume

Carbopol 934P–based formulations exhibited sedimentation volumes ranging from 0.33 to 0.70. Lower polymer concentrations produced compact sediments with poor flow. CF5 showed the highest sedimentation volume, reflecting improved suspension stability and reduced sediment compaction.

Table 10. Sedimentation volume of CF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd	Avg ± SD
1	CF1	0.327	0.332	0.325	0.328 ± 0.003
2	CF2	0.445	0.441	0.449	0.445 ± 0.004
3	CF3	0.531	0.540	0.537	0.536 ± 0.004
4	CF4	0.581	0.587	0.580	0.582 ± 0.003
5	CF5	0.698	0.694	0.701	0.697 ± 0.003

Redispersibility

CF1–CF4 exhibited poor redispersibility due to compact sediment formation. CF5 demonstrated acceptable redispersibility, requiring only 5–7 inversion cycles, indicating better floc structure and reduced particle aggregation.

Table 11. Redispersibility of CF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd
1	CF1	–	–	–
2	CF2	–	–	–
3	CF3	14	12	–
4	CF4	9	11	9
5	CF5	6	7	5

Preliminary Trials for Xanthan Gum (XF) Formulation Batches

Sedimentation Volume

Xanthan gum formulations showed sedimentation volumes between 0.27 and 0.52. XF5 demonstrated the highest sedimentation volume, suggesting improved flocculation and better physical stability compared to lower concentrations.

Table 12. Sedimentation volume of XF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd	Avg ± SD
1	XF1	0.278	0.275	0.275	0.276 ± 0.001
2	XF2	0.302	0.311	0.315	0.309 ± 0.006
3	XF3	0.384	0.385	0.389	0.386 ± 0.002
4	XF4	0.422	0.427	0.431	0.426 ± 0.004
5	XF5	0.515	0.521	0.519	0.518 ± 0.003

Redispersibility

XF5 required only 4–5 inversion cycles for complete redispersion, while other batches required significantly more cycles, confirming improved sediment structure at higher polymer concentration.

Table 13. Redispersibility of XF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd
1	XF1	–	–	–
2	XF2	–	10	–
3	XF3	10	8	8

4	XF4	7	8	7
5	XF5	5	4	4

Preliminary Trials for Methyl Cellulose (MF) Formulation Batches

Sedimentation Volume

Methyl cellulose formulations exhibited sedimentation volumes ranging from 0.22 to 0.54. MF5 showed the highest sedimentation volume, indicating improved dispersion stability.

Table 14. Sedimentation volume of MF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd	Avg ± SD
1	MF1	0.229	0.227	0.221	0.225 ± 0.004
2	MF2	0.271	0.280	0.275	0.275 ± 0.004
3	MF3	0.334	0.343	0.342	0.339 ± 0.004
4	MF4	0.443	0.447	0.446	0.445 ± 0.002
5	MF5	0.532	0.541	0.548	0.540 ± 0.008

Redispersibility

MF5 showed excellent redispersibility with only 3–4 inversion cycles, whereas lower concentrations exhibited delayed redispersion.

Table 15. Redispersibility of MF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd
1	MF1	11	–	–
2	MF2	11	7	8
3	MF3	6	6	4
4	MF4	4	4	4
5	MF5	3	4	3

Preliminary Trials for HPMC K4M (HF) Formulation Batches

Sedimentation Volume

HPMC K4M formulations demonstrated sedimentation volumes between 0.17 and 0.48. HF5 showed superior sedimentation characteristics, indicating optimal flocculation and minimal sediment compaction.

Table 16. Sedimentation volume of HF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd	Avg ± SD
1	HF1	0.171	0.183	0.179	0.177 ± 0.006
2	HF2	0.244	0.249	0.245	0.246 ± 0.002
3	HF3	0.334	0.340	0.341	0.338 ± 0.003
4	HF4	0.392	0.395	0.392	0.393 ± 0.001
5	HF5	0.478	0.477	0.472	0.475 ± 0.003

Redispersibility

HF5 showed excellent redispersibility requiring only 2–3 inversion cycles, indicating superior suspension performance compared to other polymer systems.

