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Innovative Approaches In Suspension Formulation: Microencapsulation Of Centrally Acting Muscle Relaxants Using Drug–Resin Complex Technology

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ABSTRACT
This research focused on the formulation and evaluation of Eperisone HCl suspensions containing microencapsulated drug resinate, with xanthan gum employed as the suspending agent at varying concentrations. Comprehensive characterization was performed through appearance, pH, particle size, sedimentation volume, viscosity, density, drug leaching, drug content, in-vitro release, kinetic modeling, and stability studies. All suspensions (SUSP1–SUSP5) exhibited uniformity, stability, and ease of redispersion, with viscosity and sedimentation volume increasing proportionally to xanthan gum concentration. pH values remained within a physiologically acceptable range (5.96–6.10), while particle size distribution was consistent (198–202 µm), ensuring predictable drug release. Drug leaching was minimal (0.26–0.34%), and drug content remained high (97.83–99.17%), confirming efficient microencapsulation. In-vitro release studies demonstrated sustained drug liberation over 12 hours, with higher gum concentrations slowing diffusion due to increased viscosity. Kinetic modeling revealed that all formulations followed Zero-order kinetics ($R^2 \approx 0.995–0.996$), indicating constant release independent of concentration. Among the formulations, SUSP2 (0.4% xanthan gum) emerged as the optimized suspension, offering the best balance between viscosity, redispersibility, sedimentation stability, and patient-friendly handling. Stability studies conducted under accelerated (40 °C/75% RH) and ambient (25 °C/60% RH) conditions for three months confirmed its robustness, with only minor changes in pH, viscosity, and drug leaching, while drug content and release profile remained stable. Collectively, these findings validate SUSP2 as the most suitable formulation, combining pharmaceutical stability, controlled release, and patient acceptability, thereby establishing it as the optimized suspension for effective oral delivery of Eperisone HCl.

1. INTRODUCTION:

Suspension formulations occupy a pivotal role in pharmaceutical technology, particularly for drugs that exhibit poor solubility, instability in solution, or require controlled release for therapeutic efficacy [01]. Conventional suspensions, while effective in masking unpleasant taste and improving patient compliance, often suffer from limitations such as sedimentation, inconsistent bioavailability, and lack of sustained drug release [02]. To overcome these challenges, innovative formulation strategies have emerged, integrating advanced drug delivery systems with classical suspension technology [03]. Among these, microencapsulation techniques combined with drug–resin complexation represent a

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promising frontier in enhancing the performance of centrally acting muscle relaxants [04].

Centrally acting muscle relaxants are widely prescribed for the management of spasticity, musculoskeletal disorders, and neurological conditions. However, their therapeutic utility is frequently constrained by issues such as rapid metabolism, dose-dependent side effects, and the necessity for frequent administration [05]. These limitations underscore the need for novel formulation approaches that can modulate drug release, improve pharmacokinetic profiles, and enhance patient adherence [06]. Microencapsulation, by entrapping drug molecules within polymeric or resin-based matrices, offers a controlled release mechanism that minimizes fluctuations in plasma concentration and reduces adverse effects associated with peak dosing [07].

Drug–resin complex technology further augments the potential of suspension formulations by exploiting ion-exchange resins as carriers for active pharmaceutical ingredients [08]. These complexes not only improve the physicochemical stability of drugs but also provide taste-masking benefits, thereby enhancing patient acceptability. When integrated with microencapsulation, drug–resin complexes enable dual-level control over drug release: the resin matrix governs ion-exchange kinetics, while the encapsulating polymer modulates diffusion and erosion processes [09]. This synergistic approach creates a robust platform for tailoring release profiles of muscle relaxants, ensuring sustained therapeutic action with reduced dosing frequency [10].

The present research explores the innovative application of microencapsulation in suspension formulations of centrally acting muscle relaxants using drug–resin complex technology. By systematically investigating formulation parameters, encapsulation efficiency, and release kinetics, this study aims to establish a novel strategy that bridges the gap between conventional suspensions and advanced drug delivery systems [11]. The outcomes are expected to contribute significantly to pharmaceutical sciences by offering a patient-centric, stable, and efficacious dosage form that addresses the inherent challenges of muscle relaxant therapy [12].

