European International Journal of Multidisciplinary Research and Management Studies (ISSN: 2750-8587)

Received: 20 March 2026 | Accepted: 27 April 2026 | Published: 20 May 2026

DOI: 10.55640/eijmrms-06-05-04

RESEARCH ARTICLE

Study Of The Fundamentals For Developing A Cream Formulation Based On Zinc Oxide Nanoparticles

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VOLUME: Vol.06 Issue05 2026

PAGE: 19-23

Abstract

This article presents a review of contemporary approaches to the development of creams containing zinc oxide nanoparticles. The physicochemical and pharmacological properties of ZnO nanoparticles (ZnO NPs), including their antimicrobial, anti-inflammatory, and wound-healing activities, are discussed. Particular attention is paid to the interaction of nanoparticles with the skin, as well as to the factors influencing their stability and bioavailability. Special emphasis is placed on the selection of an optimal cream base (O/W and W/O systems), the role of excipients, and the technological aspects involved in obtaining stable dosage forms. The generalization of literature data makes it possible to identify the key parameters required for the development of effective and safe creams containing zinc oxide nanoparticles.

KEYWORDS

zinc oxide nanoparticles, ZnO NPs, cream, semisolid dosage forms, nanotechnology, pharmaceutical development, dermatology, antimicrobial activity, anti-inflammatory effect, wound healing, bioavailability, stability, emulsion systems, O/W and W/O bases, excipients, controlled release, transdermal delivery, industrial pharmacy, pharmacological properties.

INTRODUCTION

Over recent decades, there has been a steady increase in interest regarding the application of nanomaterials in pharmaceutical science and practice. The development of nanotechnology has created new opportunities for the design of dosage forms with improved biopharmaceutical characteristics, including enhanced solubility, controlled release, and targeted delivery of active pharmaceutical ingredients. Due to their small size and high specific surface area, nanoparticles possess unique physicochemical properties that enable significant modification of the pharmacokinetic and pharmacodynamic profiles of medicinal products. In this regard, the incorporation of nanomaterials into semisolid dosage forms represents one of the most promising directions in modern industrial pharmacy.

Particular attention has been devoted to semisolid dosage forms, especially creams, which are widely used in dermatological practice. This is attributable to their ability to provide localized therapeutic effects, reduce systemic exposure, and improve patient compliance. The growing interest in these dosage forms is also associated with their

potential use as carriers for nanoparticles, thereby expanding the range of therapeutic effects and increasing the efficacy of treatment for skin diseases.

Among inorganic nanomaterials, zinc oxide nanoparticles (ZnO NPs) occupy a special position due to their pronounced pharmacological properties. Zinc oxide has traditionally been used in pharmacy because of its antibacterial, anti-inflammatory, and wound-healing effects. The transition to the nanoscale form significantly enhances its biological activity. This enhancement is associated with the increased surface area and the ability of nanoparticles to generate reactive oxygen species that exert damaging effects on microorganisms. In addition, ZnO NPs demonstrate high stability, relative biocompatibility, and broad-spectrum antimicrobial activity, making them promising pharmaceutical substances for the development of semisolid dosage forms.

Despite the considerable volume of studies devoted to the application of zinc oxide nanoparticles, issues related to the rational selection of cream bases, nanoparticle stabilization, and the achievement of uniform nanoparticle distribution within the system remain insufficiently investigated. Technological aspects involved in the preparation of such dosage forms, as well as their compliance with modern pharmacopoeial and regulatory requirements, also play an important role.

The aim of the present study was to systematize and analyze contemporary literature data concerning the development of creams containing zinc oxide nanoparticles, with particular emphasis on the selection of optimal bases, excipients, and technological approaches applied in industrial pharmacy.

Materials and Methods. The study employed an analytical review of scientific literature devoted to the development of creams containing zinc oxide nanoparticles. A search and analysis of contemporary publications in the fields of pharmaceutical technology, nanotechnology, and dermatological dosage forms were carried out.

Special attention was paid to data concerning the physicochemical and pharmacological properties of zinc oxide nanoparticles, their interaction with the skin, as well as approaches to the selection of cream bases (O/W and W/O systems) and excipients. Technological aspects related to the preparation and stabilization of creams, including methods for the incorporation and distribution of nanoparticles within the system, were also examined.

The generalization and systematization of literature sources were performed in order to identify the key factors influencing the efficacy, stability, and safety of the developed dosage forms.

The key parameters determining the behavior of ZnO NPs in medicinal systems include particle size, shape, and surface characteristics. As a rule, the size of such particles varies within the range of 1–100 nm, while a decrease in particle size is accompanied by an increase in surface area and the number of active sites. Nanoparticles may possess various morphologies, including spherical, rod-shaped, prismatic, or plate-like forms, which influence their ability to interact with biological structures. Surface charge (ζ-potential), degree of aggregation, and the presence of surface-modifying coatings are also of considerable importance, as these factors determine the stability of dispersions and the distribution of particles within the dosage form. The surface properties of ZnO NPs play a key role in their interaction with cellular membranes and protein structures, thereby affecting their bioavailability and therapeutic efficacy.

According to contemporary studies, zinc oxide nanoparticles exhibit pronounced antimicrobial activity against a broad spectrum of microorganisms, including Gram-positive and Gram-negative bacteria, as well as certain fungal species. It has been demonstrated that the efficacy of ZnO NPs increases with decreasing particle size and increasing concentration. Their activity against pathogens such as Staphylococcus aureus and Escherichia coli has been reported, making them promising candidates for use in topical dosage forms.