Table 17. Redispersibility of HF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd
1	HF1	–	–	9
2	HF2	–	7	8
3	HF3	5	6	5
4	HF4	5	3	4
5	HF5	2	3	2

Among all polymers evaluated, HPMC K4M (HF5) and methyl cellulose (MF5) demonstrated superior

sedimentation volume, minimal sediment compaction, and excellent redispersibility. These formulations were therefore considered most suitable for further development of Domperidone oral suspension.

Preliminary Trials for Gum Acacia (AF) Formulation Batches of Oral Suspension

Sedimentation Volume

The sedimentation behavior of gum acacia–based placebo formulations (AF1–AF5) was evaluated to assess their suitability as suspending agents. The sedimentation volume values were found to be very low, ranging from 0.056 to 0.298, indicating poor suspension stability. All formulations produced dense, clumpy sediments that adhered to the container walls and exhibited poor pourability. Even at the highest polymer concentration (AF5), the sediment formed was compact and non-flowable, suggesting inadequate flocculation behavior of gum acacia in the tested concentration range.

Table 18. Sedimentation volume of AF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd	Avg ± SD
1	AF1	0.053	0.059	0.056	0.056 ± 0.003
2	AF2	0.124	0.125	0.123	0.124 ± 0.001
3	AF3	0.179	0.186	0.184	0.183 ± 0.003
4	AF4	0.249	0.244	0.248	0.247 ± 0.002
5	AF5	0.297	0.304	0.295	0.298 ± 0.004

Redispersibility

Redispersibility studies revealed that all AF formulations showed poor redispersion characteristics. Most batches failed to redisperse even after vigorous manual shaking. AF4 and AF5 required a high number of inversion cycles (up to 14), indicating strong inter-particle attraction and formation of hard sediment cakes. These findings suggest that gum acacia is unsuitable as a primary suspending agent for the formulation of stable oral suspensions under the studied conditions.

Table 19. Redispersibility of AF placebo formulations

Sr. No.	Formulation	1st	2nd	3rd
1	AF1	–	–	–
2	AF2	–	–	–
3	AF3	–	–	–
4	AF4	–	–	14
5	AF5	–	13	12

Evaluation Study of Drug-Loaded Oral Suspension (FF Formulations)

Sedimentation Volume

The sedimentation volume of the final drug-loaded oral suspension formulations (FF1–FF5) was evaluated over a period of one week. A gradual decrease in sedimentation volume was observed with increasing storage time, indicating progressive settling of suspended particles. However, all formulations exhibited acceptable sedimentation volumes, confirming controlled flocculation behavior.

Among the formulations, FF1 and FF2 showed higher sedimentation volumes throughout the study, whereas FF4 and FF5 demonstrated slightly lower but stable sedimentation volumes. The decrease in sedimentation volume over time suggested formation of uniform, easily redispersible sediments without hard caking.

Table 20. Sedimentation volume of different FF formulations

Formulation	2 days Avg ± SD	4 days Avg ± SD	6 days Avg ± SD	1 week Avg ± SD
FF1	0.941 ± 0.0011	0.902 ± 0.0016	0.815 ± 0.0011	0.807 ± 0.0024
FF2	0.933 ± 0.0015	0.917 ± 0.0015	0.835 ± 0.0017	0.800 ± 0.0016
FF3	0.773 ± 0.0027	0.743 ± 0.0027	0.685 ± 0.0016	0.669 ± 0.0014
FF4	0.736 ± 0.0014	0.705 ± 0.0011	0.671 ± 0.0017	0.635 ± 0.0015
FF5	0.725 ± 0.0029	0.697 ± 0.0015	0.647 ± 0.0015	0.625 ± 0.0014