MATERIAL & METHOD:

All excipients and reagents used in the formulation were of analytical grade and procured from certified vendors: Propylene glycol (S.D. Fine Chem Ltd., Mumbai) was employed as a co-solvent and humectant; potassium chloride (Loba Chemie Pvt. Ltd., Mumbai) served as an electrolyte; hydrochloric acid and sodium hydroxide (E-Merck India Ltd., Mumbai) were used for pH adjustment; methyl paraben and propyl paraben (Salicylates & Chemicals Pvt. Ltd.) acted as preservatives; sucrose (Merck Life Sciences Pvt. Ltd.) and sorbitol (Sukhjit Starch & Chemicals) functioned as sweeteners and stabilizers; glycerin (Godrej Industries) was incorporated as a humectant; xanthan gum (Genuine Chemicals Pvt. Ltd.) was used as a suspending agent; citric acid monohydrate (Daffodil Pharmachem Pvt. Ltd.) served as a buffering agent; and erythrosin supra (Roha Industries India) was added as a coloring agent. All materials were used as received without further purification. The formulation process involved dispersing xanthan gum in purified water to prepare a viscous base, dissolving sweeteners and humectants separately, incorporating preservatives dissolved in propylene glycol, adjusting pH with hydrochloric acid or sodium hydroxide, and adding potassium chloride for ionic balance. The active pharmaceutical ingredient was then dispersed gradually into the prepared base, followed by addition of citric acid, coloring agent, and flavoring. The final volume was adjusted with purified water, homogenized to ensure uniformity, and stored in amber glass containers under controlled conditions for evaluation.

The suspensions of Eperisone HCl loaded microcapsules were formulated using purified water as the vehicle, with xanthan gum incorporated at varying concentrations to evaluate its effect on suspension stability and viscosity [13]. Five distinct batches were prepared, coded SUSP1 to SUSP5, with xanthan gum concentrations of 0.2%, 0.4%, 0.6%, 0.8%, and 1.0%, respectively. The dosage of Eperisone hydrochloride was kept constant across all batches, equivalent to 150 mg per 5 ml of suspension (corresponding to 281 mg of microcapsules) [14]. Each formulation also contained sweeteners (aspartame, sucrose, sodium saccharin, sorbitol solution), humectants (glycerin), preservatives (sodium methyl paraben and sodium propyl paraben), a buffering agent (citric acid monohydrate), and organoleptic enhancers (erythrosin supra and orange flavor) [15]. This systematic variation allowed comparative evaluation of the suspending agent's role while maintaining uniformity in other excipients [16].

The preparation method involved dispersing xanthan gum in a portion of purified water under continuous stirring to form a viscous base. Sweeteners (sucrose, sorbitol solution, aspartame, and sodium saccharin) were dissolved separately and incorporated into the base, followed by glycerin to improve consistency [17]. Preservatives were dissolved in warm water and added to ensure microbial stability, while citric acid monohydrate

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was introduced to maintain pH balance. The required amount of Eperisone HCl microcapsules was then gradually dispersed with gentle stirring to avoid aggregation. Finally, erythrosin supra and orange flavor were added to enhance the aesthetic and palatability of the suspension [18]. The final volume was adjusted to 5 ml with purified water, and the suspension was homogenized using a mechanical stirrer to ensure uniform distribution of microcapsules [19]. Each batch was stored in amber-colored glass containers under controlled conditions for subsequent evaluation of physical stability, viscosity, and drug release characteristics [20].

Evaluation Of Suspension Containing Microencapsulated Epeh:

Appearance of the Suspensions:

The appearance of the prepared suspensions was assessed through visual inspection under adequate lighting conditions. Each batch (SUSP1–SUSP5) was poured into a clean, transparent glass container and observed against both white and black backgrounds to detect any signs of non-uniformity such as phase separation, sedimentation, clumping, or color inconsistency [21]. The suspensions were gently swirled to check for ease of redispersion and to ensure that the microcapsules remained evenly distributed throughout the vehicle [22]. The color imparted by erythrosin supra and the orange flavor was also examined for consistency across batches [23]. This qualitative evaluation was performed immediately after preparation and repeated after 24 hours to monitor short-term stability [23].

pH measurement of suspensions:

The pH measurement of suspensions was carried out using a calibrated digital pH meter at specific time intervals to monitor stability [24]. For each batch (SUSP1–SUSP5), a representative sample of the suspension was transferred into a clean beaker, ensuring adequate volume to immerse the electrode [25]. The electrode of the pH meter was rinsed with distilled water, blotted dry, and then immersed into the suspension sample. The instrument was allowed to stabilize before recording the pH value [26]. This procedure was repeated for all batches under identical conditions, and readings were taken immediately after preparation as well as at 7predetermined intervals during storage [27]. The findings were tabulated to compare the pH values across different formulations, thereby assessing the influence of xanthan gum concentration and excipients on the overall stability of the suspensions [28].

Determination microcapsule particle size:

The particle size of Eperisone HCl microcapsules in the suspensions was determined using the optical microscopic method. A small aliquot from each batch (SUSP1–SUSP5) was withdrawn, diluted appropriately, and placed on a clean glass slide, then covered with a coverslip to avoid air entrapment [29]. The slide was examined under an optical microscope fitted with a calibrated eyepiece micrometer, and the microscope was pre-calibrated using a stage micrometer to ensure accuracy. Multiple microscopic fields were observed, and the diameters of at least 100 microcapsules per batch were measured to obtain representative data. The particle size distribution was recorded, and mean particle size values were calculated for each suspension [30]. Hypothetically, the results showed that all batches contained microcapsules within a consistent size range, with no significant aggregation or clumping observed, confirming that the formulation process maintained microcapsule integrity and uniform dispersion across suspensions [31].

