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BRIDGING THE GAP: EVALUATING EMOLLIENTS AND EMULSIFIERS IN DERMATOLOGY FOR LONG-TERM SKIN HEALTH AND BARRIER RECOVERY

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Abstract. Bridging the gap: evaluating emollients and emulsifiers in dermatology for long-term skin health and barrier recovery. Brunina L. *This study addresses the significant gap in existing literature regarding the long-term effects of emollients and emulsifiers on skin health to systematically evaluate the impact of these substances on Trans-Epidermal Water Loss (TEWL) and skin barrier functions across various skin conditions. The main aim of this research is to evaluate the effects of commonly used emollients and emulsifiers on skin barrier function across different skin conditions to provide insights that will contribute to the development of optimized skincare formulations for individuals with compromised skin barriers. A literature search was conducted across multiple databases, including PubMed, Scopus, Web of Science, and Google Scholar, using targeted search strings to gather relevant studies published over the last 20 years. The inclusion criteria focused on peer-reviewed studies that provided empirical data on the effects of emollients and emulsifiers on TEWL and skin barrier functions, specifically in human subjects. A total of 88 articles were initially identified, with 41 meeting the strict inclusion criteria after quality assessment using Joanna Briggs Institute checklists. The review revealed varied effects of emollients and emulsifiers on skin health. Natural oils were found to enhance skin barrier functions and reduce TEWL, whereas synthetic emollients raised concerns about their occlusive properties and potential to worsen skin conditions over time. Emulsifiers showed dual effects; some exacerbated TEWL in normal skin but reduced it in damaged skin, highlighting the complexity of their interaction with skin barrier components. The findings emphasize the need for standardized research methodologies and long-term studies to better understand the mechanisms by which emollients and emulsifiers influence skin health, particularly regarding TEWL measurement techniques while products do exhibit dual behavior and scientific evidence should guide the selection of emulsifiers and emollients in skincare products to ensure both efficacy and long-term safety as well as the special assessment of the safer alternative what support both human health and environmental sustainability.*

Реферат. Подолання розриву: оцінка пом'якшувачів та емульгаторів у дерматології для довгострокового здоров'я шкіри та відновлення бар'єру. Бруніна Л. *У цьому дослідженні розглядається значна прогалина в наявній літературі щодо тривалого впливу пом'якшувачів та емульгаторів на здоров'я шкіри, щоб систематично оцінювати вплив цих речовин на трансепідермальну втрату води (TEWL) і функції шкірного бар'єру при різних захворюваннях шкіри. Основна мета цього дослідження полягає в тому, щоб оцінити вплив пом'якшувачів та емульгаторів, які зазвичай використовуються, на функцію шкірного бар'єру при різних захворюваннях шкіри, щоб отримати інформацію, яка сприятиме розробленню оптимізованих рецептур засобів для догляду за шкірою для осіб із порушеним шкірним бар'єром. Пошук літератури проводився в багатьох базах даних, включаючи PubMed, Scopus, Web of Science і Google Scholar, використовуючи рядки цільового пошуку для збору відповідних досліджень, опублікованих за останні 20 років. Критерії включення були зосереджені на рецензованих дослідженнях, які надали емпіричні дані про вплив пом'якшувачів та емульгаторів на TEWL і функції шкіри, особливо в людей. Спочатку було ідентифіковано 88 статті, 41 з яких відповідає суворим критеріям включення після оцінювання якості за допомогою контрольних списків Інституту Джоанни Бріггс. Огляд виявив різноманітний вплив пом'якшувачів та емульгаторів на здоров'я шкіри. Було виявлено, що натуральні олії покращують бар'єрні функції шкіри та зменшують TEWL, тоді як синтетичні пом'якшувачі викликають занепокоєння щодо їхніх оклюзійних властивостей та потенціалу погіршення стану шкіри з часом. Емульгатори показали подвійну дію: деякі посилювали TEWL у нормальній шкірі, але знижували його в пошкодженій шкірі, підкреслюючи складність їх взаємодії з компонентами шкірного бар'єру. Результати підкреслюють необхідність стандартизованих дослідних методологій і довгострокових досліджень, щоб краще*

зрозуміти механізми, за допомогою яких пом'якшувачі та емульгатори впливають на здоров'я шкіри, зокрема щодо методів вимірювання TEWL, оскільки продукти чинять подвійну дію. Результати наукових досліджень повинні визначати вибір емульгаторів і пом'якшувачів у продуктах по догляду за шкірою, щоб забезпечити як ефективність, так і довгострокову безпеку. Також необхідно здійснювати спеціальне оцінювання безпечнішої альтернативи, яка підтримує здоров'я людини та екологічну сталість.

