



Formulation and Evaluation of Melon (*Cucumis melo* L.) Ethanolic Extract Moisturizing Serum for Facial Sheet Mask Applications

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Abstract

Addressing the increasing demand for natural and effective anti-aging skincare solutions, this study presents the development and evaluation of a moisturizing facial serum formulated with melon (*Cucumis melo* L.) extract for cosmeceutical sheet mask applications. Extracts from two cultivars, Orange Man and Hoshi Orange (grades B and C), were obtained using 70% and 99.9% ethanol. The 70% ethanol extract yielded the highest recovery ($10.73 \pm 0.55\%$) and demonstrated superior antioxidant efficacy via DPPH assay ($EC_{50} = 1.25 \pm 0.08$ mg/mL). The Hoshi Orange 70% ethanol extract, specifically chosen for its commercial viability, showed a strong profile ($EC_{50} = 1.18 \pm 0.06$ mg/mL) and a high yield ($9.85 \pm 0.48\%$). Formulation screening identified Carbopol® Aqua SF-1 combined with xanthan gum as the optimal gelling system for rapid serum absorption into the sheet mask within 90 sec. A 3% extract concentration exhibited ideal physicochemical stability following six heating–cooling cycles. Dermatological assessments on 22 volunteers confirmed the absence of irritation with the 1% extract formulation at 24 and 48 h post-application, and corneometric analysis revealed a statistically significant 59.84% increase in skin hydration 30 min post-application. These findings collectively highlight the significant potential of melon extract as a safe, effective, and sustainable bioactive moisturizing agent for natural anti-aging skincare formulations, contributing to the valorization of agricultural surplus.

Introduction

The global personal care and cosmetic products market is experiencing substantial growth, driven by increasing consumer awareness of beauty and wellness, coupled with an aging population seeking effective skincare solutions (World Health Organization, 2025;

Thakur & Prasad, 2022). Within this expanding market, there's a distinct surge in demand for natural and organic cosmetics, particularly those offering anti-aging benefits (Thakur & Prasad, 2022). Recent literature emphasizes that the cosmetic industry is undergoing a paradigm shift toward botanical bioactive compounds to meet the demand for safe and sustainable alternatives to

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synthetic ingredients (Sisodia et al., 2025). This trend is further intensified by increasing exposure to environmental stressors, such as UV radiation and urban pollution, which are recognized as leading drivers of premature skin aging (Budzianowska et al., 2025). Latest research has also highlighted the significant role of regular use of moisturizing products in preventing and slowing down the aging process by maintaining skin barrier strength (Luo et al., 2023).

Among natural sources, fruits and vegetables are rich in bioactive compounds such as vitamins, polyphenols, and antioxidants, making them valuable candidates for cosmeceutical applications (Egoumenides et al., 2018). Melon (*Cucumis melo* L.) is particularly noteworthy due to its high-water content, vitamins (A, C, and B-complex), and antioxidant compounds, which contribute to skin hydration and protection against oxidative stress (Zulfikar et al., 2020). These antioxidants play a pivotal role in maintaining skin barrier integrity and improving visual appearance by neutralizing free radicals within the skin matrix (Ngoc et al., 2023). Beyond its nutritional value, melon by-products (e.g., peels and seeds) contain a rich array of phytochemicals, offering an opportunity for sustainable valorization in the cosmetic industry, consistent with the concept of reducing food waste and developing environmentally friendly cosmetics (Morganti et al., 2022). Notably, some melon cultivars are recognized for their high content of the antioxidant enzyme superoxide dismutase (SOD), which mitigates oxidative stress and contributes to anti-aging effects (Silva et al., 2020; Silva et al., 2025).

Previous studies have explored the cosmetic potential of various plant-based ingredients for moisturizing and anti-aging effects. For instance, natural active ingredients have been extensively investigated for their hydrating properties (Afandi & Sahudin, 2022), and green tea extract for its well-documented antioxidant and barrier-improving effects (Febrinasari et al., 2025; Zheng et al., 2024). Melon, in particular, has gained attention for its rich content of bioactive compounds, including SOD (Silva et al., 2020; Silva et al., 2025), and its pectin-like polysaccharides have shown promise for skin moisturizing (Sripisut et al., 2024). Furthermore, melon extracts have demonstrated photoprotective properties and antioxidant activity in humans (Egoumenides et al., 2018). Despite these promising findings, comprehensive research on the development and evaluation of melon extract-based serums for specific applications such as facial sheet masks remains limited (Sripisut et al., 2024).