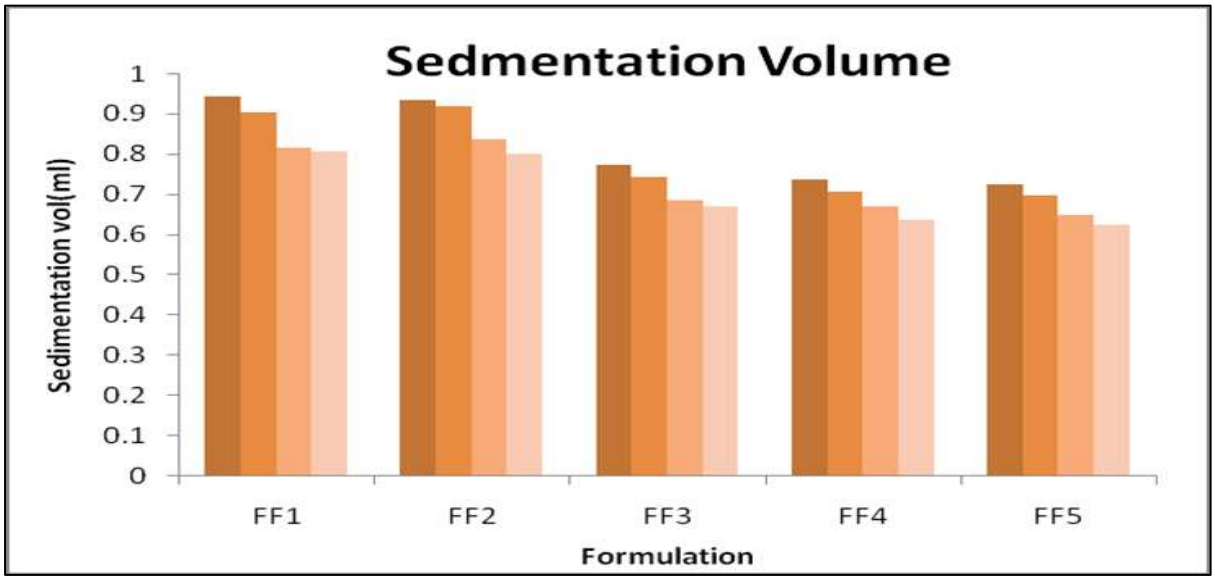

Figure 5: Effect of sedimentation volume of Oral suspensions.

Redispersibility

All FF formulations showed good redispersibility upon mild shaking. The number of inversion cycles required for complete redispersion ranged between 3 and 7 cycles. FF4 and FF5 exhibited the fastest redispersion due to the lower adhesive and cohesive nature of methyl cellulose and HPMC K4M, respectively. This property enhances patient convenience and ensures dose uniformity.

Table 21. Redispersibility of FF formulations

Sr. No.	Formulation	1st	2nd	3rd	4th	Avg ± SD
1	FF1	6	6	5	6	5.75 ± 0.50
2	FF2	6	6	5	5	5.50 ± 0.58
3	FF3	5	4	5	4	4.50 ± 0.58
4	FF4	4	4	3	3	3.50 ± 0.58
5	FF5	3	3	2	3	2.75 ± 0.50

Conductivity

Conductivity measurements showed a gradual increase over storage time for all formulations, indicating controlled electrolyte-mediated flocculation. FF5 exhibited the highest conductivity values, which may be attributed to enhanced ionic mobility in the system. The observed increase in conductivity correlated well with improved sedimentation behavior and suspension stability.

Table 22. Conductivity of FF formulations

Formulation	2 days (Ω)	4 days (Ω)	6 days (Ω)	1 week (Ω)
FF1	6.61 ± 0.031	7.02 ± 0.035	7.86 ± 0.016	8.23 ± 0.329
FF2	8.92 ± 0.267	9.86 ± 0.156	10.09 ± 0.041	11.95 ± 0.119
FF3	8.59 ± 0.180	9.42 ± 0.264	10.52 ± 0.250	10.57 ± 0.092
FF4	9.35 ± 0.240	9.64 ± 0.167	11.77 ± 0.143	11.85 ± 0.176
FF5	10.87 ± 0.042	11.89 ± 0.418	12.80 ± 0.319	12.85 ± 0.047

