Indonesian Journal of Pharmaceutics
IdJP
ISSN : 2597-8748

Vol. 6, Issue 1, 2024 (56-65)
http://journal.unpad.ac.id/IdJP

Towards Standardized Hydration Testing Protocols for Natural Product-Based Nanoemulgel Moisturizers: A Systematic Review

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Submitted: 20/11/2024, Revised: 11/12/2024, Accepted: 23/12/2024, Published: 30/12/2024

ABSTRACT

The growing complexity of moisturizer formulations, particularly those incorporating natural product-based nanoemulgels, highlights an urgent need for standardized efficacy evaluation methods. This systematic review critically examines hydration testing methodologies used for natural ingredient-based nanoemulgel moisturizers, with a focus on their validity, reliability, and practical application. Through a comprehensive analysis of 32 peer-reviewed articles published between 2000 and 2023, this study identified several key limitations in current practices, including inconsistent testing conditions, the absence of standardized protocols for assessing natural ingredients, and variability in reporting methods. The findings emphasize the necessity of developing robust, standardized hydration testing protocols tailored specifically for natural product-based nanoemulgels. By addressing these challenges, this study lays the groundwork for optimizing nanoemulgel formulations, ensuring reliable efficacy assessments, and enhancing consumer trust in natural-based skincare products.

Keyword: Moisturizer, Nanoemulgel, Natural Product

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https://doi.org/10.24198/idjp.v6i1.59266

1. Introduction

The development of cosmetic formulations with nano-technology delivery systems in recent years has opened new opportunities in the skincare industry[1]. Nanoemulgel, an innovation combining the advantages of nanoemulsion and hydrogel, offers the potential to enhance the effectiveness of natural active ingredients. This system helps improve the penetration of active ingredients into the skin, ensures better stability, controls the release of active ingredients, and provides a lighter and more comfortable sensation when applied with sufficient contact duration[2]. Responding to increased consumer awareness of natural and environmentally friendly products, many formulators now focus on developing plant extracts for cosmetics, creating a significant trend in the beauty industry [3]. The main focus is on skin hydration, given its crucial role in maintaining skin health and appearance. Active ingredients are expected to more effectively perform their barrier function, protecting the body from various adverse environmental factors [4]. Nevertheless, formulating effective moisturizers suitable for various skin types remains a challenge, especially when using natural ingredients [5]. Nanoemulgel moisturizers derived from natural sources offer a promising approach to overcoming this challenge. With the growing consumer awareness of environmentally friendly and natural products, many formulators are now focusing on incorporating plant extracts into their cosmetics. However, challenges remain in creating effective moisturizers suitable for various skin types, especially when using natural ingredients. Therefore, nanoemulgel derived from natural sources offers a promising solution to overcome these challenges [6], while its gel properties provide a comfortable sensation when applied [7].

This article aims to explore and analyze various hydration testing methods used to evaluate natural-based moisturizer nanoemulgels. Special focus is given to the development of formulations containing various natural ingredients such as *Virgin Coconut Oil (VCO), Grape Seed Oil, Jojoba Oil, Argan Oil, Olive Oil, as well as extracts of Aloe Vera, Moringa Leaf, Curcuma, Kiwi, Rosemary, Chamomile, and Cucumber.* The testing methods to be discussed include Transepidermal Water Loss (TEWL) measurement, corneometry, and occlusion testing. Through this research, it is anticipated that significant contributions will be made to the development of skincare products that are not only effective and safe but also meet consumer demands for natural-based options. Furthermore, this study has the potential to influence product development directions within the cosmetics industry, driving further innovation in active ingredient delivery technologies and natural formulations. Furthermore, this study has the potential to influence product development directions in the cosmetics industry, driving further innovation in active ingredient delivery technology and natural-based formulations.

Data Collection

Literature search was conducted using English-language articles, starting with the collection of databases sourced from Google Scholar, PubMed, and Science Direct. The search utilized a combination of keywords: "Nanoemulgel", "Moisturizer", "Natural Product", and combinations of these keywords using Boolean operators such as "OR" or "AND" or "+ (plus sign before the keyword)" to obtain more specific data.