This study aims to develop and evaluate a moisturizing facial serum formulated with extracts from two cultivars of *Cucumis melo* L. (Orange Man and Hoshi Orange), intended for use with facial sheet masks. The selection of these cultivars was motivated by their distinct content of carotenoids and known antioxidant enzymes, which suggests a promising profile for anti-aging cosmeceutical use. The research focuses on optimizing extraction conditions, assessing physicochemical stability, evaluating dermatological safety, and confirming moisturizing efficacy *in vivo*. The findings are expected to provide scientific evidence supporting the utilization of melon extracts as a safe, effective, and sustainable cosmeceutical ingredient for anti-aging skincare.

Materials and methods

1. Raw material preparation

Two cultivars of *Cucumis melo* L. were used in this study, Orange Man and Hoshi Orange. The melon fruits of both cultivars were harvested at the early stage of ripening (approximately 75 days after setting), which is the optimal stage for carotenoid accumulation. Substandard fruits were obtained from certified organic farms in Suphanburi province, Thailand, confirming cultivation without synthetic fertilizers and pesticides. The fruits were classified as substandard solely due to cosmetic defects (Grade B and C). Grade B fruits were defined as those weighing over 1 kg with minor surface blemishes, while Grade C fruits weighed less than 1 kg and showed external defects. All samples were washed, peeled, deseeded, and stored at -18°C prior to extraction.

2. Extraction process

The melon pulp was processed using two extraction techniques

2.1 Solvent extraction

For solvent extraction, fruits of Hoshi Orange Grade B and Grade C were combined in a 1:1 ratio prior to homogenization and extraction. This approach was adopted under the assumption that the concentration of major lipophilic antioxidant compounds, such as carotenoids, was not significantly different between the two substandard grades. Frozen melon pulp was homogenized and macerated in ethanol (EtOH) at two concentrations (70% and 99.9%) using a 1:1 ratio (w/v) for 7 days at room temperature (Mohammed et al., 2022). The mixtures were filtered and concentrated using a rotary evaporator under reduced pressure.

2.2 Juice concentration

Pulp was cold pressed to extract juice, which was then evaporated using a rotary evaporator under reduced pressure to concentrate the aqueous phase and obtain a crude extract.

2.3 Quality control of melon extract

The chemical quality of the concentrated melon extract was controlled using two parameters: (1) Total Soluble Solids (TSS), measured via refractometry to ensure batch consistency (AOAC International, 2005); and (2) Specific Spectrophotometric Profile, determined by measuring absorbance at the characteristic wavelength of carotenoids (470 nm) to monitor the concentration of active pigments (Sripisut et al., 2024).

3. Antioxidant activity evaluation

Antioxidant capacity of the melon extracts was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Sigma-Aldrich, Merck (Thailand) Ltd., Thailand) free radical scavenging assay (Zulfikar et al., 2020). The extracts were tested at a concentration of 5000 ppm, and absorbance was measured at 515 nm using a UV–Vis spectrophotometer (UV-1280, Shimadzu, Japan). Vitamin C was used as a positive control. The EC_{50} value, indicating the effective concentration required to inhibit 50% of DPPH radicals, was calculated to compare antioxidant efficacy.

4. Serum formulation and stability testing

Two serum base formulations were prepared with different thickening agents. The detailed composition of each formulation is shown in Table 1.

Table 1 Composition of serum base formulations

Ingredients	INCI Name	Formula 1 (%)	Formula 2 (%)
Purified Water	Aqua	q.s.	q.s.
Carbopol® Aqua SF-1	Acrylates copolymer	1.00	1.00
Xanthan Gum	Xanthan gum	0.20	–
Sepimax™ Zen	Polyacrylate crosspolymer-6	–	0.20
Glycerin	Glycerin	5.50	5.50
Triethanolamine (TEA)	Triethanolamine	0.20	0.20
Glydant Plus® Liquid	DMDM Hydantoin,	0.70	0.70
	Iodopropynyl Butylcarbamate		

The pH of each formulation was adjusted to 5.5 ± 0.2 using TEA, and stability testing was then conducted by subjecting each formulation to 6 cycles of alternating temperatures ($4 \pm 1^\circ\text{C}$ for 24 h followed by $45 \pm 1^\circ\text{C}$ for 24 h/cycle). Throughout these heating–cooling cycles, each sample was closely observed for physical changes, including pH fluctuations measured with a LAQUA pH meter (LAQUA PH1100, Horiba, Ltd., Japan), any

evidence of phase separation, changes in viscosity measured using a Brookfield Viscometer (DV-1 Prime, Brookfield Engineering Laboratories, Inc., USA), and alterations in odor (assessed through sensory evaluation by three blinded assessors) (Budiasih et al., 2018; Choochuen & Jimtaisong, 2022).

