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Rethinking Sustainability in Skincare: A Comparative Analysis of Beef Tallow and Plant-Based Oils

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ABSTRACT

As sustainability and ingredient transparency take center stage in consumer priorities, the skincare industry faces pressure to deliver products that are environmentally responsible, ethically sourced, and dermatologically effective. Beef tallow—a nutrient-rich byproduct of livestock—has reemerged in skincare discourse as a potentially sustainable, zero-waste ingredient. This narrative review compares beef tallow with commonly used plant-based oils (coconut, olive, jojoba, and argan) across environmental, cultural, ethical, and dermatologic dimensions. Drawing from peer-reviewed literature, we analyze life-cycle emissions, land and water use, biodiversity impact, and historical relevance. While tallow raises concerns related to animal agriculture, it may be viable within regenerative farming frameworks. Conversely, some plant oils contribute to deforestation and exploitative labor practices. This review proposes a multidimensional framework for ingredient evaluation, advocating for lifecycle analysis, equitable sourcing, and transparent labeling to guide sustainable skincare innovation.

Keywords: Beef Tallow, Sustainability, Plant-Based Oils, Ethical Sourcing

INTRODUCTION

The skincare industry is undergoing a paradigm shift driven by environmental concerns, consumer demand for transparency,

and the rise of ethical consumerism. The global organic skincare market—valued at $42 billion in 2022—is projected to exceed $54.5 billion by 2027, reflecting a substantial shift toward sustainable formulations [1]. However, terms such as "natural," "clean," and "green" are inconsistently regulated, often creating misleading impressions of sustainability [2,3]. This has spurred renewed interest in traditional ingredients like beef tallow, once phased out in favor of plant oils. As a byproduct of meat processing, tallow presents a complex profile: it supports circular economy principles, yet remains tied to livestock agriculture with substantial environmental and ethical concerns. This review critically examines the role of beef tallow in sustainable skincare compared to plant-based oils, integrating dermatological science, environmental data, and ethical perspectives. The central question guiding this analysis is: Can beef tallow offer a sustainable and ethical alternative to plant-based oils in skincare?

METHODOLOGY

This narrative review was conducted using a structured literature search strategy across four databases: PubMed, Scopus, Web of Science, and Google Scholar. Search terms included combinations of "beef tallow," "plant-based oils," "sustainability in skincare," "regenerative agriculture," "ethical sourcing," and "lifecycle assessment." Inclusion criteria focused on peer-reviewed articles published between 2000 and 2024 that discussed environmental impact, dermatologic use, and supply chain practices of skincare ingredients. Studies were excluded if they lacked quantitative data or were not available in English. The review methodology was guided by the GRADE framework, prioritizing high-quality evidence and transparency in evaluating the strength of included data.

CONCEPTUALIZING SUSTAINABILITY AND INGREDIENT TRANSPARENCY

Sustainability in skincare is inherently multidimensional, encompassing environmental resource use, ethical labor practices, ecological preservation, product safety, and socioeconomic accessibility. Nevertheless, popular discourse often reduces this complexity to a binary equation: "natural equals sustainable." As Rotter A, et al. [4] and Russell MF, et al. [5] note, Western cosmetic narratives increasingly co-opt Ayurvedic and traditional Chinese medical frameworks to present natural ingredients as inherently therapeutic [4,5]. Yet such ingredients—though botanically derived—are frequently tied to global supply chains with large carbon footprints, labor inequities, and ecological degradation.

Ajayi SA, et al. [6] propose five core criteria for evaluating skincare ingredient sustainability: (1) geographic origin and cultivation practices, (2) ecological farm integration, (3) byproduct minimization, (4) avoidance of pesticides and synthetic chemicals, and (5) proximity to processing and manufacturing sites [6]. Transportation emissions, often overlooked, further compound a product's carbon footprint. Talavera M& Sasse AM [7] emphasize that local ingredient sourcing significantly reduces environmental impacts across production, packaging, and distribution [7]. Companies integrating renewable energy and carbon offsetting into their supply chains demonstrate a more authentic commitment to sustainability [8].

