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Original Research Article

Enhanced glycemic control and organ protection with empagliflozin microemulsion in alloxan-induced diabetic mice

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ABSTRACT

Background: Diabetes mellitus (DM) is a serious challenge for worldwide health and is predominant in most populations living with type 2 diabetes (T2DM), thus new drug strategies must be created to enhance drug delivery and use. Empagliflozin is also a sodium-glucose cotransporter-2 (SGLT2) inhibitor that has high solubility and low intestinal permeability, thereby making its bioavailability in traditional formulations is limited. To overcome these drawbacks, we have formulated an empagliflozin microemulsion, which we expect to enhance permeability and therapeutic efficacy.
Methods: The microemulsion was formulated according to a double emulsion technique with olive oil, Tween 80, ethanol, and xanthan gum, and followed by analysis on physical properties, stability, and drug release kinetics. The microemulsion was compared to the empagliflozin tablet for glycemic control and protection of organs in alloxan-induced diabetic Swiss albino mice.
Results: The formulation yielded spherical droplets (0.2-0.3 µm), high encapsulation efficiency (EE) (84.9%), and sustained *in vitro* release (76% after 12 h). The *in vivo* findings indicated the microemulsion was more effective, with 63.50% reduction in blood glucose levels vs. 55.70% for the tablet, and a significant recovery of body weight (30.16 g vs. 28.93 g). Histopathological examination of microemulsion group revealed restored pancreatic islets and normal renal structures in contrast to significant destruction in diabetic controls.
Conclusions: These results emphasize the ability of the microemulsion to enhance the pharmacodynamic profile of empagliflozin and can be considered as a new alternative to classical drugs in diabetes treatment. This study highlights significance of the above therapeutic benefits including patient compliance in a novel phase of drug delivery systems.

Keywords: Diabetes mellitus, Alloxan, Hypoglycemic activity, Empagliflozin, Microemulsion

INTRODUCTION

Type 2 diabetes mellitus (T2DM), accounting for over 85% of diabetes cases worldwide, is a chronic metabolic disorder characterized by persistent hyperglycemia, polyphagia, polydipsia, and polyuria.[1] Current treatment approaches, including lifestyle modification, oral hypoglycemic agents, and insulin therapy, often fail to achieve sustained glycemic control and long-term prevention of complications.[2] SGLT2 inhibitors such as empagliflozin have emerged as promising therapies because they lower blood glucose independently of insulin

by increasing urinary glucose excretion.[3] However, empagliflozin exhibits poor intestinal permeability despite high solubility, limiting its bioavailability and therapeutic efficacy as a biopharmaceutics classification system (BCS) class III drug.[4]

Microemulsions are thermodynamically stable nanoscale systems composed of oil, water, surfactants, and cosurfactants that improve drug solubility, absorption, and stability.[5] Although they have shown potential in delivering poorly permeable antidiabetic drugs, their application for SGLT2 inhibitors remains limited.[6] This study aimed to develop an empagliflozin microemulsion using olive oil and evaluate its pharmacodynamic effects in alloxan-induced diabetic mice. The formulation was assessed for glycemic control, organ-protective effects, and comparative efficacy with conventional tablet formulations, with the goal of improving bioavailability, patient compliance, and long-term therapeutic outcomes.

METHODS

Chemicals and reagents

Empagliflozin was procured as a pure (99 %) API from IPCA Certified Laboratory, Indore, as a gift sample. Alloxan Monohydrate used for diabetic induction extra pure, 98% was purchased from MKJ International, Jaipur, India. Glucometer (Dr. Morepen®) was bought from Morepen Laboratories, New Delhi, India. Tween 80, PEG 400, and Olive oil were purchased from Sigma-Aldrich Chemical Co. (Budapest, Hungary). Every chemical and reagent utilized in this investigation was of analytical grade quality. Double distilled water and freshly prepared saline solution were used throughout the experimental procedure as required.

A preclinical study was conducted at Jaipur National University Institute for Medical Sciences and Research Centre (JNUIMSRC), Jaipur National University, Jaipur, Rajasthan, India from November 2024 to April 2025. The study was approved by Institutional Animal Ethics Committee at the School of Pharmaceutical Sciences, Jaipur National University, Jaipur, Rajasthan, India, authorized all animal treatment methods and procedures (JNU/SOPS/IAEC/2024/01-04).

Empagliflozin microemulsion preparation

A double emulsion method was used to prepare this microemulsion for enhanced drug encapsulation and stability. The empagliflozin (50 mg) was dissolved in 10 mL of olive oil under continuous magnetic stirring (500 rpm) to obtain a homogeneous dispersion. To prepare the surfactant-cosurfactant mixture (S mix), Tween 80 and ethanol was combined in a 2:1 ratio and then added to the drug dispersion under stirring to form a pre-emulsion. The aqueous phase was composed of xanthan gum (1% w/v) dissolved in 20 mL of double-distilled water. The pre-emulsion was added dropwise to the aqueous phase under homogenization (500–600 rpm) to give us a translucent microemulsion.[7] This procedure guaranteed a uniform distribution of droplets and high drug loading power.