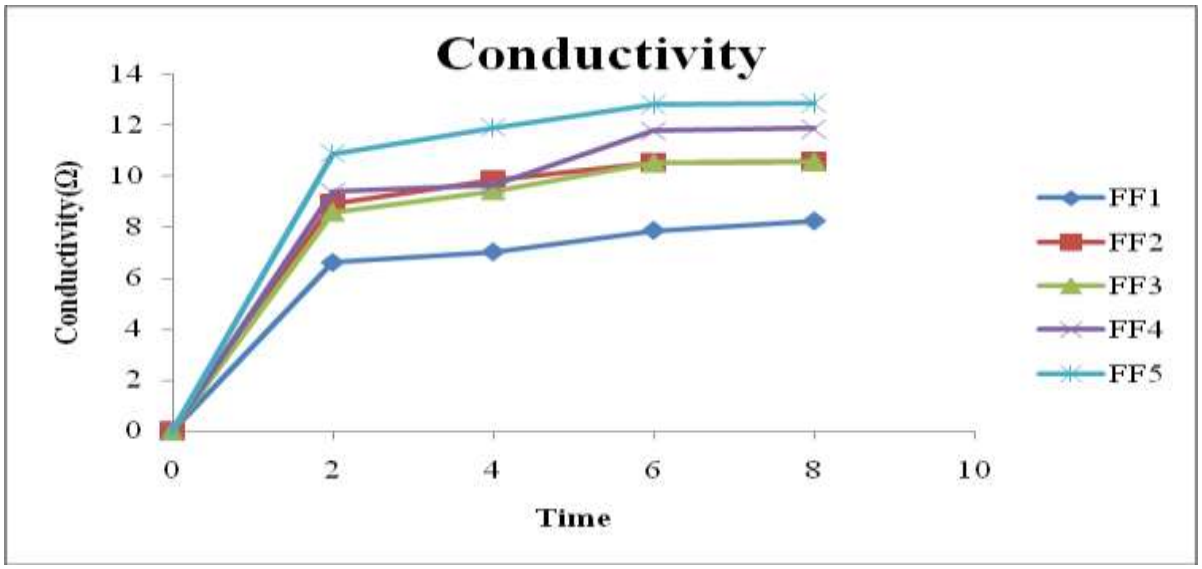

Figure 6: Effect of Conductivity on Oral suspension.

pH Study

The pH of all formulations remained within the acceptable oral range (4–7). A slight decrease in pH was observed over time, but no significant variation was noted, indicating chemical stability of the drug and excipients during storage.

Table 23. pH study of FF formulations

Formulation	2 days	4 days	6 days	1 week
FF1	6.25 ± 0.024	6.25 ± 0.034	6.10 ± 0.036	6.03 ± 0.039
FF2	6.37 ± 0.049	6.29 ± 0.017	6.21 ± 0.039	6.20 ± 0.070
FF3	6.41 ± 0.051	6.39 ± 0.034	6.37 ± 0.028	6.25 ± 0.049
FF4	6.45 ± 0.034	6.42 ± 0.028	6.23 ± 0.017	6.11 ± 0.025
FF5	7.12 ± 0.016	7.08 ± 0.041	6.89 ± 0.022	6.85 ± 0.031

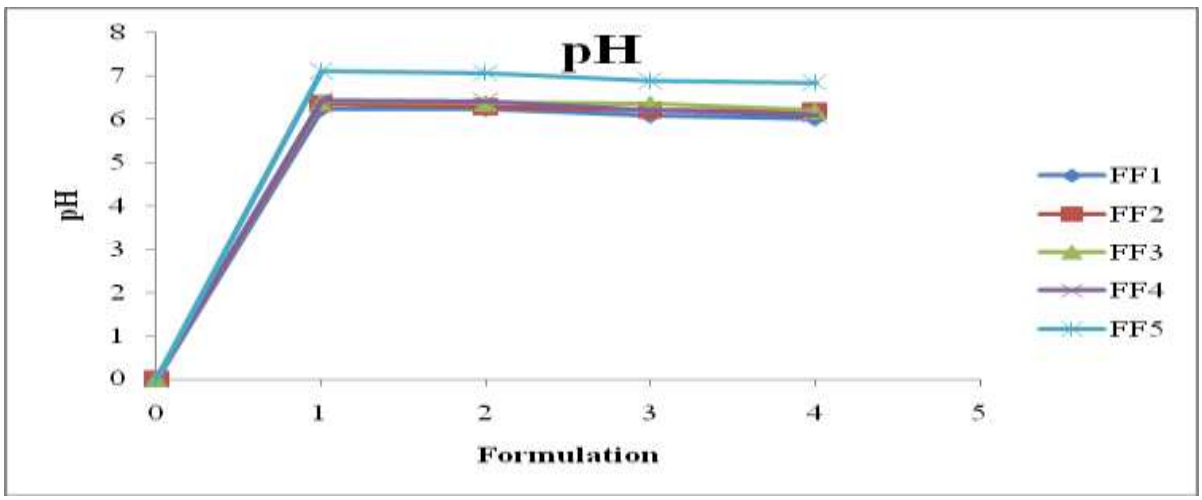

Figure 7: Effect of pH of Oral suspension.