BEEF TALLOW IN SKINCARE: UTILITY AND CONTROVERSY

Composition and Dermatological Relevance

Beef tallow comprises triglycerides rich in saturated and monounsaturated fatty acids such as oleic (41–47%), palmitic (25–32%), and stearic acids (14–20%) [9]. These lipids mimic components of the skin barrier, supporting barrier repair and hydration. Vitamins A and K promote epidermal turnover and anti-inflammatory effects, while vitamin E enhances antioxidant defense. Notably, oleic acid's ability to disrupt the lipid matrix of the stratum corneum facilitates the transdermal delivery of actives, offering unique advantages in pharmaceutical and cosmeceutical formulations.

In skincare, tallow-based products are used in salves, balms, and moisturizers targeting dry, eczematous, or compromised skin. Unlike synthetic emollients or petrochemical derivatives, tallow provides bioavailable lipids without requiring extensive refinement. However, its fatty acid composition may not be suitable for acne-prone skin due to potential pore-clogging effects, depending on formulation and processing.

Ethnomedical and Historical Use

Ethnographic evidence highlights the long-standing use of animal fats in therapeutic skincare and wound treatment. Samburu pastoralists in Kenya historically employed animal-derived fats to manage dermal infections such as smallpox [10]. In Roman antiquity, tallow and ash were integral to early soap formulations along Mount Sapo [11]. These practices underscore tallow's historical dermatologic relevance, even as industrialization diminished its cosmetic visibility.

Environmental Costs and Regenerative Opportunities

Beef production is widely acknowledged as environmentally intensive. According to Mekonnen M & Hoekstra A [12], producing one metric ton of beef requires approximately 15,400 m^3 of water—significantly more than soybeans, which require only 2,300 m^3[12]. Furthermore, up to 70% of Amazonian deforestation is linked to cattle ranching, with associated emissions exceeding 27.8 kg CO_2 per kilogram of beef [13]. However, when tallow is reframed as an upcycled byproduct within regenerative agricultural systems—those that prioritize soil health, rotational grazing, and carbon sequestration—it may serve as an ethically circular ingredient [14]. This perspective warrants serious consideration in debates about ingredient sustainability.

Plant-Based Oils: Environmental Benefits and Trade-offs

Plant-derived oils are a cornerstone of modern skincare formulations, valued for their emollient, anti-inflammatory, antioxidant, and barrier-repairing properties. Among the most widely utilized are coconut oil, olive oil, jojoba oil, and argan oil—each possessing distinct biochemical profiles that influence both clinical outcomes and ecological impact.

OVERVIEW OF COMMON OILS

Coconut Oil (Cocos nucifera)

Coconut oil functions primarily as an occlusive agent, forming a lipid barrier on the skin's surface that reduces transepidermal water loss (TEWL) and enhances hydration [15]. Its composition is rich in medium-chain fatty acids, particularly lauric acid, which contributes to its well-documented antimicrobial properties. These attributes make coconut oil beneficial in both reinforcing skin barrier function and supporting the management of cutaneous infections. A pivotal double-blind, controlled trial by Verallo-Rowell VM, et al. [16] assessed the efficacy of virgin coconut oil (VCO) in adults with atopic dermatitis [16]. Compared to virgin olive oil (VOO), VCO significantly reduced Staphylococcus aureus colonization, with only 5% of VCO-treated patients remaining colonized post-treatment versus 50% in the VOO group (relative risk = 0.10; p =.0028). Furthermore, participants using VCO demonstrated a statistically significant improvement in objective SCORAD severity index (O-SSI) scores (p =.004), underscoring its therapeutic potential as an adjunct in dermatologic care for conditions involving impaired barrier function and microbial imbalance.

Olive Oil (Olea europaea)

Rich in monounsaturated fatty acids—primarily oleic acid—and polyphenolic compounds such as hydroxytyrosol, olive oil offers anti-inflammatory and antioxidant effects. However, studies suggest olive oil may disrupt the skin barrier when used excessively, particularly in infants [17]. Its utility lies in its ability to improve elasticity and prevent transepidermal water loss in dry and aging skin.

Jojoba Oil (Simmondsia chinensis)

Jojoba oil, a liquid wax ester rather than a traditional triglyceride, closely resembles the molecular structure of human sebum [18]. This structural similarity, primarily due to its long-chain wax esters, contributes to its excellent skin compatibility, making it a non-comedogenic and hypoallergenic option for a broad range of skin types. Its unique composition facilitates effective penetration into the stratum corneum without leaving a greasy residue, thereby enhancing skin hydration and supporting barrier repair. In addition to its emollient properties, jojoba oil exhibits notable anti-inflammatory effects. In a study by Habashy RR, et al. [19], topical application of jojoba oil significantly reduced the expression of pro-inflammatory cytokines—tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6)—in lipopolysaccharide (LPS)-induced inflammation models, suggesting its capacity to mitigate inflammatory skin responses [19]. Given its biomimetic, non-irritating nature, and ability to modulate inflammation and oxidative stress, jojoba oil is particularly well-suited for individuals with sensitive or acne-prone skin.