The skin acts as a critical barrier against environmental aggressors and plays a vital role in maintaining homeostasis. Emollients and emulsifiers are commonly used in moisturizers to enhance skin barrier functions and provide relief from various dermatological conditions, such as eczema, atopic dermatitis, and psoriasis. Despite the extensive application of these compounds in skincare and therapeutic products, a comprehensive understanding of their individual and combined effects on skin health remains underexplored. Extensive research has been conducted on the impact of emollients and emulsifiers on the skin. Emollients are known to hydrate and smooth the skin by filling spaces between skin flakes with droplets of oil, whereas emulsifiers are used to stabilize product formulations and can influence the skin's barrier properties by interacting with its lipid components [1]. Most studies, however, focus on the physical properties of the moisturizer formulations, such as rheology, spreadability, viscosity, and droplet size, without an in-depth analysis of skin physiological responses, particularly Trans-Epidermal Water Loss or TEWL, which is a critical measure of the skin's barrier function [2]. Moreover, while some research integrates the effects of these substances on normal skin, the responses in damaged skin, which presents a compromised barrier [3], are not sufficiently documented [1]. This is particularly significant as the skin with impaired barrier function reacts differently to cosmetic and therapeutic formulations compared to healthy skin. The interaction between topical applications and damaged skin may accelerate or inhibit the natural recovery processes, influencing the long-term health of the skin [4].

As a result, topicality of research lies in the fact that the current literature lacks a unified model that compares the effectiveness of different emollients and emulsifiers across various skin conditions within the same experimental setup. This gap impedes the ability to draw conclusive evidence about which ingredients are most beneficial for skin barrier maintenance and repair, especially as part of a preventive skincare regime or as a complementary treatment in chronic skin diseases [5]. This study aims to address these gaps by evaluating a range of commonly used emollients and emulsifiers within a consistent experimental framework to assess their immediate and long-term impacts on TEWL and skin barrier recovery. By conducting a comparative analysis across different skin conditions, this research seeks to elucidate the differential effects of these ingredients and propose optimized strategies for skincare and treatment of skin barrier-related disorders.

MATERIALS AND METHODS OF RESEARCH

To ensure a comprehensive understanding of the current landscape of research concerning the impact of emollients and emulsifiers on skin health, a systematic search of the literature was conducted. The search aimed to identify all relevant studies that discuss the physiological effects of emollients and emulsifiers on skin, including TEWL, skin barrier function, and long-term skin health.

The search was performed using several scientific databases to ensure broad coverage of the literature. These databases included PubMed, Scopus, Web of Science, and complimented with Google Scholar as additional source. Each database was queried to maximize the retrieval of pertinent studies using a combination of the following keywords and their combinations: "emollient," "emulsifier," "skin," "TEWL," "trans-epidermal water loss," "skin barrier function," "eczema," "atopic dermatitis," "psoriasis," and "long-term effects."

The search strategy was tailored to the specific indexing terms and search capabilities of each database. As a primary search string was the PubMed search, where the search terms were used in conjunction with Medical Subject Headings [MeSH] to refine the results. The search strings were adapted for each database to align with their respective search syntax and capabilities. The search string used in PubMed was: ["emollients"[MeSH Terms] OR "emollients"[All Fields]] AND ["emulsifiers"[MeSH Terms] OR "emulsifiers"[All Fields]] AND ["skin"[MeSH Terms] OR "skin"[All Fields]] AND ["TEWL"[All Fields] OR "trans-epidermal water loss"[All Fields] OR "skin barrier"[All Fields]]. For the Scopus the search string was adapted accordingly: [TITLE-ABS-KEY [emollients] OR TITLE-ABS-KEY [emulsifiers]] AND [TITLE-ABS-KEY [skin] AND [TITLE-ABS-KEY [TEWL] OR TITLE-ABS-KEY ["trans-epidermal water loss"] OR TITLE-ABS-KEY ["skin barrier"]]]. Following the similar approach the search string for Web of Science was: [TS=[emollients] OR TS=[emulsifiers]] AND TS=[skin] AND [TS=[TEWL] OR TS=["trans-epidermal water loss"] OR TS=["skin barrier"]]. As per Google scholar the search string was: [emollients OR emulsifiers] AND skin AND [TEWL OR "trans-epidermal water loss" OR "skin barrier"].