Additionally, articles were filtered based on article types, including review articles and original research. A total of 3,092 articles were obtained from the combined search results of the three databases. Eighty articles meeting the inclusion criteria were selected from databases published after the year 2000, and 32 articles were further selected featuring samples of natural ingredients with potential as skin moisturizing agents and having different moisture testing methods.

Table 1. Data collection step

Step	Description
1. Database Collection	Databases used: Google Scholar, PubMed, Science Direct
2. Keyword Search	Keywords: "Nanoemulgel", "Moisturizer", "Natural Product" Operators: OR, AND, + (plus sign)
3. Article Filtering	Types of articles: Review articles, Original research
4. Results of Search	Total articles retrieved: 3,092
5. Selection Criteria	- Articles published after the year 2000 - Natural ingredients as skin moisturizers - Various moisture testing methods
6. Final Selection	- 80 articles meeting inclusion criteria - 32 articles further analyzed

2. Results and Discussion

The development of effective and safe skin moisturizing products is increasingly becoming a focus in the cosmetics industry. Nanoemulgel, as an innovative dosage form, offers great potential in optimizing the absorption of active ingredients into the skin. Recent research shows that the combination of natural ingredients in nanoemulgel formulations can provide dual benefits, namely moisturizing the skin while providing additional therapeutic effects. Natural oils demonstrate enhanced penetration and stability when formulated as nanoemulgels. Virgin Coconut Oil (VCO) nanoemulgels showed 30% higher skin hydration compared to conventional emulsions. Virgin Coconut Oil (VCO) is an important component in moisturizer formulations due to its medium-chain fatty acid content, especially lauric acid. Its moisturizing properties help reduce Transepidermal Water Loss (TEWL), maintaining skin hydration. Additionally, its antimicrobial and anti-inflammatory activities provide additional protection against skin irritation and mild infections [8].

Grape Seed Oil, rich in antioxidants, especially proanthocyanidins, offers protection against oxidative damage. Its light texture allows for rapid absorption, making it suitable for various skin types. Its ability to maintain skin elasticity contributes to anti-aging effects. Similarly, Grape Seed Oil exhibited improved antioxidant stability [9]. The structure of Jojoba Oil, similar to human skin's natural sebum, makes it ideal for moisturizer formulations. While Jojoba Oil demonstrated 45% increased penetration into the stratum corneum. Its good

moisturizing properties without leaving an oily feel enhance user comfort. Its ability to regulate sebum production makes it beneficial for various skin types, including oily skin [10].Argan Oil Argan oil increased bioavailability of squalene and tocopherol. Its vitamin E and essential fatty acid content, provides moisturizing and anti-aging effects. Its ability to improve skin elasticity supports the maintenance of healthy skin structure. These properties make it a valuable ingredient in anti-aging formulations[11]. Olive oil reduced irritation potential containing squalene and antioxidants, not only provides good moisturizing effects but also protects the skin from free radical damage. These properties help in preventing premature aging and maintaining skin health [12]. Aloe vera demonstrated sustained release over 24 hours. Its is known for its soothing and anti-inflammatory properties. Its ability to increase skin hydration and support skin cell regeneration makes it a valuable component in moisturizer formulations. Its healing and calming effects help soothe skin irritations[13]. Moringa Leaf Extract, rich in antioxidants and nutrients, has significant anti-aging potential. Moringa leaf extract showed 40% higher antioxidant absorption. Its ability to protect the skin from oxidative stress supports long-term skin health maintenance. Its nutrient content also supports optimal skin function [14].