Argan Oil (Argania spinosa)

Argan oil is rich in linoleic acid, tocopherols (vitamin E), and plant sterols, which contribute to its antioxidant, anti-inflammatory, and skin-conditioning properties. Linoleic acid supports skin barrier integrity and reduces inflammation, while tocopherols protect against oxidative stress. Sterols further promote skin hydration and elasticity.

A randomized controlled trial by Boucetta KQ, et al. [20] evaluated the effects of topical and oral argan oil in postmenopausal women, demonstrating significant improvements in skin elasticity and hydration [20]. Notably, the study reported increases in gross elasticity (R2), net elasticity (R5), and biological elasticity (R7), along with reduced resonance running time (RRT)—all statistically significant ($P < 0.001$ for R2, R5, and R7; $P = 0.002$ for RRT with consumption;

$P < 0.001$ for RRT with topical application). Compared to oils such as virgin coconut oil and virgin olive oil, argan oil's higher concentrations of linoleic acid and tocopherols may offer superior antioxidant and anti-aging effects, particularly in enhancing skin hydration and elasticity in mature skin.

SUSTAINABILITY, EFFICACY, AND ETHICS IN DERMATOLOGIC OILS

In dermatologic practice, oils are increasingly selected not just for their clinical efficacy but for their biochemical compatibility, sensory properties, and sustainability profiles. Coconut oil, for example, is popular for its rich texture and tropical scent, though it can exacerbate acne in predisposed individuals. Jojoba oil is favored for its lightweight, fast-absorbing qualities, particularly in formulations for oily or sensitive skin. Argan oil is often featured in anti-aging products due to its luxurious skin-feel and antioxidant properties, while olive oil, historically used in Mediterranean cultures, is now approached more cautiously given inconsistent evidence about its effect on the skin barrier.

Consumer preferences for oils are shaped not only by product performance but also by cultural familiarity, marketing language, and environmental positioning. Terms like "natural," "cold-pressed," or "organic" often carry assumptions of safety and effectiveness, despite limited supporting evidence. Younger demographics especially are drawn to eco-conscious branding and minimalist formulations, even when transparency about sourcing and lifecycle impacts is limited [21].

Palm oil exemplifies the complexities in evaluating sustainability. Though highly productive per hectare, its cultivation is associated with deforestation, biodiversity loss, and unethical labor practices [22]. Its decline in skincare highlights a growing awareness of the environmental cost of monoculture oil production. Similarly, while plant-based oils are often seen as more ethical, many are produced in regions with poor labor protections, and certification costs can exclude small-scale farmers. Current ethical labels (e.g., Fair Trade, USDA Organic) vary widely in rigor and enforcement.

Contrary to assumptions, animal-derived ingredients like tallow may in some cases offer lower lifecycle carbon emissions than certain plant-based oils when sourced from regenerative systems. For instance, tallow from regenerative cattle farming can emit up to 86% less CO_2 than conventionally grown soybean oil [14]. However, animal-based products also raise complex ethical and spiritual concerns, particularly for vegan consumers and religious groups. For example, porcine derivatives are prohibited in Islam, and bovine tallow may conflict with Hindu and Buddhist beliefs [23,24].

CONCLUSION

The debate between beef tallow and plant-based oils in skincare encapsulates the broader complexities of sustainability in cosmetic science. Rather than framing one as inherently superior, sustainability must be assessed through a comprehensive lens that includes sourcing practices, carbon footprint, land and water use, labor ethics, and dermatologic efficacy. This review highlights the need for a paradigm shift from origin-based ingredient judgment to lifecycle-informed formulation. Stakeholders—consumers, dermatologists, formulators, and policymakers—must advocate for transparency, improved certification systems, and ethical supply chains. Future research should focus on life-cycle assessments, dermatologic safety profiles across diverse skin types, and development of hybrid formulations that integrate sustainable elements from both animal and plant sources.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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