Particle Size Measurement

Particle size analysis revealed that FF1 and FF2 had comparatively smaller particle sizes, which contributed to enhanced dissolution rates. Larger particle sizes observed in FF4 and FF5 resulted in relatively slower but controlled drug release.

Table 24. Particle size of FF formulations

Formulation	Particle Size (µm)
FF1	40.43

FF2	37.15
FF3	41.97
FF4	43.83
FF5	45.34

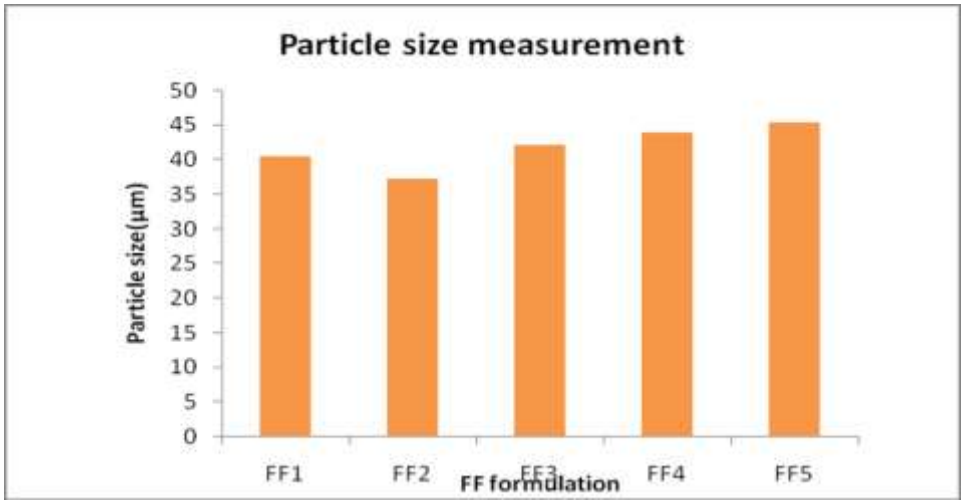

Figure 8: Effect of Particle Size Measurement of Oral suspension.

***In-vitro* Dissolution Study**

All formulations exhibited satisfactory drug release profiles. FF1 and FF2 showed comparatively slower release due to polymer agglomeration. FF3, FF4, and FF5 exhibited enhanced and rapid drug release, with FF5 showing the highest cumulative release (134.54%).

Table 25. In-vitro dissolution of FF formulations

Sr. No.	Time (Min)	FF1 Cum.% drug Release (%)±SD	FF2 Cum.% drug Release (%)±SD	FF3 Cum.% drug Release (%)±SD	FF4 Cum.% drug Release (%)±SD	FF5 Cum.% drug Release (%)±SD
1	5	6.14±0.031	5.72±0.041	8.16±0.024	14.56±0.051	12.50±0.024
2	10	12.91±0.025	12.28±0.037	18.16±0.029	30.56±0.018	26.18±0.021
3	15	20.68±0.048	20.06±0.026	31.04±0.031	47.4±0.041	43.14±0.034
4	20	30.28±0.019	31.12±0.042	47.04±0.041	65.2±0.045	61.38±0.019
5	30	41.08±0.031	44.04±0.031	65.44±0.026	85.0±0.046	82.66±0.054
6	45	57.24±0.035	62.28±0.046	87.12±0.049	106.2±0.054	107.06±0.051
7	60	78.76±0.024	82.98±0.032	113.52±0.019	129.2±0.035	134.54±0.037