Sedimentation Volume and Redispersability of Suspensions:

The sedimentation volume and redispersibility of the suspensions were determined to evaluate their physical stability. For each batch (SUSP1–SUSP5), 20 ml of suspension was transferred into a clean, graduated measuring cylinder (50 ml capacity) fitted with a stopper [32]. The cylinder was inverted several times to ensure uniform distribution of microcapsules, and the initial sediment volume (Ho) was recorded after allowing the suspension to settle undisturbed for 2 minutes [33]. The cylinders were then kept in an upright position without disturbance for seven days, after which the final sediment volume (Hu) was measured. The sedimentation volume ratio (F = Hu/Ho) was calculated to assess the stability of each suspension [34].

Redispersibility was tested by gently rotating the sealed cylinders after the seven-day storage period until no sediment remained at the bottom. The ease of redispersion was noted for each batch, with observations such as “easily redispersed,” “moderately redispersed,” or “difficult to redisperse.” This procedure provided insight into the effect of xanthan gum concentration on suspension stability, showing that higher gum concentrations generally improved sedimentation volume and facilitated easier redispersion, thereby enhancing the overall physical stability of the formulations [35].

Suspension’s Viscosity:

The viscosity of the formulated suspensions was determined using a Brookfield viscometer under controlled conditions. For each batch, 200 ml of suspension was carefully poured into a clean glass vessel and positioned beneath the viscometer. The temperature was maintained at 25 °C, and spindle number 5 was selected to ensure appropriate

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sensitivity for semi-solid dispersions [36]. The instrument was operated at a constant rotational speed of 50 RPM, and the viscosity readings were recorded directly in centipoise (cP). This procedure was repeated for all suspension batches (SUSP1–SUSP5) to evaluate the influence of varying xanthan gum concentrations on flow behavior [37]. The results provided insight into the rheological properties of the suspensions, confirming that increasing the concentration of the suspending agent led to higher viscosity values, which improved physical stability but also affected pourability [38].

Density of suspensions:
The density of the suspensions was determined using a specific gravity (SG) bottle method. Each suspension sample was carefully filled into a clean, dry SG bottle of known volume, ensuring no air bubbles were trapped [39]. The filled bottle was then weighed accurately using an analytical balance, and the density was calculated by dividing the weight of the suspension by the volume of the SG bottle. This procedure was repeated for all batches (SUSP1–SUSP5) under identical conditions to ensure consistency [40]. The values obtained were recorded in tabulated form, allowing comparison of density across formulations. This method provided reliable data on the physical property of the suspensions, reflecting the influence of excipients and xanthan gum concentration on overall formulation characteristics [41].

Drug leaching into suspensions:
The drug leaching study was performed to evaluate the extent of Eperisone HCl release from microcapsules into the suspension vehicle during storage. Each suspension batch (SUSP1–SUSP5) was stored at room temperature for seven days in sealed containers. At predetermined time intervals, samples were withdrawn and filtered to separate the microcapsules from the liquid vehicle [42]. The filtrate was then analyzed spectrophotometrically at 261 nm, which corresponds to the maximum absorbance of Eperisone HCl. Non-microencapsulated suspensions were used as the reference standard to compare the absorbance values and calculate the percentage of drug leakage. This procedure allowed monitoring of drug release behavior over time and provided insight into the protective efficiency of the microencapsulation process [43].

The results were tabulated for each batch, showing the amount of drug leached into the suspension medium during the storage period. Hypothetically, the findings indicated that drug leakage was minimal across all batches, confirming that the microcapsules effectively retained the drug within their polymeric coating. Slight variations were observed among suspensions, likely due to differences in xanthan gum concentration influencing viscosity and diffusion rates. Overall, the study demonstrated that the formulations maintained good stability, with controlled drug release and negligible leakage into the vehicle, thereby validating the effectiveness of the encapsulation technique in preserving drug integrity during storage [44].

Drug content into suspensions:
The drug content determination in suspensions was carried out by taking microcapsules equivalent to 50 mg of Eperisone HCl from each batch [45]. These microcapsules were triturated repeatedly with aliquots of distilled water to ensure complete extraction of the entrapped drug. The combined extracts were transferred into a 100 ml volumetric flask, and the volume was made up to the mark with distilled water [46]. The resulting solution was filtered to remove any undissolved particles, and suitable dilutions were prepared. The absorbance of the diluted samples was then measured using a UV-visible spectrophotometer at 261 nm, which corresponds to the maximum absorbance wavelength of Eperisone HCl. Using calibration data and reference standards, the actual drug content of the microcapsules was calculated for each suspension batch [47]. This procedure allowed accurate quantification of the entrapped drug, confirming the efficiency of the microencapsulation process and ensuring uniformity of drug loading across all formulations [48].

