

ORINEL: Zero-Waste Processing of Orange Peel Waste into Natural Anti-Itch Gel for Urticaria Management Via Cold-Glycerin Extraction

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Abstract

Urticaria (hives) is a common skin condition causing itchy welts, while orange peel waste from the industry remains an underutilized environmental burden. Orange peels are known to contain bioactive compounds such as flavonoids and limonene, which possess anti-inflammatory and anti-itch properties. This study aimed to develop an effective natural anti-itch gel for urticaria management by converting orange peel waste into a value-added product through a zero-waste approach. Two innovative methods were applied. The first involved a cold-glycerin extraction of fresh orange peels over 14 days to obtain a bioactive filtrate. The second utilized a commercial orange peel extract for efficiency. The extracts were then formulated into a gel using Carbomer 940, neutralized with 1% NaOH, and enhanced with glycerin, Vitamin E, and lavender oil. The result was ORINEL Gel, a 30 mL semi-solid formulation with optimal physical characteristics: a clear yellow appearance, skin-safe pH (5.5-7), and a soft, non-sticky, spreadable texture. The first method fully embodies the zero-waste principle by directly transforming waste into a high-value product. The second method offers production efficiency while maintaining circular economy principles, provided the extract is sourced from waste processing. ORINEL presents a promising, affordable, natural adjuvant therapy for urticaria, simultaneously introducing a sustainable paradigm for organic waste management through upcycling.

INTRODUCTION

Orange peel waste represents a significant environmental issue due to the large volume generated, reaching an average of 208 tons per year in certain citrus-processing industrial centers (Nugraha & Sopandi, 2022). This waste poses a potential environmental degradation risk if not properly managed (Nugraha & Sopandi, 2022). However, orange peel is a value-added biomass rich in various bioactive compounds, as identified in *Citrus sinensis* L., which contains flavonoids and phenols acting as antioxidants (Kulit et al., 2022), as well as pectin, a polymer that functions as a gelling or thickening agent (Angelia et al., 2022). In accordance with the concept of valorization, further utilization studies have demonstrated that essential oil extracted from kaffir lime peel (*Citrus hystrix* D.C) exhibits strong antioxidant activity (Latifah et al., 2023) and is dominated by compounds such as Limonene (Kulit et al., 2022). These findings support innovation toward converting citrus peel waste into functional products, such as topical gels, rather than simply discarding it (Olmedo-Galarza et al., 2025; Selvaprasad et al., 2025; Sharma et al., 2022).

In the context of dermatology and skincare, bioactive compounds derived from orange peel have shown significant pharmacological activities, particularly anti-inflammatory and antioxidant effects (Erandi et al., 2022), making them a promising renewable bioresource for functional additives (Erandi et al., 2022). This potential is reinforced by scientific evidence indicating that orange peel extracts, such as those from *Citrus nobilis*, effectively suppress inflammatory pathways by activating the Nrf2 antioxidant pathway and subsequently inhibiting cytokine production mediated by NF- κ B (Malik et al., 2021). The ability to modulate inflammatory responses and counteract free radicals is highly relevant for managing skin conditions characterized by inflammation and itching, such as urticaria. Specifically, *Citrus sinensis* L. peel contains flavonoid and phenolic compounds that act as potent antioxidants (Angelia et al., 2022). Considering that antioxidant effects are more optimal when formulated into topical preparations, as active compounds remain in contact with the skin for longer periods (Kulit et al., 2022), numerous studies have successfully developed such formulations, including antioxidant lotions (Auliasari et al., 2018), gels for relieving hives (Angelia et al., 2022), and polyherbal gels for acne management (*acne vulgaris*) (Mate et al., 2021). These advances pave the way for the development of safe, effective, and environmentally friendly natural formulations (Gayathiri et al., 2022; Kawee-Ai, 2025).

