CHAPTER 7

SUMMARY AND CONCLUSION

The research conducted on the "Formulation and Evaluation of Mesoporous Silica Nanoparticles (MSNs) Loaded Antiarthritic Gel as a Targeted Drug Delivery System" presents a novel approach for enhancing the therapeutic efficacy of antiarthritic drugs through advanced nanotechnology. The study comprehensively investigates the structural, morphological, and textural properties of MSNs using various analytical techniques including FTIR spectroscopy, particle size analysis, TEM, SEM, DSC, and BET analysis. These characterizations confirm the successful functionalization and high surface area of MSNs, making them an ideal candidate for targeted drug delivery systems.

The antiarthritic drugs Methotrexate and Tofacitinib Citrate were effectively loaded into the surface-modified MSNs, as confirmed by the combination of FTIR and pXRD analyses, which demonstrated the structural integrity of the MSNs post-drug loading. The loaded MSNs exhibited high drug loading efficiency and a sustained release profile, which are crucial for improving drug solubility, stability, and targeted delivery, ultimately enhancing therapeutic outcomes for arthritis patients. The *in-vitro* and *ex-vivo* evaluations demonstrated that the MSNs-based formulation could achieve controlled and sustained drug release, highlighting its potential as a robust drug delivery platform.

The study successfully developed an antiarthritic gel incorporating drug-loaded MSNs, employing Carbopol 940 as the gelling agent due to its compatibility, desirable viscosity properties, and ease of application. The formulation process involved precise dispersion, hydration, and pH adjustments to achieve optimal consistency and stability. The incorporation of MSNs into the gel matrix was optimized to ensure uniform distribution, appropriate viscosity, and spreadability, resulting in a stable and effective gel formulation. The particle size and distribution analysis revealed that the nanogels were within the optimal range for effective skin penetration, with a low polydispersity index indicating homogeneity. Zeta potential measurements further confirmed the stability of the nanogels, suggesting minimal particle aggregation.

The texture analysis of the nanogels indicated favorable properties, including minimal adhesiveness, high hardness, and good cohesiveness and extrudability, which are essential for

the transdermal delivery of antiarthritic drugs. The dermatokinetic analysis demonstrated effective drug absorption with both Methotrexate and Tofacitinib Citrate reaching their maximum concentration (C_{max}) at around 4 hours post-application. Methotrexate exhibited a relatively rapid elimination with a half-life of 13.81 hours, while Tofacitinib Citrate showed a prolonged half-life of 65.07 hours, indicating a slower elimination rate. The area under the curve (AUC) values of 2065 ng.h/mL for Methotrexate and 2477 ng.h/mL for Tofacitinib Citrate indicated significant overall drug exposure, which is critical for achieving long-lasting therapeutic effects.

The study also observed distinct differences in the drug diffusion profiles, with Tofacitinib demonstrating a faster and higher permeation rate compared to Methotrexate. This was reflected in the maximum concentrations achieved, where Tofacitinib reached 99.13 µg with a rate constant of 0.91 hr^{-1}, while Methotrexate reached 66.37 µg with a rate constant of 0.88 hr^{-1}. These findings underscore Tofacitinib's superior skin penetration efficiency, which is crucial for enhancing the therapeutic efficacy of the antiarthritic gel.

The successful fitting of an exponential model to the drug concentration data underscores the robustness of the study's methodology and provides a predictive framework for drug permeation behavior, thereby facilitating the design and optimization of future formulations. The formulation's robustness was further confirmed through stability studies, which demonstrated its resilience under various storage conditions.

In conclusion, the formulated MSNs-loaded antiarthritic gel offers a promising approach for the targeted transdermal delivery of antiarthritic drugs, providing sustained and controlled drug release that could significantly enhance therapeutic outcomes for arthritis patients. The study's findings highlight the potential of mesoporous silica nanoparticles in developing advanced drug delivery systems that improve drug solubility, stability, and targeted delivery.

Future work will focus on *in vivo* studies to validate these *in vitro* findings, optimize the formulation for clinical application, and further explore the clinical potential of this novel drug delivery system in improving patient outcomes in arthritis therapy. In addition to in vivo studies and clinical application optimization, future research should explore the potential of mesoporous silica nanoparticles (MSNs) for delivering a broader range of therapeutic agents beyond antiarthritic drugs. Expanding the scope to include other chronic inflammatory

diseases could significantly enhance the versatility of MSN-based formulations. Moreover, investigating the incorporation of bioactive molecules like peptides, proteins, or nucleic acids into MSNs can open new avenues for treating various conditions where targeted and controlled drug delivery is essential. Further studies on the use of MSNs in combination therapies, where multiple drugs are delivered simultaneously, could also improve therapeutic outcomes. Advancements in surface modification techniques and the development of stimuli-responsive MSNs that release drugs in response to specific biological triggers will enhance precision in drug delivery, thereby minimizing side effects. Finally, scalability and manufacturing considerations for large-scale production should be addressed to make these innovative drug delivery systems commercially viable.