Characterization of microemulsion

Physicochemical properties of empagliflozin microemulsion

Physical appearance and pH of microemulsion

During the study period, physical appearance (color, homogeneity, etc.) was checked. pH stability was determined weekly for four weeks using a digital pH meter and measured in triplicate.[8]

Particle size and distribution of microemulsion

Particle size and shape were monitored through optical microscopy at 100×magnification to determine the formation of uniform spherical droplets.[9]

Rheological characterization of microemulsion

Rheological properties of microemulsion were determined on a rotational viscometer (LMDV60) to determine that the formulations could tolerate the desired oral viscosity.[10,11]

FT-IR characterization of microemulsion

Physical compatibility of the drug with an excipient was confirmed using Fourier-transform infrared (FTIR) spectroscopy. Spectra were taken over the range of 4000-400 cm^{-1}.[12,13]

Entrapment efficiency and loading capacity

EE% and drug loading (LE%) were determined as follows:

Entrapment efficiency (EE%) = [(Amount of empagliflozin added - amount of empagliflozin in sample)/ amount of empagliflozin added in the emulsion] × 100

Loding efficiency (LE%) = [Amount of empagliflozin encapsulated / Weight of the carrier] × 100

In vitro release profile of microemulsion

In vitro release profile of microemulsion was studied using a dialysis membrane (MWCO 10,000-16,000) in phosphate buffer (pH 7.4) at 37°C±1°C by using Franz diffusion cell apparatus.[14,15]

In vivo evaluation

DM was induced in Swiss albino mice (20-30 g, 8-12 weeks of age) using intraperitoneal injection of alloxan monohydrate (150 mg/kg).[16] Following 72 h, mice with

fasting blood glucose (FBG) levels ≥150 mg/dL were selected and formed four groups (n=6): normal, diabetic, standard (empagliflozin tablet), and test (empagliflozin microemulsion). On days 0, 7, and 14, blood glucose levels and body weight were monitored. At the end point of the study, mice were sacrificed, and pancreatic and renal tissues were collected for histopathological testing. Tissues were fixed in 4% formaldehyde, embedded in paraffin, sectioned and stained with hematoxylin and eosin (H&E), for morphological evaluation.[17]

Statistical analysis

All experiments were performed in triplicate, with data expressed as mean±standard deviation (SD). The results of one-way ANOVA and Tukey post hoc testing were then compared, with only $p \leq 0.05$ in significance.

RESULTS

Physicochemical properties of empagliflozin microemulsion

Physical appearance and pH of empagliflozin microemulsion

The formulated empagliflozin microemulsion had good physical properties, necessary for oral drug application. When looked at upon visualization, the preparation presented as a clear, translucent liquid, with no visible phase separation or precipitation, reflecting the suitable amount and ratio of excipients. Microscopic examination confirmed the spherical shape of the globules and the uniform distribution of them throughout the formulation. This mechanical stability indicates that the surfactant-cosurfactant system (Tween 80: ethanol, 2:1 ratio) successfully maintained the thermodynamic stability of the microemulsion.

The pH stability of the formulation was assessed and measured in four successive weeks to evaluate its suitability for oral formulations. At the beginning of the study pH was 6.37±0.12, stable throughout the entire time (6.35-6.42 at week 4). This near neutral pH range is essential for drug stability and patient comfort, as it reduces possible gastrointestinal irritation. The modest change (<0.1 pH units) over time indicates superior buffering capacity, likely due to the xanthan gum stabilizer applied in the aqueous media. The solubility and permeability of empagliflozin can be pH-dependent, making these pH characteristics especially important. The physical stability and suitable pH profile in this microemulsion formulation point to an ability to retain empagliflozin properties before storage or gastrointestinal tract transit. A translucent image supports this, suggesting that nanoscale droplet size provides enhanced drug absorption. Overall, these attributes of the microemulsion favor the potential of it as a more potent delivery medium for empagliflozin as compared with tablet-based formulations.

The particle size and distribution of microemulsion.

The particle size characterization of the empagliflozin microemulsion provided crucial information regarding its mechanical properties and its potential for improved drug delivery. Optical microscopy at 100× magnification showed that spherical droplets tended to be evenly distributed, with an average diameter between 0.2-0.3 µm, keeping in line with the anticipated size range for microemulsion systems. Low size variation as illustrated by reduced aggregation or coalescence of droplets implies good thermodynamic stability of the formulation. The homogeneity of the compositions is advantageous during oral drug delivery with a more predictable drug release and absorption profiles. The small droplet size in this study (200-300 nm) is considerably below the 1 µm limit seen in microemulsions, indicating even greater dissolution ability over traditional formulations. This nanometer-sized dimension provides a relatively high surface area to volume ratio and enables the rapid transfer, interfacing with the bioactive agent, and possibly improves intestinal permeability, which is important for empagliflozin, as it classifies as BCS class III.