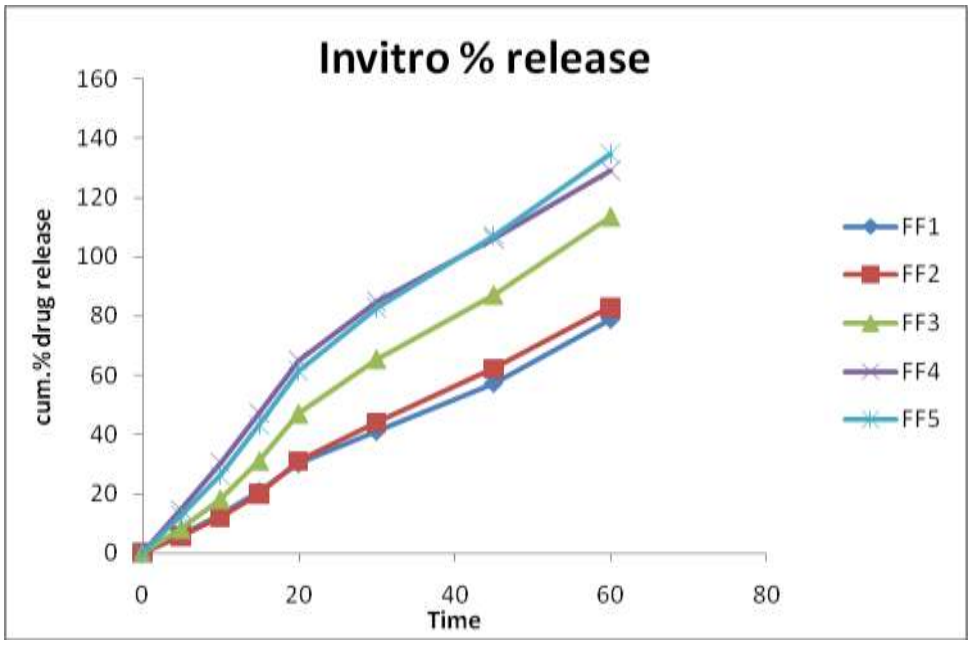

Figure 9: Effect of *in-vitro* dissolution study of oral suspension

Viscosity

Viscosity measurements indicated pseudo plastic flow behavior. FF1 and FF2 showed higher viscosity, whereas FF4 and FF5 exhibited lower viscosity, improving pourability and patient compliance.

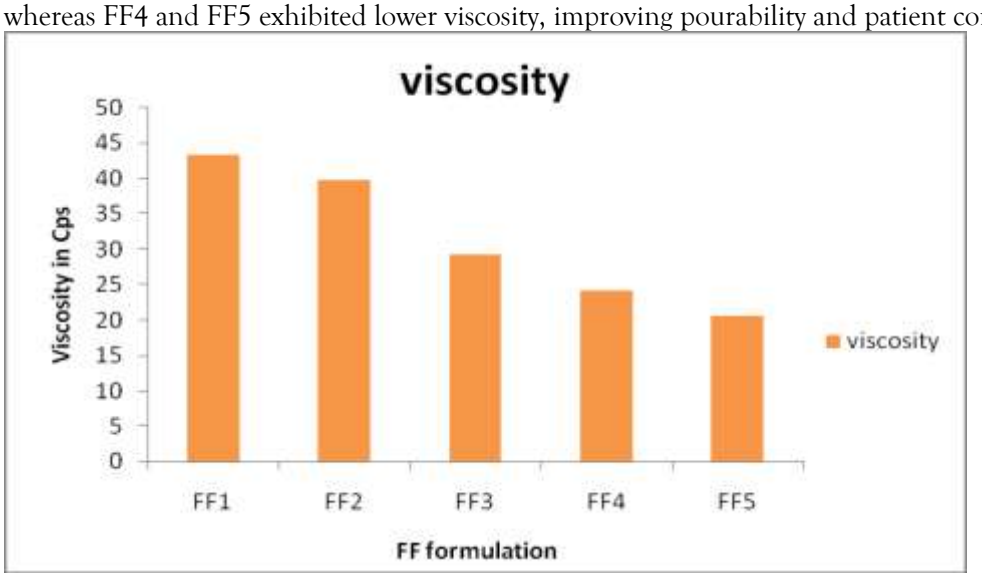

Figure 10: Effect of Viscosity of Oral suspension.