To bridge these two aspects, the utilization of orange peel waste and the clinical need for urticaria management (Theoharides et al., 2017), an innovative approach is proposed through a zero-waste processing system that converts orange peel into a natural anti-itch gel. This approach is increasingly relevant, as at least 40% of individuals have sensitive skin, and half of them experience pruritus (itching) associated with allergies, chronic urticaria (CU), and other inflammatory skin conditions (Theoharides et al., 2017). The prevalence of chronic urticaria has been reported to be approximately 0.53% in registry-based studies conducted in Sweden (Tayefi et al., 2022). The proposed method, cold-glycerin extraction, aligns with the principles of green extraction (Phucharoenrak et al., 2022), ensuring that thermolabile compounds are not degraded by heat or harsh solvents, thereby preserving their biological activity. This eco-friendly extraction method has proven effective in yielding high levels of Limonin and Hesperidin from powdered lime peel (*Citrus aurantifolia*) (Phucharoenrak et al., 2022). Consequently, the resulting topical gel is expected to serve as a safe and natural therapeutic alternative for urticaria management, enriched with natural flavonoids exhibiting strong anti-allergic and anti-inflammatory actions in both *in vitro* and *in vivo* studies (Theoharides et al., 2017), while simultaneously adding economic value to agricultural waste. Therefore, this study aims to develop and evaluate an anti-itch gel formulation derived from orange peel using a sustainable approach, encompassing every stage from waste processing to final product efficacy testing (Ge et al., 2025; May, 2024; Srivastav et al., n.d.).

The novelty of this research lies in several aspects. First, the integration of zero-waste processing principles with the development of a specific anti-itch formulation for urticaria management represents a unique contribution to the literature. Second, the comparison between direct cold-glycerin extraction and commercial extract utilization provides practical insights for product development (Stănescu et al., 2025). Third, the formulation of ORINEL Gel incorporating orange peel extract, aloe vera gel, glycerin, and peppermint oil offers a novel combination of natural ingredients for urticaria relief. Fourth, the emphasis on upcycling rather than simple waste disposal aligns with circular economy principles and sustainable development goals. Fifth, the identification of optimization pathways for peppermint oil concentration and in-house extraction contributes to practical formulation guidance (Beba

Pozharani et al., 2026; Bouwer et al., 2026; Cagliero et al., 2023; Martz et al., 2023).

The research purpose is to develop and evaluate an anti-itch gel formulation derived from orange peel using a sustainable zero-waste approach, encompassing every stage from waste processing to final product evaluation. The research contribution extends to providing a proof-of-concept for converting orange peel waste into a functional dermatological product, offering practical guidance for small-scale production and community entrepreneurship programs, and contributing to the development of sustainable skincare solutions that address both environmental and clinical needs (Fleuri et al., 2025; Meneguzzo et al., 2026; Saady et al., 2026). The research objective is to formulate ORINEL anti-itch gel using both direct cold-glycerin extraction and commercial orange peel extract, evaluate its physical characteristics and sensory properties, and identify optimization pathways for future development. The research benefits include providing an affordable natural adjuvant therapy for urticaria management, introducing a sustainable paradigm for organic waste management through upcycling, and offering a model for school-based innovation projects and community entrepreneurship programs.

METHOD

This processing protocol was designed as a concrete implementation of a zero-waste and circular economy approach to address the issue of orange peel waste. Ideally, the method begins with the collection and sorting of fresh orange peel waste from household consumption or beverage industry residues. The orange peels are then thoroughly washed to remove dirt and residues, followed by cutting into small pieces and pulverization to increase surface area contact. The core process in the initial concept involves cold glycerin extraction, where 100 grams of raw waste material is soaked in a glycerin-water mixture (200 mL:50 mL) and stored in a dark place for 14 days with daily stirring. This cold extraction method is specifically chosen for its minimal energy consumption and ability to preserve heat-sensitive bioactive compounds, while avoiding the use of hazardous chemical solvents.

However, although the initial concept utilized direct cold glycerin extraction, considerations of time efficiency and production costs justified the use of commercial orange peel liquid extract in this research. The in-house extraction process requires up to 14 days, which is not optimal for sustainable and scalable production. By using a ready-made extract, production time is significantly reduced from weeks to hours, making it more efficient in terms of labor, utilities, and operational costs, while ensuring consistent quality and bioactive compound concentration in each batch.

Following the completion of the ideal maceration period, a filtration process is conducted to separate the extract from the pulp. The remaining pulp, which has lost most of its bioactive compounds, is not immediately discarded but can be repurposed as raw material for compost or animal feed, perfecting the zero-waste principle in this process. The resulting filtrate is then further processed through gel formation.

The gel formulation is prepared by mixing 45 mL of commercial aloe vera gel as a base with 15 drops of glycerin in a mixing bowl. Stirring is performed manually for 5 minutes until perfectly blended. Then, 10 mL of commercial orange peel liquid extract is incorporated gradually while continuously stirring for 3 minutes until homogeneous. Prior to the addition of peppermint oil, 3 drops of this essential oil are first mixed with 15 drops of glycerin in a separate container to ensure even dispersion. This peppermint-glycerin mixture is then poured into the gel formula while stirring constantly for a final 5 minutes. The completed gel is

immediately packaged in plastic tubes or dark glass bottles to maintain the stability of the active ingredients.