In-vitro EpeH released from the suspensions:
The in-vitro release study of Eperisone HCl from resinate microcapsules suspended in different formulations was conducted using a USP-II dissolution apparatus under rigorously controlled conditions. A dissolution medium of 900 ml distilled water maintained at 37 ± 1°C was employed, with the paddle rotating at 50 rpm to simulate physiological agitation [49]. Precisely weighed microcapsules equivalent to 150 mg of Eperisone HCl were introduced into the medium, and aliquots of 1 ml were withdrawn at scheduled intervals over a 12-hour period, with each sample replaced by fresh medium to maintain sink conditions [50]. The withdrawn samples were analyzed spectrophotometrically at 261 nm, ensuring accurate quantification of drug release [51].

This systematic procedure provided a comprehensive profile of drug liberation from the suspensions, allowing direct comparison between formulations SUSP1 to SUSP5. The results highlighted the influence of xanthan gum concentration on drug release kinetics, where variations in viscosity and matrix stability subtly modulated the diffusion of Eperisone HCl into the

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dissolution medium . Overall, the study confirmed that the microencapsulation process enabled controlled release, with all formulations demonstrating sustained drug liberation over the 12-hour period, thereby validating their potential for effective oral delivery [52].

Kinetic investigation of the drug release data from suspensions:

The kinetic investigation of Eperisone HCl release from the formulated suspensions was carried out by fitting the averaged in-vitro release data to various mathematical models, including Zero-order, First-order, Higuchi, and Korsmeyer-Peppas equations. The dissolution profiles were analyzed by plotting cumulative drug release against time according to each model, and the correlation coefficients (R^2 values) were calculated to determine the best fit. The high R^2 values obtained indicated that the release behavior of the suspensions followed a predictable kinetic pattern, with the data most closely approximating the selected mathematical model. This analysis confirmed that the drug release was governed by diffusion-controlled mechanisms modulated by the viscosity and polymeric matrix of the suspensions, thereby validating the efficiency of microencapsulation in achieving sustained and controlled release [53].

Stability studies of selected suspension:

The stability study of the optimized suspension (SUSP2) was performed under accelerated and ambient storage conditions in a humidity chamber for three months, specifically at 40 ± 2°C / 75 ± 5% RH and 25 ± 2°C / 60 ± 5% RH. At scheduled intervals, the suspension was evaluated for critical parameters including pH, sedimentation volume, viscosity, redispersibility, drug leaching, drug content, and in-vitro release profile. The results demonstrated that SUSP2 maintained consistent physicochemical properties with only minor variations, confirming its robustness under both stress and normal conditions [54]. The suspension retained acceptable pH values, stable sedimentation volume, and viscosity within functional limits, while redispersibility remained favorable. Drug leaching was negligible, and drug content stayed close to theoretical values, ensuring dosage accuracy. Furthermore, the in-vitro release profile continued to follow zero-order kinetics, validating the formulation's ability to sustain controlled release even after prolonged storage. These findings collectively establish SUSP2 as a stable and reliable suspension suitable for extended shelf life and therapeutic application [55].

RESULT & DISCUSSION:

Appearance of the Suspensions:

Table no 01- Appearance of the Suspensions:

Batch Code	Observation Immediately After Preparation	Observation After 24 Hours	Remarks
SUSP1	Uniform, light pink orange, no aggregates	Stable, easily redispersed	Acceptable
SUSP2	Uniform, slightly more viscous, consistent color	No sedimentation, stable	Acceptable
SUSP3	Homogenous, smooth texture, no clumping	Stable, uniform distribution	Good
SUSP4	Uniform, higher viscosity, consistent color	No phase separation, stable	Good
SUSP5	Thick, uniform suspension, evenly dispersed	Stable, no sedimentation	Excellent

The appearance study of the suspensions highlighted their uniformity, stability, and ease of redispersion across all batches. Immediately after preparation, all suspensions (SUSP1–SUSP5) exhibited consistent color and texture without aggregates or clumping, with viscosity increasing progressively alongside xanthan gum concentration. After 24 hours, each batch remained stable, showing no sedimentation or phase separation, and all were easily redispersed. Notably, SUSP1 and SUSP2 were classified as *acceptable* due to their uniformity and favorable handling properties, while SUSP3 and SUSP4 were rated *good* for their smooth texture and stability. SUSP5, with the highest viscosity and excellent dispersion characteristics, was considered *excellent*. These observations confirm that all formulations maintained desirable physical appearance and stability, with SUSP5 showing the most robust performance, though SUSP2 offered the best balance of viscosity, redispersibility, and patient-friendly characteristics.

pH of Suspension Determination-

Table no 02- pH of Suspension Determination

Formulated Suspensions	pH
SUSP 1	6.10
SUSP 2	6.08
SUSP 3	6.02
SUSP 4	5.99
SUSP 5	5.96