The spherical shape of the droplets was supported by the microscopic analysis and it also demonstrates the stability of the system, by reducing the interfacial tension between the oil and the aqueous phase. Macroscopic and microscopic observations confirmed the clarity of the microemulsion, providing further evidence for its thermodynamic stability. Unlike coarse emulsions that might look milky due to light scattering by larger droplets, the transparent nature of this formulation demonstrates the size of the suspended phase being submicron. This optical characteristic is consistent with droplet parameters measured and indicates the choice of surfactant-cosurfactant (Tween 80: ethanol, 2:1 ratio) as one that is able to stabilize the oil-water interface. The reported particle properties directly meet an empagliflozin's main restriction such as the low intestinal permeability, since the delivery system in the formulation facilitates a favorable drug dissolution and absorption. The small and homogeneous distribution of droplet size are particularly advantageous in oral drug delivery because they facilitate transport across the surface of the body's membranes and are conducive to maintenance of drug stability. Such results establish a basis for the subsequent evaluation of the microemulsion's pharmacodynamic properties in diabetic mice, in which the resulting physicochemical profile yields better therapeutic properties.

Rheological characteristics of microemulsion

The rheological properties were determined using rotational viscometer for the empagliflozin microemulsion to determine the flow and oral acceptability. The formulation was described to be viscous at 60 rpm with a viscosity of 21.1 cP, which is characteristic of low viscous species of Newtonian fluids. This low viscosity makes it easy to handle and dose the drug while promoting

consistent dispersion of the drug after delivery, which is essential for a sustained drug delivery. The Newtonian tendency which the viscosity of the microemulsion exhibits in which the liquid was allowed to mix, which is a characteristic that we will mention below is that it does not decrease in response to shear rate is desired for oral formulations because the expected behavior of the fluid is predictable through the fabrication and application. The small uniform droplet size (0.2-0.3 µm) and successful stabilization of the surfactant-cosurfactant mix (Tween 80: ethanol, 2:1 ratio) can account for this phenomenon, because it reduces interfacial tension and prevents droplet aggregation. The low viscosity of the microemulsion also promotes its rapid diffusion within gastrointestinal fluids, improving drug release and absorption kinetics. Its consistent viscous measurements from storage at room temperature for 4 weeks showed that the microemulsion remains thermodynamically stable; during these sessions its viscosity varied less than 5% over time. This stability is essential for shelf life consistency of the formulation. Given both its low viscosity and its Newtonian behaviour, it is highly suitable for oral administration, so low viscosity can be easily administered while providing stable drug distribution. These rheological characteristics of the microemulsion are responsible for its superior performance on the shelf life against conventional empagliflozin-based tablets, in that lower viscosity and stable flow properties, enable faster release and absorption of the drug into the gastrointestinal tract of the individual. The results of these experiments are consistent with earlier research confirming that optimal rheological properties are very crucial to ensure a high degree of therapeutic application in microemulsion-based drug delivery systems. The microemulsion response demonstrated under investigation shows potential as an optimized empagliflozin formula for delivery, overcoming significant permeability restrictions related to this drug while allowing for superior stability and handling characteristics.

FTIR analysis of the empagliflozin microemulsion

To verify the structural integrity of empagliflozin used in microemulsion formulation and to assess some drug-excipient interactions Fourier-transform infrared (FTIR) spectroscopy was employed. When the spectrum was analyzed for pure empagliflozin, characteristic absorption bands due to its functional groups were assessed which were compared with the other atoms in microemulsion as evidence of chemical continuity. This wide peak at 3496 cm^{-1} is due to O-H stretching vibrations from hydroxyl groups present in the drug molecule. This is an unchanged peak in the microemulsion spectrum, suggesting the preservation of empagliflozin's hydrogen bonding capacity. The aromatic nature of the drug was also confirmed by the three peaks at 3066 cm^{-1}, 1553 cm^{-1}, and 1432 cm^{-1} (which represent C=C stretching of benzene rings), which were retained in the formulation without any significant change. The fingerprint region has important information related to the molecular structural nature of the drug in the microemulsion. The powerful C-O stretching vibrations at 1054 cm^{-1}, 1014 cm^{-1} and 981 cm^{-1} characteristics of the alcohol and ether linkages in empagliflozin were discernible from the two spectra. However, a smaller number of smaller peaks at 687 cm^{-1} and 619 cm^{-1} associated with C-H out-of-plane bending to substituted aromatic systems were also retained in the microemulsion. The lack of the new peaks and the significant changes (>10 cm^{-1}) in the microemulsion spectrum verified empagliflozin maintained chemical activity without the formation of new covalent bonds with excipients. This stability is important due to surfactant (Tween 80) and cosurfactant (ethanol) constituents that may form complexes with the drug. The findings show empagliflozin effective incorporation into the microemulsion while remaining pharmacologically active. The FTIR analysis provided fundamental evidence that the process to prepare the microemulsion did not change empagliflozin's molecular structure. This result is consistent with the after-*in vivo* data that demonstrate preserved pharmacological activity, given that any alterations in the drug could have attenuated the SGLT2 inhibiting properties. The spectral homogeneity of pure drug and microemulsion further supports the stability and therapeutic activity of the formulation. Overall, the FTIR results confirm that empagliflozin maintains its expected chemical structure and key functional groups (Figure 1).