5. Sheet mask absorption test

The serum (with and without 3% Hoshi Orange 70% ethanol extract) was applied to standard non-woven facial sheet masks. Absorption time was measured at 30, 60, 90, and 120 sec, and the weight difference before and after absorption was used to assess serum uptake efficiency (Kusumawati et al., 2020).

6. Skin irritation test

This study was approved by the Institutional Review Board (IRB) for Health Sciences of Suan Dusit University (Approval No. SDU-RDI-HS 2024-036). All participants provided informed consent prior to their inclusion in the study.

A semi-experimental patch test was conducted under dermatological supervision to evaluate the skin irritation potential of the serum formulations. A total of 22 healthy volunteers aged between 40 and 60 years were recruited for the study according to established cosmetic safety testing protocols (Dewi et al., 2024; Johnson et al., 2018; Maya et al., 2024). Four designated sites were marked on each subject's inner forearm to apply the test substances: 1) distilled water, serving as the negative control; 2) 1% sodium lauryl sulfate, serving as the positive control; 3) the base serum formulation without melon extract; and 4) the serum formulation containing 1% melon extract. Each patch was occlusively applied for 24 h, after which the application sites were evaluated at 24 and 48 h for any signs of erythema, irritation, or inflammation.

The 1% concentration was intentionally selected for the safety assessment to represent a sensitive, high-exposure testing condition under occlusion, distinct from the final use concentration of 3% applied in the efficacy trial.

7. Skin moisturization efficacy

Volunteers who passed the irritation test were included in a double-blind randomized trial ($n = 22$). The inner forearms were cleaned and acclimatized in a climate-controlled room ($21 \pm 2^\circ\text{C}$, RH 40–60%) for 30 min. The test formulation (serum containing 3% (w/w) Hoshi Orange 70% ethanol extract applied via a facial sheet mask) and the base formulation (sheet mask) were applied to the designated sites. Skin hydration was assessed

using a Corneometer® (CM825, Courage + Khazaka Electronic GmbH, Germany). Three measurements were recorded on each test site, before and 30 min after application. The percentage increase in hydration was calculated as:

$$\Delta\% \text{ Moisture} = [(Post - Pre) / Pre] \times 100$$

8. User satisfaction evaluation

Participants completed a questionnaire assessing the physical characteristics (texture, color, scent, spreadability) and perceived efficacy (hydration, absorption, skin feel) of the serum using a 5-point Likert scale. Results were summarized to evaluate consumer acceptability of the product.

Results and discussion

This study focused on the development and evaluation of a moisturizing facial serum enriched with melon (*Cucumis melo* L.) extracts for application with a facial sheet mask, addressing the increasing demand for natural and effective anti-aging skincare solutions. The findings highlight the potential of melon extracts as a valuable cosmeceutical ingredient, supporting sustainable utilization of an agricultural surplus.

1. Extract preparation and yield

The melon fruits used in this study were surplus/off-grade melons obtained from specific farms. The physical characteristics of the Orange Man and Hoshi Orange surplus fruits are illustrated in Fig. 1, highlighting the visual defects that classify them as non-marketable grades. Orange Man melons, characterized by a fruit weight exceeding 1 kg and blemished peels, were kindly provided by Homkhajorn Farm. Hoshi Orange melons were purchased from Coco Melon Farm (11/2 Moo 9, Yan Yao, Sam Chuk, Suphan Buri province), which is part of a community enterprise group in Suphan Buri province. These Hoshi Orange melons had a total soluble solids content of less than 10–12°Brix and were further categorized into two grades: Grade B, with fruit weights exceeding 1 kg but possessing blemished peels and indistinct netting; and Grade C, with fruit weights less than 1 kg, also featuring blemished peels and indistinct netting.

The ethanolic extraction of melon pulp from these cultivars yielded extracts with a distinct yellowish-orange color, as shown in Fig. 2. This visual characteristic is primarily due to the presence of carotenoids and other pigments naturally found in the melon fruit. The extracts also resulted in varying yields depending on the solvent concentration and melon cultivar. The results for extract

yield, summarized in Table 2, confirm that the 70% ethanol concentration yielded the highest recovery for both Orange Man (10.73%) and Hoshi Orange (9.85%) cultivars, substantially higher than the 99.9% ethanol extracts. The Hoshi Orange aqueous juice extracts showed comparable yields for Grade B (10.29%) and Grade C (10.33%). The selection of ethanol at varying concentrations in this study was based on the premise that solvent polarity significantly influences the extraction efficiency of phenolic and flavonoid compounds, as well as the resulting antioxidant capacity (Mohammed et al., 2022).