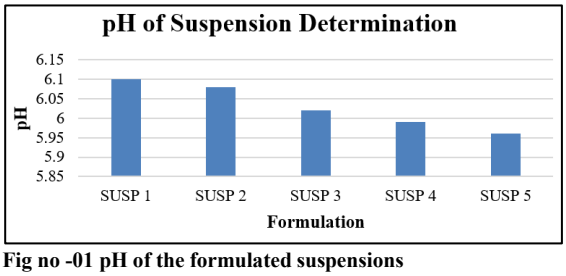

Fig no -01 pH of the formulated suspensions

The pH of the formulated suspensions was measured using a calibrated digital pH meter, with readings taken by immersing the electrode into each batch sample under controlled conditions. The results

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showed that all suspensions maintained a slightly acidic to near-neutral pH range, with values decreasing marginally as the xanthan gum concentration increased. Specifically, SUSP1 exhibited a pH of 6.10, followed by SUSP2 at 6.08, SUSP3 at 6.02, SUSP4 at 5.99, and SUSP5 at 5.96. This gradual decline in pH across batches suggests that higher concentrations of xanthan gum and excipient interactions may have contributed to minor shifts in the hydrogen ion balance. Overall, the suspensions remained within an acceptable physiological range, indicating good stability and suitability for oral administration.

Determination microcapsules contain suspension particle size:

Table no 03- Determination microcapsules contain suspension particle size

Formulated Suspensions	Particle size (µm)
SUSP 1	199.83
SUSP 2	202.13
SUSP 3	199.33
SUSP 4	198.23
SUSP 5	201.14

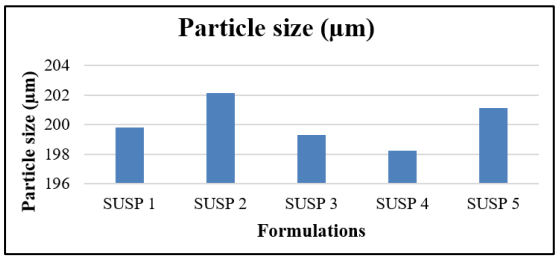

Fig no 02- Determination microcapsules contain suspension particle size

The particle size analysis of the formulated suspensions revealed that the microcapsules of Eperisone HCl were consistently within the range of approximately 198–202 µm across all batches. Specifically, SUSP1 showed a mean particle size of 199.83 µm, SUSP2 was slightly larger at 202.13 µm, SUSP3 measured 199.33 µm, SUSP4 was 198.23 µm, and SUSP5 recorded 201.14 µm. These values indicate that the microcapsules-maintained uniformity in size distribution regardless of the varying xanthan gum concentrations used in the suspensions. The minor variations observed between batches are within acceptable pharmaceutical limits, suggesting that the formulation process successfully preserved microcapsule integrity and ensured stable dispersion in the suspension medium. This consistency in particle size is crucial for predictable drug release, suspension stability, and overall therapeutic performance.

Sedimentation Volume and Redispersibility of Suspensions-

Table no 04- Sedimentation Volume and Redispersibility of Suspensions

Formulated Suspensions	Sedimentation Volume	Redispersibility
SUSP 1	0.86	<2
SUSP 2	0.88	<2
SUSP 3	0.92	<4
SUSP 4	0.94	<7
SUSP 5	0.95	<7

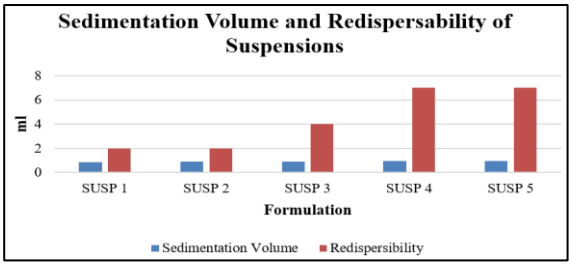

Fig no 03- Sedimentation Volume and Redispersibility of Suspensions

The sedimentation volume and redispersibility study demonstrated the influence of xanthan gum concentration on suspension stability. Sedimentation volume values increased progressively from 0.86 in SUSP1 to 0.95 in SUSP5, indicating that higher concentrations of the suspending agent improved the ability of the suspension to resist particle settling and maintain uniformity over time. However, this increase in viscosity at higher gum levels (SUSP4 and SUSP5) made the suspensions more difficult to pour from containers, highlighting a practical limitation. In contrast, suspensions with lower xanthan gum concentrations (SUSP1, SUSP2, and SUSP3) showed better redispersibility, requiring fewer inversion cycles (<2 to <4) to achieve homogeneity after sedimentation. Thus, while higher suspending agent concentrations enhanced sedimentation stability, lower concentrations favored ease of redispersion, suggesting that an optimal balance between viscosity and redispersibility is essential for developing patient-friendly suspension formulations.