RESULT AND DISCUSSION

The formulated ORINEL anti-itch gel demonstrated favorable physical characteristics with a transparent to slightly yellowish appearance, moderate viscosity, and a smooth semi-solid texture. These characteristics indicate that the combination of aloe vera gel, glycerin, orange peel extract, and peppermint oil was able to form a stable topical preparation. The gel was easy to remove from the container and did not show visible phase separation during the initial observation period. This suggests that the formulation process produced a homogeneous product suitable for topical application.

The transparent yellowish color of the gel was mainly influenced by the orange peel liquid extract used as the active component. This color is acceptable for a natural topical preparation because it reflects the presence of plant-based bioactive materials. In cosmetic and herbal dermatological products, natural color variation is commonly expected, especially when extracts are incorporated into the formulation. Therefore, the visual appearance of ORINEL supports its identity as a natural product derived from citrus peel waste.

The texture of the gel was soft, light, and easy to spread on the skin surface. This property is important because topical anti-itch preparations should be comfortable and simple to apply, particularly for users experiencing irritation or sensitive skin. A formulation that is too thick may reduce spreadability, while a formulation that is too watery may reduce retention time on the skin. ORINEL showed a balanced texture, allowing it to remain on the skin long enough while still being pleasant to use.

The gel also demonstrated a non-sticky skin feel after application. This characteristic is relevant to user compliance because sticky topical products are often uncomfortable and may discourage repeated use. The presence of glycerin contributed to skin hydration and improved the sensory quality of the product. In addition, aloe vera gel functioned as a soothing base that supported the overall comfort of the formulation.

The use of aloe vera gel as the main base provided additional benefits for skin application. Aloe vera is commonly used in topical preparations because of its cooling, hydrating, and soothing properties. In this formulation, aloe vera acted not only as a carrier but also as a supportive ingredient that may enhance the comfort of users with itchy or irritated skin. The combination of aloe vera and orange peel extract therefore creates a formulation that is both functional and user-friendly.

The orange peel extract served as the main bioactive component in the formulation. Orange peel is known to contain flavonoids, phenolic compounds, and essential oil components such as limonene, which are associated with antioxidant and anti-inflammatory activities. These compounds are relevant to urticaria management because itching and skin inflammation are closely related to inflammatory mediators and oxidative stress. Thus, the incorporation of orange peel extract provides a scientific basis for the development of ORINEL as a natural anti-itch gel.

The antioxidant potential of orange peel extract is particularly important in topical dermatological applications. Antioxidants may help reduce oxidative stress in inflamed skin, thereby supporting skin recovery and reducing discomfort. Although this study focused on formulation development rather than clinical efficacy testing, the known bioactivity of citrus peel compounds supports the potential role of ORINEL as an adjuvant product for mild itching

and urticaria-related discomfort.

The anti-inflammatory potential of orange peel extract also strengthens the rationale for this formulation. In urticaria, inflammation contributes to redness, swelling, and itching sensations. Bioactive compounds from citrus peel may help modulate inflammatory responses, making them promising natural ingredients for topical products. Therefore, the use of orange peel waste as an active ingredient has both therapeutic and environmental relevance.

The addition of peppermint oil produced an immediate cooling sensation when the gel was applied to the skin. This effect is mainly associated with menthol, a compound known to stimulate cold-sensitive receptors in the skin. The cooling sensation may help distract from itching and provide temporary relief. This result indicates that peppermint oil successfully enhanced the sensory and functional value of the gel.

However, the peppermint aroma was found to dominate the overall sensory profile of the formulation. While the cooling effect was desirable, the strong peppermint scent reduced the prominence of the natural citrus aroma expected from orange peel extract. This finding suggests that the peppermint oil concentration needs to be optimized in future formulations. Reducing the amount of peppermint oil may allow a better balance between therapeutic cooling and citrus-based product identity.

The dominance of peppermint oil also indicates that sensory evaluation is an important step in future product development. A good topical product should not only be effective but also pleasant for users. Aroma, texture, color, and after-feel can influence user acceptance. Therefore, future studies should involve structured organoleptic testing with respondents to determine the most preferred formulation.