Fig. 1 Visual documentation of raw material preparation: (a–c) Agricultural surplus melon fruits used in the study, including (a) Orange Man off-grade, (b) Hoshi Orange Grade B, and (c) Hoshi Orange Grade C; (d) Peeled Hoshi Orange melon pulp (orange flesh) ready for extraction; and (e–f) Key steps in the solvent extraction process, showing (e) Pulp immersed in EtOH (Maceration) and (f) Crude melon pulp extract in ethanol prior to solvent evaporation

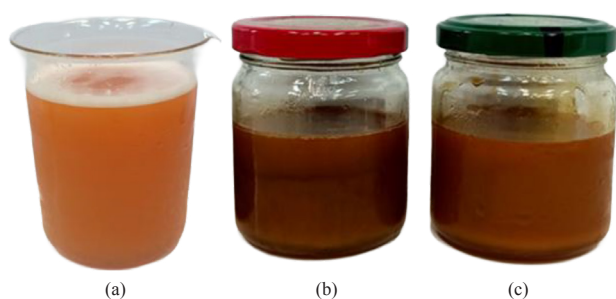


Fig. 2 Visual comparison of Hoshi Orange juice samples: (a) Freshly extracted Hoshi Orange melon juice; (b) Concentrated aqueous extract from Hoshi Orange Grade B pulp; and (c) Concentrated aqueous extract from Hoshi Orange Grade C pulp.

Table 2 Extract yield and antioxidant activity (EC_{50}) of melon extracts

Extract source and method	Extract type	Yield (% w/w) $\pm$ SD	Antioxidant activity (EC_{50} , mg/mL) $\pm$ SD
Orange man (70% EtOH)	Solvent extraction	10.73 $\pm$ 0.55	1.25 $\pm$ 0.08
Orange man (99.9% EtOH)	Solvent extraction	6.26 $\pm$ 0.30	1.90 $\pm$ 0.15
Hoshi orange (70% EtOH)	Solvent extraction	9.85 $\pm$ 0.48	1.18 $\pm$ 0.06
Hoshi orange (99.9% EtOH)	Solvent extraction	5.90 $\pm$ 0.25	2.10 $\pm$ 0.18
Hoshi orange juice grade B	Juice concentration	10.29 $\pm$ 0.40	3.55 $\pm$ 0.25
Hoshi orange juice grade C	Juice concentration	10.33 $\pm$ 0.45	3.60 $\pm$ 0.30

Remark: EC_{50} represents the concentration of extract required to scavenge 50% of DPPH radicals; lower EC_{50} value indicates stronger antioxidant activity.

This variation in yield aligns with solvent polarity theory, where a blend of water and ethanol often enhances the extraction of a broader range of bioactive compounds by improving solvent penetration into the plant matrix and increasing the solubility of both polar and semi-polar constituents, a phenomenon well-documented in studies comparing different extraction solvents and their impact on yield and compound recovery from plant materials (Do et al., 2014; Doflin, 2024; Mohammed et al., 2022; Olivira et al., 2023). Based on these findings, the Hoshi Orange 70% ethanol extract was selected for formulation; it showed a Total Soluble Solids (TSS) value of $5.8 \pm 0.2^\circ\text{Brix}$ and a specific absorbance at 470 nm of 0.85 ± 0.03 , confirming batch consistency and active pigment concentration for subsequent formulation studies.

Optimizing extract yield and selecting the appropriate solvent system, such as the 70% ethanol used here, is crucial for cosmeceutical applications. A higher yield directly translates to greater cost-effectiveness in large-scale production and ensures a higher concentration of beneficial bioactive compounds in the final product. The efficacy of hydroethanolic mixtures for optimizing

the yield of antioxidant compounds and other valuable metabolites from fruit by-products, including melon peels, has been well-documented in recent studies. These studies highlight how such mixtures enable the efficient recovery of diverse phytochemicals, enhancing the valorization of agricultural surplus into functional ingredients (Ain et al., 2020; Dhakal et al., 2024; Dimtsas et al., 2024; Kumar et al., 2021; Patra et al., 2022; Silva et al., 2020; Silva et al., 2025). The observed differences between cultivars further suggest inherent variations in their phytochemical profiles and matrix structures, which significantly influence extraction efficiency and thus the final cosmetic potential, consistent with findings on the diverse biochemical compounds present in various *Cucumis melo* L. cultivars (Zulfikar et al., 2020). It should be noted that the current study focused exclusively on the pulp due to its higher content of carotenoids in the chosen cultivars and better consumer acceptance in direct skin applications, although the valorization of the peel remains an area for future investigation.