In addition to their antimicrobial effects, ZnO NPs demonstrate anti-inflammatory activity. This effect is associated with their ability to reduce the production of pro-inflammatory cytokines and decrease oxidative stress within tissues. Furthermore, zinc oxide contributes to the acceleration of tissue regeneration processes.

The primary mechanism of action of ZnO NPs following topical application is associated with their localization within the stratum corneum and hair follicles. Most particles do not penetrate into the systemic circulation, making them relatively safe for local application. However, they are capable of forming a depot of active substance on the skin surface, thereby providing prolonged therapeutic action. Their

interaction with the skin barrier also depends on the condition of the skin, as permeability increases significantly in the presence of damage.

Cream bases used in industrial pharmacy are divided into several principal categories. The most common are emulsion systems of the oil-in-water (O/W) and water-in-oil (W/O) types. O/W systems are characterized by a lighter texture, better washability, and a pronounced moisturizing effect, whereas W/O systems possess more pronounced protective and occlusive properties.

Hydrophilic and lipophilic bases are also distinguished according to the predominance of either the aqueous or lipid phase. The selection of the base type directly influences the release of the active substance and the stability of the dosage form.

From a pharmaceutical perspective, the cream base should ensure system stability, remain inert toward nanoparticles, and not alter their physicochemical properties. An important requirement is the absence of chemical interactions between the base and ZnO NPs, as well as the ability to maintain uniform particle distribution.

In addition, the base should provide controlled release of the active substance and maintain its therapeutic concentration at the site of application. The rheological properties of the system are also of major importance, as they determine both ease of application and formulation stability.

According to literature data, different types of bases influence the efficacy of ZnO NPs in different ways. O/W emulsion systems provide more rapid release of the active substance, whereas W/O systems promote prolonged retention of nanoparticles on the skin. It has also been demonstrated that the composition of the base may significantly affect nanoparticle aggregation and bioavailability.

Table 1.

Comparative Characteristics of Creams, Ointments, and Gels.

Dosage Form	Base / Matrix	Moisture Content	Occlusiveness	Texture / Sensory Characteristics	Preferred Area of Application
Cream	Emulsion (O/W or W/O)	>20% water and volatile substances	Moderate	Less greasy, easily spread, washable	Areas with exudation, normal skin
Ointment	Fatty or hydrocarbon/oily base	Low water content (<20%)	High	Greasier, forms a film, remains longer on the skin	Dry, scaly skin; localized areas
Gel	Polymer matrix + liquid (usually aqueous)	High water content	Low to moderate	Lightweight sensation, cooling effect, rapid absorption	Hair-bearing areas, large surfaces, situations where greasiness is undesirable

Excipients play a key role in the development of stable dosage forms containing zinc oxide nanoparticles. Emulsifying agents ensure the formation and stabilization of emulsion systems by reducing interfacial tension and preventing phase separation.

Nanoparticle stabilizers perform the important function of preventing the aggregation of ZnO nanoparticles (ZnO NPs), thereby preserving their nanoscale properties. Preservatives are incorporated to inhibit microbial growth, while pH regulators provide optimal conditions for system stability.

Humectants such as glycerol and propylene glycol enhance skin hydration and may influence the permeability of the dosage form. Contemporary approaches to excipient selection are based on the principle of minimizing interactions with the active pharmaceutical ingredient while maximizing overall

system stability.

The appropriate selection of a semisolid dosage form is important from the perspectives of ease of application (patient compliance), the desired delivery profile (localized retention versus rapid release), aesthetic characteristics (sensory feel, greasiness, and residue formation), skin compatibility, and the physiological condition of the skin (dry, moist, or damaged). For example, in cases of moist skin or the presence of exudation, a cream (O/W) or gel formulation is generally preferred over a greasy ointment. The formulation of semisolid dosage forms should take into account the properties of the base, its interaction with the active substance, the skin surface, and the excipient components.

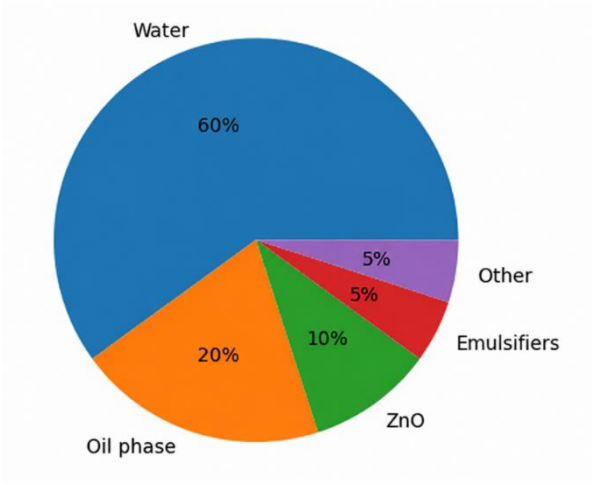

Diagram 1. Cream Composition

Conclusion. The analysis of literature data demonstrates that the development of creams containing zinc oxide nanoparticles represents a promising direction in contemporary pharmaceutical technology. The efficacy of such systems is determined by the properties of the nanoparticles, the type of cream base, and the composition of excipients. Rational selection of components and technological approaches makes it possible to ensure the stability, safety, and the desired release profile of the active substance. The summarized data may serve as a basis for further research and optimization of technologies for the preparation of creams containing zinc oxide nanoparticles.

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