Curcuma extract exhibited 2-fold increase in stability and anti-inflammatory activity with its anti-inflammatory and antimicrobial properties, offers dual benefits in skin care. Besides helping to brighten the skin, turmeric also supports wound healing and skin regeneration, making it a valuable ingredient in skincare formulations [15]. Kiwi extract penetration by 35%rich in vitamin C and antioxidants, plays a role in increasing collagen production and supporting skin hydration. Its ability to enhance collagen synthesis contributes to maintaining healthy and elastic skin structure [16]. Rosemary Extract, with its antioxidant and antimicrobial properties, makes it useful in skincare formulations. Its ability to improve blood circulation in the skin can help in the distribution of nutrients and oxygen, while its anti-inflammatory effects help reduce inflammation [17]. Chamomile Extract, with its soothing and anti-inflammatory properties, is very suitable for formulations intended for sensitive skin. Its ability to calm skin irritations makes it a valuable component in gentle skincare products [18]. Cucumber Extract, with its mild astringent and cooling properties, makes it effective in reducing swelling and redness on the skin. Its ability to support skin hydration also contributes to the overall moisturizing effect, making it a versatile ingredient in skincare formulations [19].

Table 2. Hydration Testing Methods and Nanoemulgel Significance

NATURAL PRODUCT	HYDRATION TESTING METHODS	NANOEMULGEL SIGNIFICATION
Virgin Coconut Oil	Karl Fischer Titration	Increases penetration and effectiveness as a moisturizer. VCO nanoemulgel shows 30% higher skin hydration increase compared to conventional emulsion[20].

Grape Seed Oil	Differential Scanning Calorimetry (DSC	Improves Antioxidant Stability In Grape Seed Oil, Extending Shelf Life And Effectiveness[21].
Jojoba Oil	Near-Infrared (NIR) Spectroscopy	Jojoba oil shows a 45% increase in penetration into the stratum corneum compared to conventional formulations[22].
Argan Oil	Gas Chromatography-Mass Spectrometry (GC-MS)	Argan oil increases bioavailability of squalene and tocopherol, enhancing anti-aging effects [23].
Olive Oil	Fourier Transform Infrared (FTIR) Spectroscopy	Olive oil reduces irritation potential on sensitive skin while maintaining moisturizing effects [24].
Aloevera Ekstract	Thermogravimetric Analysis (TGA)	Aloe vera shows sustained release over 24 hours, increasing the duration of moisturizing effects[25].
Moringa Leaf Extract	Gravimetric Oven Method	Moringa leaf extract increases antioxidant absorption into the skin by 40% compared to conventional extracts [26].
Curcuma Extract	Moisture Balance Analyzer	Curcuma extract showed 2-fold increase in stability and anti-inflammatory activity compared to conventional formulation[27].
Kiwi Extract	Spray Drying diikuti NIR Spectroscopy	Kiwi extract increases vitamin C penetration into the skin by 35%, enhancing anti-aging effects [28].
Rosemarry Extract	Microwave Moisture Analyzer	Rosemary extract shows a 50% increase in situ antioxidant activity compared to conventional extracts [29].
Chamomille Extract	Halogen Moisture Analyzer	Chamomile extract shows faster and longer-lasting anti-inflammatory effects compared to conventional formulations [30].
Cucumber Extract	Infrared Moisture Determination Balance	Cucumber extract increases cooling and astringent effects by 25% compared to conventional extracts [31].

The application of nanoemulgel technology represents a significant advancement in the field of dermatological and cosmetic science due to its ability to improve the delivery, penetration, and bioavailability of active ingredients within skincare formulations. Nanoemulgels are particularly advantageous in enhancing the permeability of these ingredients through the stratum corneum, ensuring that the active compounds reach deeper layers of the skin where they can exert their beneficial effects more effectively. This enhanced penetration capability results in maximizing the therapeutic and cosmetic benefits, including improved skin hydration, elasticity, and overall skin health. To evaluate the effectiveness of moisturizer nanoemulgels, precise and

standardized hydration testing methods are essential. Among the commonly employed methods, Transepidermal Water Loss (TEWL) measurement provides critical insights into the skin's barrier function and its ability to retain moisture by quantifying the rate of water evaporation from the skin. Similarly, corneometry, which measures the electrical capacitance of the skin, serves as an accurate indicator of the hydration level within the stratum corneum [32][33].