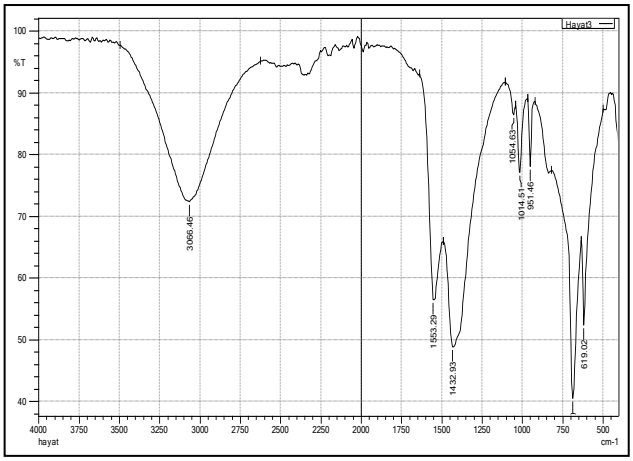

Figure 1: FTIR of empagliflozin microemulsion showing characteristic functional group and peaks.

EE% and LC

The EE% and LC of the empagliflozin microemulsion demonstrated its strong drug delivery potential. The formulation achieved a high EE% of 84.9%, indicating efficient incorporation of empagliflozin into the microdroplets, while the LC of 47.1% reflected substantial drug loading with maintained stability. These results suggest effective interaction between empagliflozin, olive oil, and the surfactant-cosurfactant system. Xanthan gum further enhanced drug retention by stabilizing the droplets. High EE% and LC improved drug availability, minimized administration volume, and enhanced pharmacodynamic

performance, supporting the superiority of the microemulsion over conventional empagliflozin tablets for BCS class III drugs.

In vitro release profile of empagliflozin microemulsion

In vitro release profile of empagliflozin microemulsion showed a biphasic release pattern characteristic of optimized drug delivery systems. An initial burst release of 28.4% occurred within the first hour, likely due to drug molecules located near the droplet surface, enabling rapid absorption. This was followed by sustained release, reaching 76.0% cumulative release over 12 hours. The prolonged release was attributed to the small droplet size, olive oil core, and stable surfactant-cosurfactant interfacial film, which controlled drug diffusion. Kinetic analysis showed the Higuchi model had the highest correlation (R^2=0.963), indicating diffusion-controlled release, while the Korsmeyer-Peppas model suggested non-Fickian transport. Sustained release profile may support once-daily dosing and improved plasma concentration control compared with conventional tablets. Improved *in vitro* release correlated with enhanced *in vivo* glycemic control, suggesting microemulsion offers rapid onset, prolonged action, better bioavailability, and optimized therapeutic performance for empagliflozin delivery.