2. Antioxidant activity evaluation

Antioxidant activity, assessed by the DPPH radical scavenging assay, was expressed as the EC_{50} value and is summarized in Table 2. The EC_{50} results clearly indicate that 70% ethanol extracts possessed superior antioxidant capacity compared to the 99.9% ethanol and aqueous juice extracts. The Hoshi Orange 70% ethanol extract demonstrated the strongest activity, with the lowest EC_{50} value (1.18 ± 0.06 mg/mL), followed closely by the Orange Man 70% ethanol extract (1.25 ± 0.08 mg/mL). Additionally, studies, such as that of Mohammed et al. (2022), further emphasize how extraction solvent choices directly influence the recovery of these beneficial compounds and their antioxidant efficacy. The significant antioxidant capacity of various melon fruit extracts has been consistently demonstrated in other studies, supporting their potential for cosmeceutical applications (Zulfikar et al., 2020). Beyond general antioxidant effects, specific melon concentrates have been shown to exhibit photoprotective benefits in healthy adults, further underscoring their potential for comprehensive skin protection (Egoumenides et al., 2018).

The weakest antioxidant activity was observed in the aqueous Hoshi Orange Juice extracts (Grade B: 3.55 ± 0.25 ; Grade C: 3.60 ± 0.30 mg/mL). This low potency is to be expected due to the poor solubility of key lipophilic antioxidants, such as carotenoids, in water. While the difference in EC_{50} between the two aqueous

grades was minimal, it supports the general finding that quality differences, even within agricultural surplus, can influence metabolite concentration. This difference underscores the impact of fruit quality (even within surplus grades) on the concentration and efficacy of bioactive compounds. Grade B fruits, despite being cosmetically substandard, likely retain a richer profile of secondary metabolites compared to Grade C fruits, which might have undergone more degradation of active constituents. In contrast, the 70% ethanol concentration was the optimal solvent for extracting these key lipophilic compounds, consistent with previous findings on fruit extracts (Mohammed et al., 2022).

The superior activity of the Hoshi Orange 70% ethanol extract (lowest EC_{50}) highlights its potential as the primary active ingredient. Although the Orange Man 70% ethanol extract yielded the highest extractive content (Table 2), the Hoshi Orange 70% ethanol extract was selected for subsequent product development due to its robust antioxidant potency and practical considerations related to the consistent and abundant supply from the Coco Melon Farm community enterprise, aligning with the project's goal of facilitating sustainable development.

The robust antioxidant capacity demonstrated by these melon extracts is profoundly significant for their application in skincare, aligning with the known pharmacological importance of *Cucumis melo* L. (Vishwakarma et al., 2017). Antioxidants play a crucial role in protecting the skin from oxidative stress induced by environmental factors like UV radiation and pollution, which are major contributors to premature skin aging and damage. By scavenging free radicals, these compounds help maintain skin integrity, reduce inflammation, and promote a healthier, more youthful appearance (Hussen et al., 2025). Prior research supports the evaluation that higher-quality raw materials generally yield extracts with greater antioxidant potential. Moreover, the high antioxidant capacity of melon surplus, including peels, has been further highlighted in recent research, supporting their valorization for functional ingredients (Gómez-García et al., 2020; Silva et al., 2020). These findings collectively strengthen the rationale for utilizing melon extracts as a potent antioxidant component in natural anti-aging cosmeceuticals.

3. Serum formulation and sheet mask absorption

The formulation screening identified Carbopol® Aqua SF-1 (The Lubrizol Corporation, USA) combined with xanthan gum (NovaXan® AF, CP Kelco, USA) as the optimal gelling system for the serum, achieving a

suitable consistency that ensured rapid and efficient absorption into the facial sheet mask material. The optimized gelling system utilized Carbopol® Aqua SF-1 as a synthetic rheology modifier, combined with xanthan gum, a natural stabilizer. Sepimax™ Zen (Seppic S.A., France) was also employed as a synthetic polymeric control for comparative studies during the screening process. Furthermore, Glydant Plus® Liquid (Arxada AG, Switzerland) served as the broad-spectrum preservative for the final formulation to ensure microbiological stability. The serum demonstrated optimal saturation of the sheet mask within 90 sec, and the active formulation (with 3% Hoshi Orange 70% ethanol extract) resulted in higher serum uptake (7.16 g) compared to the base (6.53 g) (Fig. 3). The 3% extract concentration was selected based on pre-formulation screening that showed it was the minimum effective concentration, which ensured: 1) optimal physicochemical stability (passing 6 cycles); and 2) a sufficient level of bioactive compounds ($EC_{50} = 1.45 \pm 0.10$ mg/mL) without negatively affecting the serum's sensory or absorption profile for the sheet mask application. This rapid absorption is crucial for convenient and effective product delivery, particularly in a sheet mask format, which enhances skin contact time and moisture retention through occlusion. Sheet masks are well-regarded for providing a simplified and effective skincare routine, especially beneficial for elderly users by delivering concentrated active ingredients efficiently and enhancing skin hydration.