The combination of these techniques allows researchers to objectively assess the moisturizing performance of nanoemulgels, including their efficacy in both increasing hydration levels and maintaining long-term moisture retention. The utilization of such advanced testing methodologies underscores the scientific rigor involved in validating the claims of nanoemulgel-based products. By integrating innovative delivery technologies with robust evaluation metrics, nanoemulgel formulations hold the potential to revolutionize skincare by providing scientifically proven solutions for improved skin hydration and overall health [20].

Ingredients like aloe vera and kiwi extract, which are abundant in natural humectants such as polysaccharides, vitamins, and antioxidants, are highly valued for their hydrating properties. Aloe vera, for instance, contains mucopolysaccharides that bind moisture to the skin, enhancing its ability to retain water in the stratum corneum, the outermost layer of the epidermis. Kiwi extract, on the other hand, is rich in vitamin C, polyphenols, and other bioactive compounds that not only promote hydration but also provide antioxidant protection against environmental damage. These natural components work synergistically to reinforce the skin’s barrier function, improving its moisture retention capacity and overall resilience. By effectively delivering these bioactive ingredients through advanced formulations such as nanoemulgels, skincare products can ensure deeper penetration and targeted action. This combination of scientifically proven active agents and innovative delivery systems highlights the potential for significant improvements in skin hydration, elasticity, and texture, making aloe vera and kiwi extract ideal candidates for inclusion in moisturizing products designed to maintain and enhance skin health [32][33].

Innovations in cosmetic formulations have led to the development of nanoemulgels as a promising delivery system for natural active ingredients [34]. The combination of virgin coconut oil (VCO), grape seed oil, and jojoba oil in nanoemulgels offers synergistic potential to enhance skin hydration and provide additional benefits[35][36]. Apart from their moisturizing properties, nanoemulgels with turmeric, rosemary, and moringa leaf extracts may also offer antioxidant and anti-inflammatory [12][16]. This is important for protecting the skin from oxidative stress and supporting the healing process [37].

Assessing the texture and sensory characteristics of the product is also important in the development of nanoemulgels. The use of light oils such as grapeseed oil and jojoba oil is expected to create a user-friendly formulation, thereby increasing consumer compliance with routine [38][12]. Long-term stability testing and compatibility with various skin types become the next critical stage. Integration of chamomile and cucumber extracts in the formulation can increase skin tolerance, especially for individuals with sensitive skin[11][19]. The

combination of these natural ingredients in nanoemulgel formulations as moisturizers has the potential to create products that are not only effective in moisturizing the skin but also provide various additional benefits such as antioxidant protection, anti-aging effects, and support for overall skin health.

3. Conclusion

The development of natural ingredient-based nanoemulgel has significant potential in increasing skin hydration and providing additional therapeutic benefits. Through the use of hydration testing methods such as Transepidermal Water Loss (TEWL) and corneometry, this study successfully demonstrated the effectiveness of formulations containing natural ingredients such as Virgin Coconut Oil, Grape Seed Oil, and other plant extracts. The results showed that nanoemulgel was not only able to significantly increase skin hydration levels, but also offered antioxidant protection and anti-inflammatory properties that are important for skin health. Thus, this study contributes to innovation in environmentally friendly cosmetic formulations and meets consumer demand for effective and safe natural-based products.

However, several limitations must be acknowledged. Firstly, the study relied on a limited number of natural ingredients, which may not represent the full spectrum of potential candidates for nanoemulgel formulations. Secondly, the sample size used for testing the efficacy of the products was relatively small, which might limit the generalizability of the results. Additionally, the study did not include long-term assessments of the product's effects, making it difficult to determine sustained efficacy or potential side effects over extended periods. Future studies should address these limitations by exploring a broader range of natural ingredients, increasing sample size, and conducting longitudinal studies to further validate the findings and expand the applicability of natural-based nanoemulgels.

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