Blood glucose levels in the period after treatment

The use of empagliflozin microemulsion showed better glycemic control than conventional tablet formulations in alloxan-induced diabetic mice. The mean blood glucose level in the microemulsion group at 7 days post-treatment was 123.50 mg/dL, lower than the 144.50 mg/dL (Figure 2) in the conventional tablet group ($p \leq 0.05$). These early improvements suggest increased absorption and fast onset of action with the microemulsion, that is perhaps due to the microemulsion's microscale droplet size and optimized permeability properties. By day 14, the difference in glycemic control was even better, as the microemulsion group had a mean glucose of 96.16 mg/dL (Table 1) with a standard of 111.66 mg/dL (Figure 2). This is a 63.50% decrease from baseline of the microemulsion versus 55.70% of the tablet composition ($p \leq 0.01$). The continued progress of both groups confirms the sustained release profile of the microemulsion *in vitro* which allowed it to retain drug delivery *in vitro* to 12 hours. The percentage inhibition of hyperglycemia was maintained by the microemulsion for the entire study period. On the seventh day, the standard formulation exhibited 45% inhibition (140.83 mg/dL) (Figure 3) while the microemulsion was inhibited by 52% (123.5 mg/dL). This discrepancy widened by day 14 as well as the microemulsion, remaining on top when it came to drug treatment (63.50% vs. 55.70%). The time pattern indicates that the microemulsion is not only more rapid when applied in achieving early glycemic control but also more sustained in its efficacy against standard tablets. Such results were consistent with the microemulsion's physicochemical characteristics, especially its small droplet size (0.2-0.3 μm) and high EE (84.9%) which can promote improved intestinal absorption and better SGLT2 inhibition. The enhanced effect may also derive from the formulation's capability to protect empagliflozin from degradation in the gastrointestinal tract and therefore facilitate high doses of active drug entry into systemic circulation. These blood glucose data are clearly enough proof that microemulsion technologies may be able to compensate for empagliflozin's bioavailability drawbacks and that its high solubility can lead to better therapeutic outcomes. Such prolonged glycemic control with the microemulsion implies clinical convenience, even more so for patient whose response to conventional tablet formulations is worse. These results reinforce the research value and the potential of the microemulsion as an advanced delivery system for empagliflozin, the latter of which also plays an important role in diabetes treatment where maintaining stable glycemic control continues to be difficult for many patients. The differential response across formulations highlights the need for effective drug delivery optimization of BCS class III compounds such as empagliflozin, where permeability limitations commonly limits therapeutic potential. This work suggests that empagliflozin can have a significantly advanced pharmacodynamic profile by potentiating intestinal absorption through microemulsion technology and therefore can be an important new route for treating diabetes. As a key part of the microemulsion's overall performance evaluation, the blood glucose results complement findings on body weight recovery as well as organ protection presented below.

Effect on diabetes mice body weight

The empagliflozin microemulsion showed superior weight recovery compared to conventional tablets in alloxan-induced diabetic mice. Diabetic control mice exhibited progressive weight loss due to uncontrolled hyperglycemia and metabolic dysfunction. In contrast, mice treated with standard tablets gained 22.5% body weight, (Table 2 and Figure 4) while microemulsion group achieved a significantly higher 29.1% gain by day 14 ($p \leq 0.05$). Enhanced recovery was attributed to improved glycemic control, sustained drug release, increased bioavailability, and supportive effects of olive oil components. These findings suggest that microemulsion improves metabolic recovery, therapeutic efficacy, and overall diabetic management beyond conventional empagliflozin formulations.

Histopathological examination of kidney and pancreas

Histopathological analysis (Figure 5) showed that empagliflozin microemulsion provided superior pancreatic and renal protection in diabetic mice. Compared with diabetic controls and standard tablets, microemulsion preserved islet morphology, β-cells, glomeruli, and renal tubules. Enhanced bioavailability, sustained drug release, and antioxidant effects contributed to reduced tissue damage and improved therapeutic efficacy.

Table 1: Antihyperglycemic effect of empagliflozin microemulsion vs standard drug (empagliflozin tablets) in diabetic mice.

Treated/untreated groups, (n=6)	Dose (mg/kg)	Mean blood glucose concentration (mg/dl)±SD (% inhibition)		
		Day 0	Day 7	Day 14
Control group	-	82.03±2.78	86.83±3.97	89.33±2.98
Diabetes control	-	244.83±4.49	246.83±9.35	251.16±5.69
Standard group (empagliflozin tablets)	10 mg/kg	256±7.69	140.83±1.83 (45.00%)	111.66±3.07 (55.70%)
Test group (empagliflozin microemulsion)	10 mg/kg	258.16±5.34	123.5±3.39 (51.56%)	96.16±3.02 (63.15%)