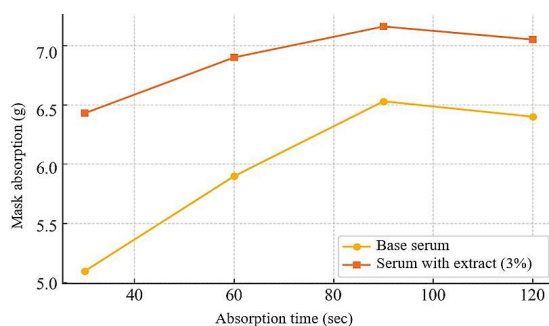


Fig. 3 Serum absorption by sheet masks over time (30, 60, 90, and 120 sec)

Recent clinical evaluations strongly support these benefits; for instance, Janssens-Böcker et al. (2024) demonstrated in their comprehensive clinical assessment that the application of a native collagen sheet mask significantly improved skin health and appearance, directly validating the effectiveness of the sheet mask delivery system itself. Furthermore, the efficacy of the

active ingredients within serums is paramount. Studies such as the one conducted by Filatov et al. (2024), which investigated the synergistic effects of Aloe vera extract with trimethylglycine for targeted Aquaporin 3 (AQP3) regulation and long-term skin hydration, highlight the importance of effective delivery to maximize the benefits of such moisturizing compounds. Similarly, Febrinasari et al. (2025) comprehensively reviewed how green tea catechins contribute to skin health, including their antioxidant properties and roles in skin repair and protection. The occlusive environment created by a sheet mask helps to drive these beneficial ingredients, such as the polyphenols and hydrating agents found in *Cucumis melo* L. extract, deeper into the dermal layers. This delivery is particularly vital as flavonoids, a major class of polyphenols, have been identified as promising natural compounds for preventing skin damage (Čižmarová et al., 2023), thereby maximizing the potential for enhanced skin hydration and overall protection. Furthermore, as highlighted by Ciupei et al. (2024), the therapeutic efficacy of polyphenols is fundamentally determined by their bioavailability; thus, employing an effective delivery system is crucial to ensuring these bioactive compounds reach the target skin layers to exert their full antioxidant and restorative effects. In addition, the selected Hoshi Orange melon 70% ethanol extract demonstrated a robust antioxidant capacity ($EC_{50} = 1.45 \pm 0.10$ mg/mL). When incorporated at a 3% concentration, this extract contributes significantly to the serum's potential anti-aging benefits by protecting the skin from oxidative stress, thus complementing the primary moisturizing efficacy of the mask.

4. Physicochemical stability

The physicochemical stability assessment of the formulated serum containing 3% melon extract (w/w) demonstrated excellent results over 6 heating–cooling cycles. It exhibited no pH shift (pH remained at 5.5 ± 0.2), no precipitation, and no significant odor change, indicating that the formulation is robust under accelerated stress conditions. The pH values remained within the range suitable for topical application (5.5–6.5), minimizing the risk of skin irritation. This remarkable stability is critical for cosmetic products, as it directly impacts their safety, ensures the sustained efficacy of active ingredients, and maintains their aesthetic appeal throughout their shelf life. The findings are consistent with prior work on the stability of natural plant-derived ingredients in cosmetic formulations, such as natural seed oils, which have

demonstrated good stability under various conditions (Costa et al., 2022).

Furthermore, these results align with the emphasis placed on comprehensive stability assessments in recent research. For example, Maya et al. (2024), in their evaluation of a facial serum containing Sacha inchi oil, highlighted the critical importance of characterizing various physicochemical parameters, including organoleptic properties (odor and appearance), homogeneity, viscosity, spreadability, and pH. Such thorough assessments are essential to confirm the product's integrity, predict its shelf-life under diverse storage conditions, and ultimately ensure consumer safety and satisfaction. The robust stability observed in this study not only confirms the potential for safe and effective consumer use but also significantly enhances its commercial viability and ease of scaling-up for industrial production, as a stable formulation provides confidence in consistency and quality across large batches and over time.