Assay of Oral Suspension

Drug content of all formulations ranged between 95–101%, confirming uniform drug distribution and compliance with pharmacopeial limits. Among all formulations, FF5 (HPMC K4M-based suspension) demonstrated optimal sedimentation behavior, excellent redispersibility, acceptable viscosity, stable pH, and superior drug release, making it the optimized oral suspension formulation**.**

ACKNOWLEDGEMENT

The authors are grateful to Kasturi Shikshan Sanstha, College of Pharmacy, Shikrapur, Tal. Shirur, Dist. Pune – 412208, Maharashtra, India, for providing the necessary facilities, infrastructure, and continuous support to carry out this research work successfully. The authors also extend their sincere thanks to the faculty and technical staff of the institution for their guidance and assistance during the study.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest associated with this study.

CONCLUSION

The present investigation successfully demonstrated the formulation and evaluation of a stable oral suspension of Domperidone using different polymeric suspending agents. Preformulation studies confirmed the suitability of the drug for suspension formulation, particularly due to its poor aqueous solubility and bitter taste. Preliminary placebo studies identified HPMC K4M and methyl cellulose as superior suspending agents based on sedimentation volume and redispersibility. The optimized drug-loaded formulation exhibited acceptable physicochemical properties, including good redispersion, controlled viscosity, stable pH, uniform drug content, and enhanced in-vitro dissolution. Overall, the developed oral suspension offers a promising alternative dosage form for Domperidone with improved stability and patient compliance, especially for pediatric and geriatric use.