The author formed a set of articles from the 20 years' time span starting from 2004 and excluded repeated articles, where the total set was 1022 unique articles and proceeded to the formation of the sample for the review. Studies included in the review were those that:

1. Were published in peer-reviewed journals.
2. Included empirical data on the effects of emollients and/or emulsifiers on skin properties.
3. Addressed outcomes related to TEWL, skin barrier function, or related physiological measurements.
4. Were conducted on human subjects; animal and in vitro studies were excluded to focus on clinically relevant data.
5. Were written in English.

The exclusion criteria for the sources when conducting the search were:

1. Studies that did not specifically address the effects of emollients or emulsifiers.
2. Review articles, commentaries, opinion pieces, and editorials were excluded to focus on original research.
3. Studies that only measured cosmetic outcomes without physiological data.
4. Studies with insufficient methodological transparency or unverified data.

As part of the methodology, the author employed a structured data extraction process. Key parameters recorded from each article included: authorship, year of publication, study type and design, sample size, demographics, emollient or emulsifier type, targeted skin condition (if any), measurement techniques and major outcomes. Accordingly, the final sample of 88 articles was formed, where the relevant data were extracted from each study, including the author(s), year of publication, study design, sample size, type of emollient or emulsifier used, skin condition treated (if any), outcome measures, and key findings.

The quality of the included studies was assessed using standardized checklists from the Joanna Briggs Institute (JBI), tailored for each study design. This assessment helped determine the reliability and validity of the findings reported in the literature. The assessment was performed and the cross-referred data were excluded finalizing in the final sample of 41 articles. This data extraction facilitated a structured synthesis of the findings across the collected literature.

This research was conducted in accordance with the principles of the Declaration of Helsinki (2013) and the Universal Declaration on Bioethics and Human Rights (UNESCO, 2005). The study protocol was reviewed and approved by the Research Ethics Committee of Turība University (previously, SKK), protocol number 3-36/23-011. The confidentiality and anonymity were preserved in accordance with legal and ethical standards.

RESULTS AND DISCUSSION

The systematic review of the literature revealed a diverse array of studies that examined the impact of various emollients and emulsifiers on skin health, presenting a broad spectrum of findings that often appeared contradictory. This section synthesizes the findings from the literature, highlighting key trends, discrepancies, and the implications of these findings on the use of emollients and emulsifiers in dermatological practice. A significant variance was observed in the outcomes related to the effectiveness of different emollients in improving skin conditions. Studies ranged from those touting the benefits of natural oils like sunflower and jojoba oil in enhancing skin barrier functions [6, 7] and reducing TEWL [8, 9], to research indicating potential adverse effects of synthetic emollients like mineral oil and petrolatum, which could occlude the skin excessively, potentially worsening certain skin conditions over long-term use [10, 11]. The review identified several studies that focused on the role of occlusive emollients in skin care. These emollients, including petrolatum and dimethicone, were frequently highlighted for their ability to significantly reduce TEWL, especially in conditions like atopic dermatitis [9] and psoriasis [12]. However, the occlusivity of these substances also raised concerns regarding their potential to trap bacteria and other irritants against the skin [13], which could exacerbate skin conditions in susceptible individuals [14]. An emerging area of interest was the use of emollients in neonatal care [15, 16, 17], particularly the hypothesis that early introduction of barrier-enhancing emollients [7] could reduce the incidence of atopic dermatitis and potentially prevent the development of food allergies. Studies [18] in this area presented mixed results, with some showing promising outcomes in allergy prevention, while others indicated minimal or no effect, underscoring the need for more targeted research. Numerous studies [19, 20] focused on the measurement of TEWL in different scenarios, ranging from the impact of skin cleansing agents like sodium lauryl sulfate [SLS] to assessments of skin barrier function [6] in healthy individuals. These studies commonly employed a range of emollients and evaluated their protective or restorative properties [12] on the skin's moisture barrier.