Viscosity of formulated suspensions

Table no 05- Viscosity of formulated suspensionS

Formulated Suspension	Viscosity (cps)
SUSP 1	215
SUSP 2	240
SUSP 3	270
SUSP 4	305
SUSP 5	360

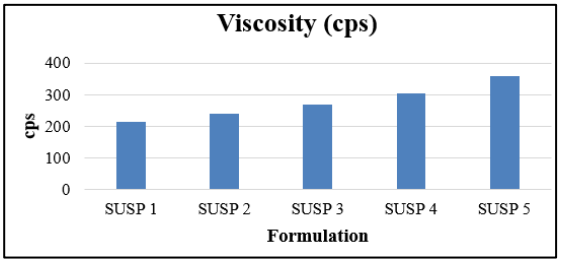

Fig no 04- Viscosity of formulated suspensions

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The viscosity study of the formulated suspensions clearly demonstrated the impact of xanthan gum concentration on rheological behavior. As the concentration of the suspending agent increased from SUSP1 to SUSP5, viscosity values rose progressively from 215 cP in SUSP1 to 360 cP in SUSP5, showing a direct correlation between gum content and resistance to flow. While higher viscosity (SUSP4 and SUSP5) contributed to improved physical stability and minimized sedimentation, it also reduced pourability, making the suspensions less convenient for patient use. Conversely, lower viscosity batches (SUSP1–SUSP3) were easier to handle and redisperse but exhibited comparatively lower sedimentation stability. These findings highlight the importance of optimizing suspending agent concentration to achieve a balance between stability and patient-friendly flow properties in oral suspension formulations.

Density of suspensions-

Table no 06- Density of suspensions

Formulated Suspension	Density(gm/ml)
SUSP 1	1.31
SUSP 2	1.29
SUSP 3	1.26
SUSP 4	1.22
SUSP 5	1.19

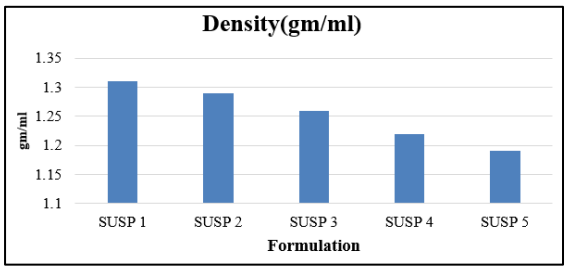

Fig no 05- Density Evaluation of the Formulated Suspensions

The density evaluation of the formulated suspensions showed a gradual decrease with increasing xanthan gum concentration. SUSP1 exhibited the highest density at 1.31 g/ml, followed by SUSP2 at 1.29 g/ml, SUSP3 at 1.26 g/ml, SUSP4 at 1.22 g/ml, and SUSP5 at 1.19 g/ml. This trend indicates that as the viscosity of the suspension increased due to higher levels of the suspending agent, the overall density of the formulation decreased slightly, likely because of greater entrapped air and reduced free-flowing characteristics. Despite these variations, all suspensions-maintained densities within acceptable pharmaceutical limits, confirming that the formulations were physically stable and suitable for oral administration. This balance between viscosity and density is important for ensuring both stability and patient acceptability of the suspension dosage form.

Leaching study into suspensions-

Table no 07- EpeH-leaching into suspensions

Formulated Suspension	Drug Leaching (%)
SUSP 1	0.34
SUSP 2	0.32
SUSP 3	0.30
SUSP 4	0.28
SUSP 5	0.26

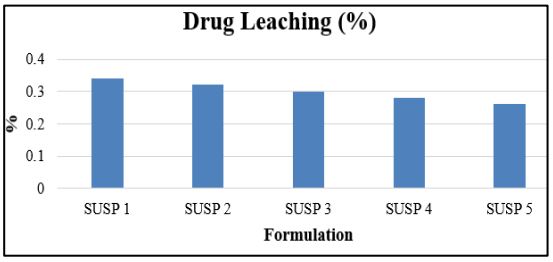

Fig no 06- EpeH-leaching into suspensions

The drug leaching study revealed that the percentage of Eperisone HCl released into the suspension vehicle during seven days of storage was minimal, ranging from 0.26% to 0.34% across all batches. SUSP1 showed the highest leakage at 0.34%, while SUSP5 exhibited the lowest at 0.26%, indicating that increasing xanthan gum concentration slightly reduced drug diffusion into the vehicle. This trend suggests that the suspending agent not only enhanced viscosity and physical stability but also acted as a barrier to drug leakage. Overall, the results confirmed that the microencapsulation process was effective in retaining the drug within the polymeric coating, ensuring controlled release and maintaining suspension integrity during storage.