REFERENCES

1. Jain DK, Baviskar D. Novel drug delivery systems. 2nd ed. Pune: Nirali Prakashan; 2010. p. 127–155.
2. Kewal K. Drug delivery systems. 2nd ed. Pune: Sumeru Publications; 2008.
3. Subramanyam CVS. Textbook of physical pharmaceutics. 2nd ed. New Delhi: Vallabh Prakashan; 2004. p. 374–387.
4. Chukka S, Puligilla S, Yamsani MR. New formulation and evaluation of domperidone oral suspension. World J Pharm Pharm Sci. 2013;2(4):2278–4357.
5. Aulton ME. Pharmaceutics: The science of dosage form design. 2nd ed. Edinburgh: Churchill Livingstone; 2002. p. 84–86, 273.
6. Martin A. Physical pharmacy. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2001. p. 479–481.
7. Gennero RG, editor. Remington: The science and practice of pharmacy. 20th ed. Philadelphia: Lippincott Williams & Wilkins; 2000. p. 298–307.
8. Panda M, Patro G, Malpani A, Rao MEB. Formulation and evaluation of norfloxacin suspension with β-cyclodextrin complexation. Int J Pharm Sci Rev Res. 2011;9(2):0976–044X.
9. Bardeskar C, Geeverghese R. Reconstitutable oral suspension (dry syrup): an overview. World J Pharm Res. 2015;4(2):2277–7105.
10. Valizadeh H, Farajnia A, Zakeri-Milani P. Formulation of cefuroxime axetil oral suspension and investigation of its pharmaceutical properties. Adv Pharm Bull. 2011;1(2):93–96.
11. Suthar AM, Patel MM. Formulation and evaluation of taste-masked suspension of metronidazole. Int J Appl Pharm. 2010;2(3):0975–7058.
12. Kumar KS, Kiran AV, Somasekhar C. Physical stability of rofecoxib oral suspension. Int J Pharm Chem Sci. 2012;1(4):2277–5005.
13. Singh VK, Mishra VK, Maurya JK, Singh SK, Mishra A. Formulation and evaluation of cephalexin monohydrate reconstitutable oral suspension with piperine and antibacterial activity. World J Pharm Res. 2014;3(6):2277–7105.
14. Chen LW. Preparation and evaluation of taste-masked oral suspension of arbidol hydrochloride. Asian J Pharm Sci. 2015;10(4):029–2882.
15. Sompur CK, Doijod RC, Patil SM, Maske AP. An approach for development of oral sustained-release suspension. Int J Pharma Bio Sci. 2011;2(3):0975–6299.
16. Sharma SK, Chauhan M. Span-60 niosomal oral suspension of fluconazole. J Pharm Health Care Sci. 2009;1(2):142–156.
17. Aggarwal J, Singh G, Saini S. Oral suspension: a novel approach in oral drug delivery. Res J Pharm. 2016;2(12):69–74.
18. Brion F, Nunn AJ, Rieutord A. Extemporaneous preparation of oral medicines for children in European hospitals. Acta Paediatr. 2003;92:486–490.
19. Attwood D. Disperse systems. In: Aulton ME, editor. Aulton's pharmaceutics: The design and manufacture of medicines. 3rd ed. Hungary: Churchill Livingstone Elsevier; 2007. p. 70–98.
20. Ashford M. Bioavailability: physicochemical and dosage form factors. In: Aulton ME, editor. Aulton's pharmaceutics. 3rd ed. Hungary: Churchill Livingstone Elsevier; 2007. p. 286–303.
21. Rasve V, Chakraborty AK, Jain SK, Vengurlekar S. Study of phytochemical profiling and in vitro studies on antioxidant properties of ethanolic extract of *Clematis triloba*. Eur Chem Bull. 2022;11(12):2658–2677. doi:10.53555/ecb/2022.11.12.2162022.
22. Marriott C. Rheology. In: Aulton ME, editor. Aulton's pharmaceutics. 3rd ed. Hungary: Churchill Livingstone Elsevier; 2007. p. 42–58.
23. Marriott JL, Nation RL. Splitting tablets. Aust Prescr. 2002;25:133–135.
24. Twitchell AM. Mixing. In: Aulton ME, editor. Aulton's pharmaceutics. 3rd ed. Hungary: Churchill Livingstone Elsevier; 2007. p. 152–167.
25. Florence AT, Attwood D. Physicochemical principles of pharmacy. 4th ed. London: Pharmaceutical Press; 2006. p. 93–138.
26. Costello I, Long PF, Wong ICK, Tuleu C, Yeung V. Paediatric drug handling. Cornwall: Pharmaceutical Press; 2007.
27. Allen LV. Extemporaneous prescription compounding. In: Troy DB, editor. Remington: The science and practice of pharmacy. 21st ed. Baltimore: Lippincott Williams & Wilkins; 2006. p. 1903–1912.
28. Barnes AR. Product stability and stability testing. In: Aulton ME, editor. Aulton's pharmaceutics. 3rd ed. Hungary: Churchill Livingstone Elsevier; 2007. p. 650–665.
29. Gohel M, Rajesh P, Amirali P, Ashutosh M, Bhavesh B, Chetan P, et al. Development of pharmaceutical suspensions. Indian J Pharm Sci. 2007;69(3):412–418.
30. Carter SJ. Tutorial pharmacy. 6th ed. New Delhi: CBS Publishers & Distributors; 2005.
31. Prapaporn B, Narubodee P, Suthimaln I. Formulation development and stability study of norfloxacin suspension. Thammasat Int J Sci Technol. 2004;7:1–4.
32. Murakawa GJ, Sable D. Quinolones in dermatology. Clin Dermatol. 2003;21(1):56–63.
33. Nangia A, Lam F, Hung CT. Stability study of aqueous solution of norfloxacin. Drug Dev Ind Pharm. 1991;17(5):681–694.

34. Sutar B, Bukovec N, Bukovec P. Polymorphism and stability of norfloxacin. J Therm Anal. 1993;42:475–481.
35. Rasve VR, Chakraborty AK, Jain SK, Vengurlekar S., Comparative evaluation of antidiabetic activity of ethanolic leaves extract of *Clematis triloba* and their SMEDDS formulation in streptozotocin-induced diabetic rats. *J Popul Ther Clin Pharmacol.* 2022; 29(4):959-71. doi:10.53555/jptcp.v29i04.2360.
36. Rathore YKS, Chatterjee PK, Mathur S, Sunderlal C, Sethi PD. Stability studies of pharmaceutical suspensions. Indian Drugs. 1990;27:215–217.
37. Florey K. Analytical profiles of drug substances. Vol. 20. New York: Academic Press; 1991. p. 557–600.
38. Kuchekar BS, Pattan SR, Godge RK. Formulation and evaluation of norfloxacin dispersible tablets using natural disintegrants. J Chem Pharm Res. 2009;1(1):336–341.