5. Skin irritation test

The dermatological safety evaluation, conducted via patch testing on 22 healthy volunteers, confirmed that neither the base serum nor the serum containing 1% melon extract induced any signs of irritation, erythema, or edema at 24 and 48 h post-application (Fig. 4). The positive control (1% sodium lauryl sulfate) elicited the expected mild irritation response, validating the test methodology. These results strongly support the dermal safety of the formulated melon extract-based serum, indicating its suitability for sensitive skin and long-term use. The importance of ensuring cosmetic product safety cannot be overstated, as it is foundational for consumer trust, regulatory compliance, and overall product success, especially for formulations intended for daily application or use by vulnerable populations such as the elderly, who may have more fragile skin (World Health Organization, 2025; Zheng et al., 2024). This alignment with stringent safety standards further reinforces the potential of melon-derived ingredients in safe cosmetic applications. This strategic difference in concentration reflected the distinct objectives of the tests: the irritation test (patch test) utilized the serum directly at a lower concentration (1%) under occlusive conditions to establish dermal safety in a worst-case scenario. In contrast, the moisturizing efficacy test was conducted using the final sheet mask product (3% extract) to simulate the intended use and measure its actual performance as a functional delivery system.

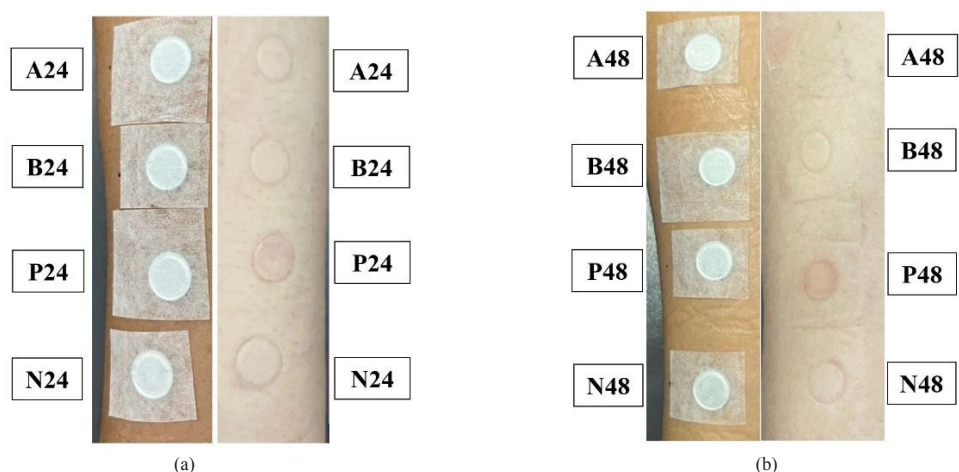


Fig. 4 Patch test reactions at 24 h (a) and 48 h (b) post-application

6. Moisturizing efficacy

Corneometric analysis revealed a statistically significant increase in skin hydration after a single application of the melon extract-based serum via a sheet mask ($p<0.05$). The double-blind randomized trial was conducted on 22 volunteers who passed the irritation test. The mean skin hydration level increased from 51.83 to 82.85 units after 30 min of serum application—a 59.84% increase ($p<0.05$, Fig. 5). This improvement in hydration is a critical indicator of the serum's efficacy in enhancing skin moisture levels, which is essential for maintaining healthy skin barrier function, improving elasticity, and contributing to an overall youthful appearance, particularly vital for aging skin that naturally experiences decreased hydration. Such findings align with clinical studies emphasizing the long-term benefits of consistent

moisturizer use in skin aging prevention, highlighting their role in maintaining skin health and appearance (Luo et al., 2023). This finding is highly consistent with extensive previous research demonstrating the potent hydrating and anti-aging effects of various plant-derived emollients and active ingredients in skincare formulations (Afandi & Sahudin, 2022; Sisodia et al., 2025). The occlusive nature of the sheet mask further optimizes the delivery and retention of these moisturizing agents, facilitating deeper penetration and absorption into the skin, thereby contributing significantly to the observed immediate hydration boost.