Research on emulsifiers revealed a complex picture, with various types such as PEGs, stearates, lecithin, and sulfates being analyzed for their roles in topical formulations [19, 21, 22]. Recent studies raised significant concerns about the health implications of certain emulsifiers like PEGs, which were linked to potential carcinogenicity [23], the development of anti-PEG antibodies [24], adverse impacts on mitochondrial function [25], and

inhibition of cell proliferation [26]. These findings highlight the critical need for careful consideration of emulsifier types in cosmetic and pharmaceutical formulations to mitigate potential risks. As a result, the literature review uncovered a complex landscape of research on emollients and emulsifiers, with significant variations in study outcomes and methodologies. While some emollients showed potential for improving skin barrier functions and managing dermatological conditions, the long-term effects and the implications of certain synthetic emollients and emulsifiers require careful scrutiny. The findings underscore the necessity for ongoing research to elucidate the mechanisms by which these substances affect skin health and to develop guidelines that optimize their use in clinical and cosmetic contexts. Future studies should aim to harmonize methodologies and focus on longitudinal effects to better understand the implications of emollient and emulsifier use on skin health and disease management.

The current landscape of dermatological research reveals a significant gap in the comprehensive understanding of the long-term impacts of emollients and emulsifiers on skin health, particularly those that are synthetic and non-biodegradable. These substances exhibit varying effects on damaged versus healthy skin, contributing to an ongoing challenge in dermatology: the lack of consistent and long-term data that could guide therapeutic interventions more reliably. This variability is especially problematic when considering the management of conditions with impaired barrier functions, such as atopic dermatitis [27], psoriasis [28], and eczema [29]. TEWL has been extensively utilized to assess skin barrier integrity, playing a pivotal role in the evaluation of skin conditions and the effectiveness of topical formulations. The wide array of methodologies [30] applied across different studies, however, has resulted in diverse findings [5] that complicate the ability to draw definitive conclusions. For example, studies [31, 32] employing various types of emulsifiers have shown that these can either increase TEWL in normal skin or decrease it in damaged skin, suggesting a dual role that depends heavily on the specific skin condition and the type of emulsifier used.

In normal skin, certain emulsifiers may disrupt the natural lipid matrix, leading to increased TEWL and indicating a compromised barrier function. Conversely, in surfactant-irritated skin, these same emulsifiers might act protectively or reparatively by integrating into and modifying the damaged barrier, thereby reducing TEWL. This paradoxical effect underscores the complex interactions between emulsifiers [33] and the skin barrier and highlights the potential therapeutic benefits of these substances if they can be harnessed correctly [34]. The discussion around synthetic versus natural emulsifiers is critical [11, 35], particularly given the growing body of evidence suggesting that synthetic emulsifiers may accumulate within the skin's lipid matrix, potentially leading to long-term disruption of barrier integrity [27, 36]. This accumulation can exacerbate conditions in patients with sensitive skin or those with barrier impairments, leading to a cycle of dependency on topical formulations for barrier maintenance.

In studies, the relationship between the structure of commonly used emulsifiers and their effects on skin was explored using non-invasive bio-engineering methods [33]. The findings indicate that emulsifiers, varying in ethoxylation and alkyl chain lengths, do not consistently affect skin erythema but significantly increase TEWL without inducing inflammation. This increase suggests that these emulsifiers may disrupt the skin barrier by altering the lipid membranes, which could enhance the bioavailability of drugs and potentially harmful substances [36]. Notably, the same emulsifiers that increased TEWL in normal skin also decreased it in surfactant-damaged skin, suggesting their dual ability to modify barrier properties depending on the skin's condition [34]. As a result, the ability of certain emulsifiers to decrease TEWL in damaged skin while increasing it in normal skin may have important therapeutic implications. It suggests that emulsifiers could be utilized to regulate drug absorption by modulating skin permeability [37]. This could be particularly beneficial for enhancing drug absorption in areas of low permeability or reducing it in areas where permeability is too high. This regulatory potential of emulsifiers could make them valuable in both pharmaceutical formulations and skincare products, where precise control over drug delivery and barrier integrity is crucial [38]. Given these opposing effects, it is crucial to determine the underlying mechanisms by which emulsifiers interact with skin lipids. One possible explanation is that emulsifiers disrupt lipid bilayers in healthy skin by increasing fluidity, leading to greater permeability. In damaged skin, however, emulsifiers may instead fill in structural gaps, stabilizing the lipid layers and reducing water loss [39]. This dual nature raises important questions regarding their suitability for long-term use in skincare formulations. Further investigation is needed to establish guidelines on the safe and effective incorporation of emulsifiers in both cosmetic and therapeutic applications [40]. The ability of emulsifiers to modulate permeability suggests a potential role in enhancing or restricting the absorption of active ingredients [41]. However, achieving this level of precision requires further

research into the structural properties of emulsifiers and their interactions with various skin types.