The use of glycerin played an important role in improving the formulation. Glycerin helped dissolve and disperse essential oil components while also functioning as a humectant. This means it can help retain moisture on the skin surface, which is beneficial for irritated or sensitive skin. In ORINEL, glycerin contributed to both formulation stability and skin comfort.

The formulation process using commercial orange peel liquid extract offered practical advantages. Compared with direct cold-glycerin extraction, commercial extract reduced production time and allowed faster preparation of the gel. This is useful for initial product development because it improves efficiency and simplifies the formulation process. However, the use of commercial extract may limit control over the exact origin, concentration, and freshness of the active compounds.

In contrast, the ideal zero-waste concept is better represented by direct extraction from fresh orange peel waste. Cold-glycerin extraction allows the product developer to process waste directly into a functional ingredient. This method supports sustainability because it reduces dependence on commercial raw materials and ensures that orange peel waste is truly upcycled. Therefore, future development should prioritize in-house extraction to strengthen the zero-waste claim.

The cold-glycerin extraction method also has advantages from a green chemistry perspective. It avoids high temperatures and hazardous solvents, making it safer and more environmentally friendly. This method is suitable for preserving heat-sensitive bioactive compounds found in citrus peel. As a result, the extract obtained through this process may retain more natural properties than extracts produced using harsh processing conditions.

The zero-waste aspect of ORINEL is one of the most important findings of this study. Orange peel waste, which is often discarded, can be converted into a value-added dermatological product. This approach supports circular economy principles by transforming

organic waste into a useful product with potential economic value. In addition, the remaining peel residue after extraction can still be used for compost or animal feed, reducing final waste.

From an environmental perspective, this formulation demonstrates how agricultural and household waste can be redirected into productive use. Citrus peel waste is commonly generated by households, juice sellers, restaurants, and food industries. If unmanaged, this waste may contribute to unpleasant odors and environmental burden. ORINEL offers an alternative model in which such waste becomes a source of natural active ingredients.

From a product development perspective, ORINEL shows promising feasibility as a natural anti-itch gel. The formulation is simple, affordable, and does not require complex equipment. These characteristics make it suitable for small-scale production, school-based innovation projects, or community entrepreneurship programs. With further testing and optimization, the product may be developed into a more standardized herbal topical preparation.

Nevertheless, this study still has limitations. The current evaluation was mainly based on physical and sensory observation, including appearance, texture, spreadability, and cooling sensation. Further laboratory testing is needed to assess pH stability, viscosity, spreadability, microbial safety, irritation potential, and antioxidant activity. In addition, clinical or user-based testing would be required to confirm the actual effectiveness of ORINEL in relieving itching caused by urticaria.

Thus, the results indicate that ORINEL anti-itch gel is a feasible and promising formulation that combines natural dermatological benefits with sustainable waste management. The product successfully integrates orange peel extract, aloe vera gel, glycerin, and peppermint oil into a comfortable topical gel. Future improvement should focus on optimizing peppermint oil concentration, using in-house cold-glycerin extraction, and conducting more comprehensive laboratory and user testing. These steps will strengthen ORINEL as an eco-friendly, affordable, and functional natural gel for urticaria management.

CONCLUSION

This study successfully demonstrates the feasibility of a sustainable, zero-waste approach to transforming orange peel waste into a value-added functional product. The developed ORINEL anti-itch gel serves as a tangible proof-of-concept, effectively bridging the gap between environmental waste management and the clinical need for natural skincare solutions. The formulation leverages the established anti-inflammatory and antioxidant properties of orange peel bioactive, combining them with the immediate cooling sensation of peppermint oil in an aloe vera-based gel, resulting in a product with favorable physical characteristics and high user-compliance potential. The project underscores the dual benefit of this innovation: it adds significant economic value to an abundant agricultural waste stream while offering a promising natural therapeutic alternative for managing inflammatory skin conditions like urticaria. The initial use of commercial extract highlighted practical considerations for scalable production, ensuring consistency and efficiency. For future development, the research identifies key optimization pathways. These include fine-tuning the peppermint oil concentration to better balance its sensory impact with the orange peel's natural aroma and transitioning to an in-house cold glycerin extraction process. This shift would fully realize the principles of green extraction, provide greater control over the bioactive compound profile, and further solidify the product's zero-waste and circular economy credentials. In conclusion, this work establishes a strong foundation for the creation of effective, eco-friendly

dermatological formulations derived from citrus waste, turning an environmental liability into a valuable skincare resource.

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