7. User satisfaction

User satisfaction surveys showed high acceptance in both physical properties and efficacy. Most participants rated the serum's texture, absorption, and moisturizing

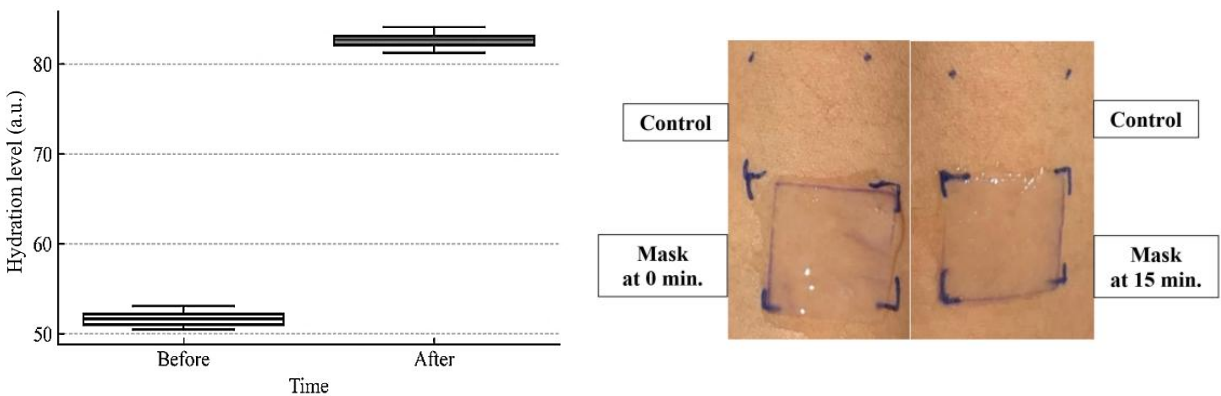


Fig. 5 Skin hydration before and after serum application

effect as “satisfactory” to “very satisfactory” on a 5-point Likert scale. This high level of acceptance is a crucial indicator that the developed formulation is not only effective in its physiological benefits but also aesthetically pleasing and well-received by consumers. In the highly competitive cosmetic market, consumer perception and awareness—specifically regarding sensory attributes such as tactile feel, scent, and ease of application—are vital factors that significantly influence purchasing decisions and overall product success (Mahalakshmi et al., 2023).

This strong positive feedback from users suggests that the melon extract-based serum possesses considerable market potential and aligns with consumer preferences for products that deliver both tangible results and a pleasant sensory experience.

8. Limitations and future work

While this study successfully demonstrated the formulation, stability, and efficacy of a melon extract-based moisturizing serum for facial sheet mask applications, it has certain limitations. The sample size in clinical testing was relatively small ($n = 22$), and the efficacy assessment was limited to a single application. Furthermore, the study did not examine specific biochemical pathways or cellular responses to the extracts. Future research should include larger cohorts, long-term efficacy trials (e.g., 4–8 weeks) to assess sustained benefits, and evaluation of additional parameters such as transepidermal water loss (TEWL) to further quantify barrier function improvement. Mechanistic studies using skin cell lines could uncover the molecular pathways influenced by melon extracts, such as SOD-related oxidative stress modulation. Additional formulations incorporating other melon components—such as seed oil, rind extract, or pectin—may further enhance functional properties. Finally, pilot-scale manufacturing and extensive consumer testing in aging populations could validate the formulation’s commercial viability.

Conclusion

This study successfully developed and evaluated a moisturizing facial serum formulated with extracts from two cultivars of *Cucumis melo* L. (Orange Man and Hoshi Orange, grades B and C) for use with facial sheet masks, thereby addressing the growing demand for natural, effective, and sustainable anti-aging skincare solutions. Among the various extraction conditions, 70% ethanol was found to be the most effective solvent,

yielding higher extractive content and stronger antioxidant activity than absolute ethanol. Serum formulations containing 3% extract demonstrated optimal physicochemical stability, compatibility with sheet mask substrates, and favorable dermatological tolerance. *In vivo* testing confirmed statistically significant improvements in skin hydration (59.84%) and no irritation in 22 volunteers. In summary, the serum formulation containing the selected 3% (w/w) Hoshi Orange 70% ethanol extract demonstrated the optimal balance of high antioxidant capacity, physicochemical stability, dermal safety, and superior moisturizing efficacy, confirming its potential for commercial development as a cosmeceutical sheet mask product. These comprehensive findings underscore the significant potential of melon extract-based formulations as safe, effective, and sustainable cosmeceuticals, offering a promising natural alternative, particularly for anti-aging skin care, and contributing to the valorization of agricultural surplus. Further studies may explore long-term efficacy, mechanistic pathways, and incorporation of additional melon-derived ingredients for enhanced multifunctionality.

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Conflicts of interest

The authors declare no conflicts of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the authors used ChatGPT, and Gemini for enhancing language clarity or improving grammar. The final content was reviewed and edited by the authors, who take full responsibility for the accuracy and integrity of the publication.

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