The analytical review conducted in this study highlights the significant heterogeneity in findings regarding the effects of emollients and emulsifiers on skin barrier function and TEWL. Across the 41 rigorously selected studies, a common trend emerged: while natural emollients such as plant-based oils (e.g., sunflower, jojoba) consistently demonstrated beneficial effects on the restoration of the skin barrier and reduction of TEWL, synthetic emollients often posed concerns regarding long-term occlusivity and barrier impairment. This duality aligns with emerging dermatological theories emphasizing the importance of lipid compatibility and skin-type-specific response to topical agents. Furthermore, the evidence regarding emulsifiers was even more fragmented. Studies reported that emulsifiers may increase TEWL in healthy skin by disrupting lipid bilayers, while simultaneously reducing TEWL in damaged skin through barrier integration. This dichotomous behavior underscores the need for targeted formulation strategies depending on the skin condition being treated. Notably, the literature also reflects a lack of longitudinal studies assessing the cumulative effects of emulsifiers, especially PEG-based compounds, which have raised safety concerns due to potential carcinogenicity, immune sensitization, and mitochondrial toxicity.

Despite the methodological advances in TEWL measurement and skin barrier assessment, the review revealed significant variation in study design, sample size, duration, and outcome reporting, making direct comparisons challenging. The scarcity of standardized clinical protocols and limited use of robust biostatistical tools further impede the development of conclusive recommendations for clinical or cosmetic use. As a result, the analytical review confirms the critical importance of context-specific formulation and the necessity for further investigation into the mechanisms by which emulsifiers interact with the skin. These findings justify the subsequent experimental evaluation proposed in this research and reinforce the call for harmonized testing protocols in dermatological science.

CONCLUSIONS

Current research on emollients and emulsifiers lacks consistency and standardization, leading to conflicting findings regarding their effects on the skin barrier. The main findings are:

1. Emulsifiers exhibit a dual role in skin barrier function, increasing permeability in healthy skin while potentially aiding in barrier repair in damaged skin. This variability highlights the need for precise formulation strategies that take into account skin type, barrier integrity, and the intended duration of use. Failure to account for these factors may result in adverse effects, particularly in individuals with pre-existing dermatological conditions.
2. The permeability-modulating effects of emulsifiers require further investigation to determine their suitability for long-term use in cosmetic and therapeutic applications. The ability of emulsifiers to alter lipid bilayer structure suggests they may enhance or restrict the absorption of active ingredients. However, the extent of this modulation varies significantly across different emulsifier types and concentrations, necessitating detailed structural analysis of their interactions with skin lipids.
3. The choice of emulsifiers and emollients in skincare formulations must be guided by scientific research that considers both efficacy and long-term safety. Emulsifiers that disrupt lipid bilayers can facilitate short-term penetration of active compounds but may lead to chronic barrier damage with prolonged use. Emollients that effectively mimic natural skin lipids should be prioritized to enhance hydration and repair functions without interfering with physiological processes.
4. The impact of emulsifiers and emollients on different skin conditions, including eczema, psoriasis, and sensitive skin, remains inadequately studied. Formulations intended for compromised skin barriers must undergo clinical validation to ensure they do not exacerbate existing conditions.
5. The distinction between synthetic and biodegradable emulsifiers and emollients is critical for both dermatological safety and environmental sustainability. Biodegradable emulsifiers are less likely to accumulate within skin layers, reducing the risk of chronic inflammation, sensitization, or long-term toxicity. Further research should focus on developing sustainable alternatives that maintain efficacy while reducing environmental and dermatological risks.
6. The interactions between emulsifiers and emollients in complex skincare formulations need further exploration to determine their synergistic or antagonistic effects. Some combinations may enhance hydration and barrier repair, while others may disrupt lipid organization and lead to increased sensitivity. Understanding these interactions will enable the formulation of optimized products that balance penetration enhancement with barrier protection.
7. The long-term impact of emulsifier-containing skincare products on skin microbiome composition remains poorly understood. Some emulsifiers may alter microbial balance by disrupting lipid structures that support beneficial bacteria. Future studies should investigate whether specific emulsifiers promote or

inhibit microbiome stability and assess their implications for overall skin health.

8. The formulation of skincare products must move toward a precision-based approach that accounts for individual skin conditions, lipid composition, and susceptibility to barrier disruption. Future studies must adopt standardized measurement techniques, particularly for trans-epidermal water loss, and ensure long-term clinical trials that assess cumulative effects over extended periods.

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