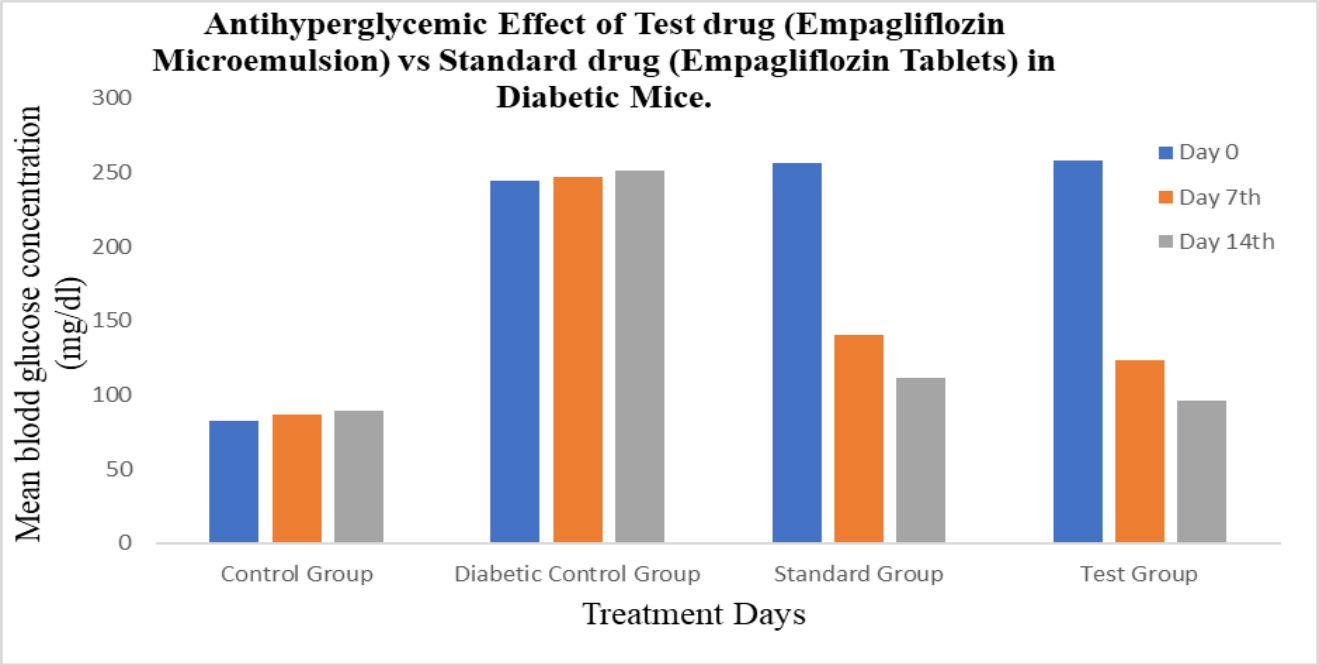

Figure 2: Effects of empagliflozin microemulsion and standard drug (Empagliflozin tablet) on fasting blood glucose levels in alloxan-induced diabetic mice on day 7th and day 14th.

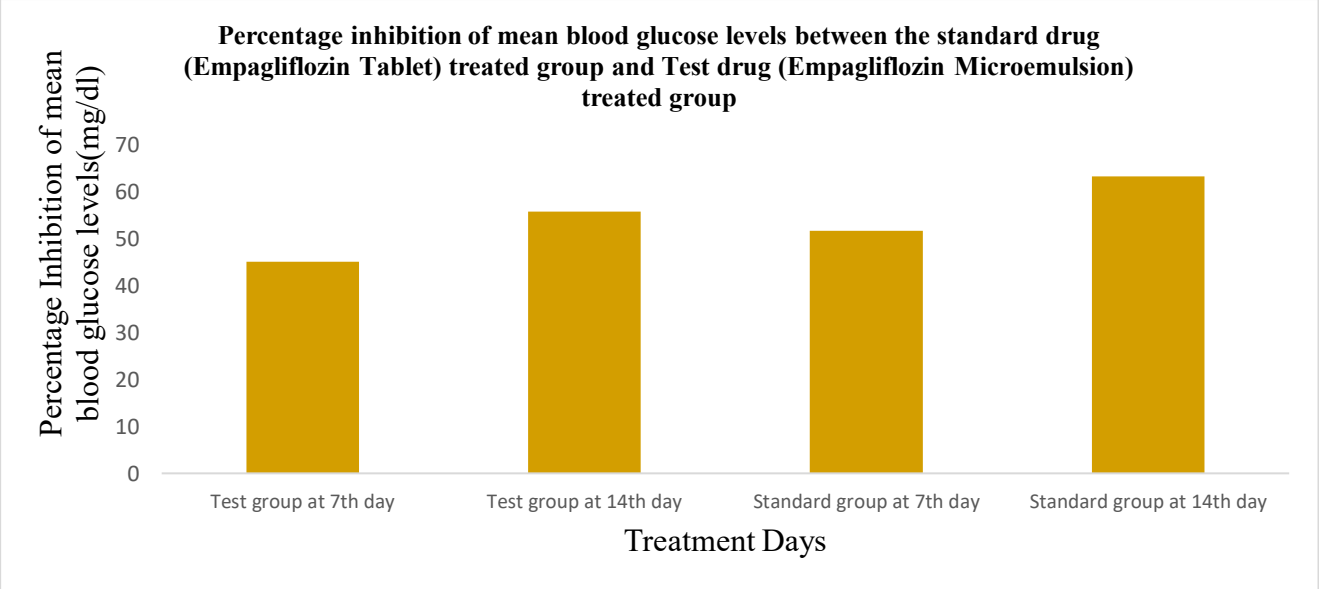

Figure 3: Percentage inhibition of mean blood glucose levels between the standard drug (Empagliflozin tablet) treated group and test drug (Empagliflozin microemulsion) treated group in alloxan-induced diabetic mice.

Table 2: Effect of empagliflozin microemulsion vs standard drug (empagliflozin tablets) on average body weight (g) of alloxan-induced diabetic mice.