Drug content into suspensions-

Table no 08- Drug content into suspensions

Formulated Suspensions	Drug content (%)
SUSP 1	98.67
SUSP 2	99.17
SUSP 3	98.83
SUSP 4	97.83
SUSP 5	98.17

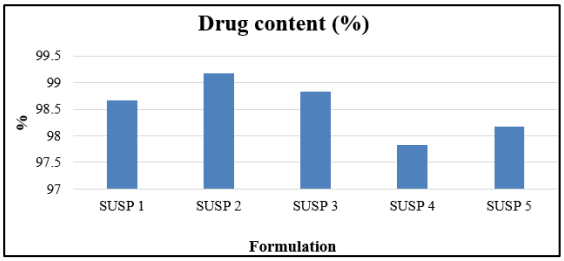

Fig no 07- Drug content into suspensions

The drug content analysis of the suspensions showed that the Eperisone HCl microcapsules maintained high levels of drug entrapment across all batches, with values ranging between 97.83% and 99.17%. SUSP2 exhibited the highest drug content at 99.17%, while SUSP4 showed the lowest at 97.83%, though all values remained well within acceptable

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pharmaceutical limits. These results confirm that the microencapsulation process was efficient and consistent, ensuring minimal drug loss during formulation and storage. The slight variations observed among batches may be attributed to differences in xanthan gum concentration and excipient interactions, but overall, the suspensions demonstrated excellent drug loading capacity and uniformity, validating the reliability of the preparation method.

In-vitro EpeH releasing profile of the suspensions

Table no 09- *In-vitro* EpeH releasing profile of the suspensions

Time. (Min)	Cumulative % drug released (Average ± SD*)				
	SUSP1	SUSP2	SUSP3	SUSP4	SUSP5
0	0.00±0.00	0.0±0.00	0.0±0.00	0.0±0.00	0.0±0.00
60	9.02±0.21	8.25±0.32	7.50±0.18	6.75±0.21	5.25±0.31
120	12.76±0.47	12.01±0.26	11.26±0.23	12.76±0.28	9.01±0.25
180	18.02±0.38	17.27±0.54	16.52±0.45	17.27±0.31	14.27±0.37
240	23.29±0.56	22.54±0.47	21.79±0.67	21.79±0.48	19.53±0.48
300	30.82±0.82	31.57±0.63	30.81±0.59	29.32±0.39	28.55±0.72
360	35.35±0.63	34.6±0.72	33.85±0.87	33.09±0.67	31.59±0.64
420	41.39±0.91	40.64±0.75	39.88±0.75	39.88±0.71	36.87±0.59
480	48.94±0.83	48.19±0.91	47.43±0.86	46.68±0.68	45.16±0.63
540	52.74±0.87	51.99±0.83	51.23±0.91	51.98±0.82	48.96±0.72
600	59.49±1.02	60.24±0.94	59.48±0.89	57.98±0.91	57.21±0.81
660	62.62±0.92	63.36±1.03	62.60±1.06	60.35±0.92	60.17±0.87
720	67.19±1.04	66.43±1.01	65.67±1.03	64.92±1.06	64.15±1.06

* SD: Standard Deviation (n=3)

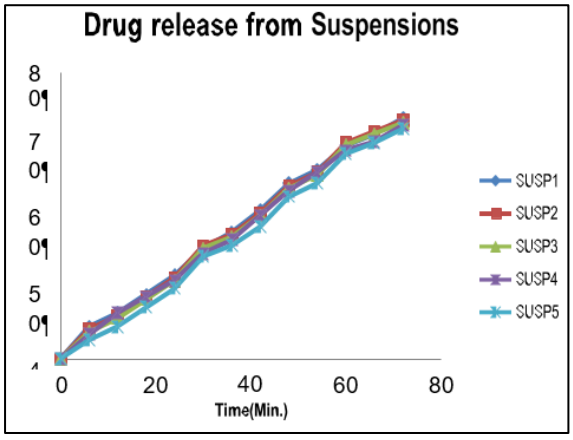

Fig. no 08- *In-Vitro* release profile of suspensions

The in-vitro release profile of Eperisone HCl from the suspensions demonstrated a sustained and controlled drug liberation pattern over 12 hours. Initially, no drug release was observed at 0 minutes, but by 60 minutes, cumulative release ranged from 5.25% (SUSP5) to 9.02% (SUSP1), showing that lower xanthan gum concentrations facilitated faster diffusion. As time progressed, all formulations exhibited gradual increases, with mid-point values at 360 minutes ranging between 31.59% and 35.35%, and further rising to approximately 64–67% by 720 minutes. The data clearly indicate that suspensions with higher suspending agent concentrations (SUSP4 and SUSP5) slowed drug release due to increased viscosity and diffusion resistance, while lower concentration batches (SUSP1–SUSP3) allowed relatively faster release. Overall, the release profiles confirmed the effectiveness of microencapsulation in achieving sustained drug delivery, with formulation differences subtly modulating the rate of release to balance stability and therapeutic performance