Treated/untreated groups, (n=6)	Dose (mg/kg)	Mean body weight (g)±SD		
		Day 0	Day 7	Day 14
Control group	-	25.03±1.98	26.53±2.14	27.47±2.04
Diabetes control	-	26.74±2.88	23.85±1.89	21.06±1.29
Standard group (empagliflozin tablet)	10 mg/kg	23.61±1.14	25.61±1.40	28.93±0.93
Test group (empagliflozin microemulsion)	10 mg/kg	23.36±1.06	27.63±0.79	30.16±1.42

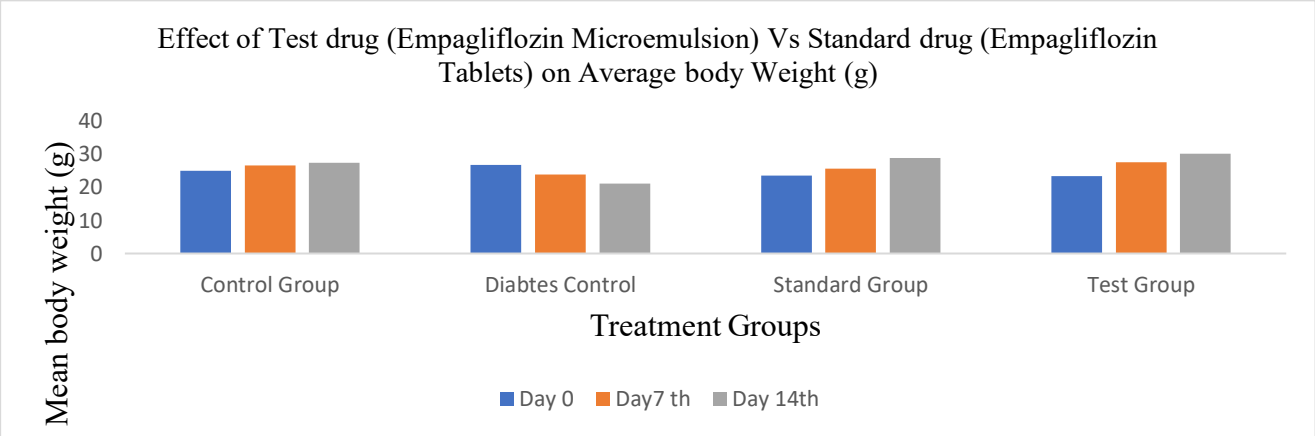

Figure 4: Test group (Empagliflozin microemulsion) showed a progressive increase in body weight, with a weight gain of +2.02 grams on the 7th day and final of +3.25 grams by the 14th day.
*In comparison, the standard group exhibited less weight improvement over the same period.