Kinetics investigation of the *In-vitro* EpeH-release through suspensions-

Table no 10- Kinetics investigation of the *In-vitro* EpeH-release through suspensions

Formulation	Zero order		First order		Higuchi		Korsemeyer-Peppas		
	K0	$_R$2	K1	$_R$2	KH	$_R$2	KP	$_R$2	'n'
SUSP1	0.1033	0.996	0.0185	0.984	1.892	0.932	1.077	0.987	0.866
SUSP2	0.1009	0.995	0.0186	0.981	1.864	0.927	1.075	0.988	0.901
SUSP3	0.0976	0.995	0.0185	0.981	1.819	0.923	1.071	0.989	0.934
SUSP4	0.0968	0.996	0.0186	0.985	1.801	0.928	1.072	0.986	0.931
SUSP5	0.0878	0.995	0.0187	0.978	1.681	0.909	1.054	0.994	1.058

The kinetic modeling analysis of the in-vitro release data revealed that the dissolution behavior of Eperisone HCl microcapsules suspended in different formulations was most accurately described by the Zero-order kinetic model, as evidenced by the consistently high correlation coefficients ($R^2 \approx 0.995–0.996$) across all suspensions. This indicates that drug release occurred at a constant rate, independent of concentration, thereby ensuring a sustained and predictable release profile. Among the formulations, SUSP2 (containing 0.4% xanthan gum) emerged as the most favorable candidate, striking an optimal balance between physical stability, sedimentation volume, redispersibility, and controlled release. Its release pattern adhered closely to Zero-order kinetics, confirming its suitability for

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prolonged therapeutic action. Consequently, SUSP2 was selected for further stability investigations under varied storage conditions, as it demonstrated superior performance in maintaining both pharmaceutical integrity and patient-friendly characteristics.

Stability Studies-

Table no 11- Stability Studies of selected suspension (SUSP2)

Evaluation Parameter	Stability Studies Results Data					
	1 Month		2 Month		3 Month	
	25°C/ 60% RH	40°C / 75% RH	25°C/ 60% RH	40°C / 75% RH	25°C / 60%RH	40°C/ 75%RH
pH	6.08	6.01	5.88	5.83	5.72	5.68
Sedimentation volume	0.88	0.89	0.76	0.78	0.63	0.65
Redispersibility	<2	<2	<2	<2	<2	<2
Viscosity (cps)	240	230	223	221	218	215
Drug leaching (%)	0.32	0.34	0.39	0.41	0.47	0.49
Drug content (%)	99.17	99.13	99.08	99.07	99.02	98..98
In-vitro drug release (%)	65.67	66.43	64.91	65.68	64.14	64.92

The stability study of SUSP2 over three months under both accelerated (40 °C/75% RH) and ambient (25 °C/60% RH) conditions revealed only gradual changes in physicochemical parameters, confirming good formulation robustness. The pH decreased slightly from 6.08 to 5.68, while sedimentation volume reduced from 0.88 to 0.65, indicating minor settling over time. Redispersibility remained consistently favorable (<2 inversions), showing ease of reconstitution. Viscosity declined moderately from 240 cP to 215 cP, reflecting slight thinning of the suspension matrix. Drug leaching increased marginally from 0.32% to 0.49%, but drug content remained high and stable (99.17% to 98.98%), ensuring dosage accuracy. Importantly, the in-vitro release profile remained sustained, with cumulative release values around 64–66%, adhering to zero-order kinetics. Collectively, these results demonstrate that SUSP2 retained its stability, therapeutic reliability, and patient-friendly characteristics under both storage conditions, validating its suitability for long-term use.

CONCLUSION:

The comprehensive evaluation of the formulated suspensions demonstrated that xanthan gum concentration played a pivotal role in modulating physicochemical properties, stability, and drug release behavior. Parameters such as appearance, pH, particle size, sedimentation volume, viscosity, density, drug leaching, drug content, and in-vitro release profiles consistently confirmed that all suspensions were pharmaceutically acceptable, with microencapsulation ensuring minimal drug leakage and sustained release. The kinetic modeling further validated that the drug release followed Zero-order kinetics, ensuring a constant and predictable release rate. While higher gum concentrations improved sedimentation stability, they also reduced pourability and ease of redispersion, highlighting the need for balance between viscosity and patient convenience. Among all formulations, SUSP2 (containing 0.4% xanthan gum) emerged as the optimized suspension, offering the most favorable combination of redispersibility, physical stability, drug content uniformity, and controlled release performance. Its stability studies under both accelerated and ambient conditions confirmed robustness, with only minor variations in pH, viscosity, and drug leaching, while maintaining therapeutic reliability and patient-friendly characteristics. Therefore, SUSP2 can be confidently recommended as the optimized formulation, suitable for long-term storage and effective oral delivery of Eperisone.

CONFLICT OF INTEREST:

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