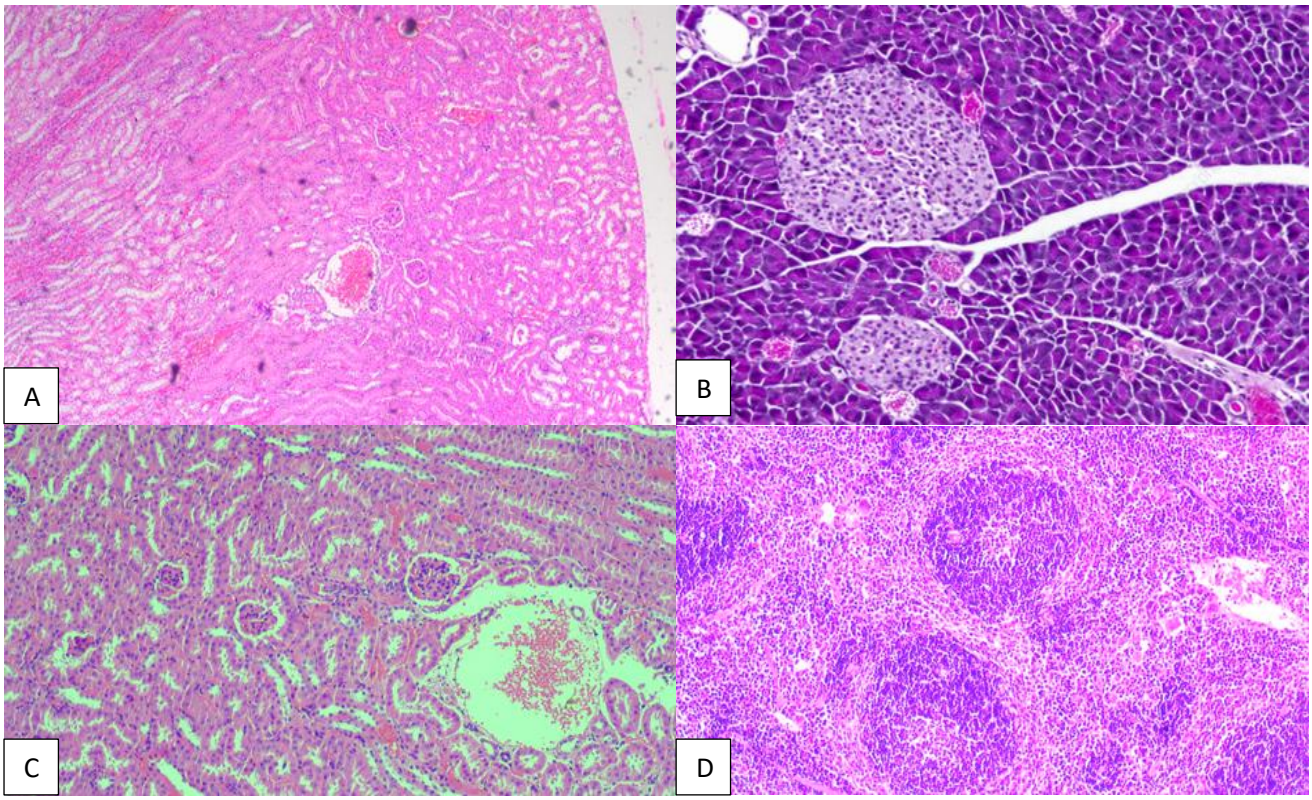

Figure 5: Photomicrograph of tissue (Pancreas and kidney) sections stained by hematoxylin and eosin (magnification 40×). A. Effect of empagliflozin microemulsion on tissue levels; B. Diabetic control kidney with irregular shape size; C. Diabetic control pancreas with β-cell destruction and atrophy; D. Empagliflozin Microemulsion treated group-kidney showed restoration of shape and size.

DISCUSSION

The microemulsion formulation containing empagliflozin demonstrated a notable EE of 84.9% and a loading capacity (LC) of 47.1%, consistent with findings from prior research investigations.[18-25] Empagliflozin microemulsion showed an initial burst release of 28.4% occurred within the first hour, followed by sustained release, reaching 76.0% cumulative release over 12 hours. This drug release profile of empagliflozin microemulsion was in concordance with previously conducted drug release profiles of different drug formulations.[26-28] The development of an empagliflozin microemulsion represents a promising strategy to overcome the poor intestinal permeability associated with conventional SGLT2 inhibitor formulations. The microemulsion demonstrated superior glycemic control, reducing blood glucose levels by 63.5% compared to 55.7% with standard tablets, suggesting improved bioavailability and therapeutic efficacy for BCS class III drugs. These findings indicate enhanced drug absorption and therapeutic effectiveness particularly for BCS class III substances, aligning with prior research outcome.[29-31] Sustained drug release and enhanced *in vivo* performance may improve patient adherence and reduce complications associated with long-term diabetes management. Histopathological findings further indicated pancreatic and renal protective effects, highlighting the formulation's potential beyond glucose regulation. Histopathological results of empagliflozin microemulsion corroborates with the results of previously conducted organ protective effects of different microemulsion formulations.[32-36]

Despite these advantages, several limitations remain such that the alloxan-induced diabetic mouse model does not fully replicate human type 2 diabetes, particularly chronic complications, and the 14-day study period was insufficient to evaluate long-term efficacy and safety. Additionally, large-scale industrial production of stable microemulsions requires further optimization. Future studies should include pharmacokinetic evaluations in larger animal models, long-term efficacy studies, and investigations into combination therapies with other antidiabetic agents. The role of olive oil in providing antioxidant and anti-inflammatory benefits also warrants further exploration. Overall, this study highlights the potential of microemulsion-based delivery systems to improve empagliflozin therapy and may provide a broader strategy for enhancing bioavailability of other poorly permeable oral antidiabetic drugs.

CONCLUSION

Indeed, the findings showed from this study that empagliflozin formulating microemulsions drastically enhances its therapeutic efficacy in alloxan-induced diabetic mice, alleviating major shortcomings of typical tablet formulations. The higher glycemic control and organ protection rate of microemulsions are consistent with our conjecture that a progressive delivery system can provide an optimal pharmacodynamic profile of BCS class III drugs. These results reinforce the increasing evidence for microemulsion technology as a feasible approach for enhancing the bioavailability and therapeutics of poorly permeable agents. In the future, we recommend that the preclinical results can be transferred to clinical practice, especially studying the pharmacokinetic profile of microemulsions in humans, and their long-term effects for diabetes complications. The possibility to integrate this formulation with other antidiabetic drugs or to extend this technology to alternative drugs is something we would very much like to explore. This work enhances knowledge of empagliflozin delivery and is a springboard for the generation of superior solutions for diabetes management and other therapeutic interventions for which the drug permeability renders the process therapeutically inefficient.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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