

Antioxidant properties and development of liquid body soap containing pomelo (*Citrus maxima* Burm.f. Merr.) peel extract

Rattana Panriansaen^{1*}, Pornchita Wutth², Nutthakamol Naksep³ and Wayu Phudang⁴

College of Allied Health Sciences, Suan Sunandha Rajabhat University,
Samut Songkram, Thailand

E-mail: rattana.pa@ssru.ac.th^{1*}, s63122235004@ssru.ac.th², s63122235018@ssru.ac.th³,
s63122235003@ssru.ac.th⁴

Abstract

This study aimed to (1) evaluate the antioxidant properties of pomelo peel extract, (2) develop a liquid body soap containing pomelo peel extract, and (3) assess user satisfaction with the formulated products. The pomelo peel extract exhibited potent antioxidant activity with an IC₅₀ value of 0.49 ± 0.09 µg/mL, significantly lower than that of vitamin E (133.27 ± 13.97 µg/mL). Four liquid soap formulations containing pomelo peel extract (0%, 1%, 3%, and 5%) were produced and subjected to Stability testing under accelerated temperature cycling (4 °C and 40 °C). All formulations remained physically stable, with only minor changes in pH and viscosity. A Closed Patch Test on 20 volunteers revealed no signs of irritation for any formulation, confirming dermatological safety. Consumer satisfaction scores ranged from 4.0 to 4.2, with the 3% extract formulation achieving the highest acceptance. The results indicate that pomelo peel extract is a promising natural antioxidant suitable for incorporation into stable, consumer-accepted liquid soap formulations.

Keywords: Pomelo peel extract, antioxidant activity, liquid body soap, cosmetic development

1. Introduction

1.1 Bioactive Potential of Pomelo Peel

Pomelo (*Citrus maxima* Burm.f. Merr.) is one of the most commercially significant citrus species in Southeast Asia, particularly in Thailand, where it constitutes a major agricultural commodity and carries strong cultural, economic, and geographical importance (Makkurail et al., 2021). The substantial volume of pomelo by-products—especially peel waste—poses both environmental and economic challenges. Recent assessments indicate that several hundred tons of pomelo peel are discarded annually, despite its high potential as a source of valuable bioactive phytochemicals (Boonchoo, 2024; Rojanabenjakun, 2023). Consequently, the valorization of pomelo peel aligns with global trends in sustainable agriculture, the circular bioeconomy, and green cosmetic innovation.

Phytochemical profiling of pomelo peel has revealed a diverse array of secondary metabolites, including flavonoids, phenolics, coumarins, phenylpropanoids, and essential oils (Ajirul et al., 2024). Among these compounds, naringin is the predominant flavonoid, occurring at concentrations of 13–58 mg per 100 g fresh weight (Pichaiyongvongdee & Haruenkit, 2009). Essential oil extracted from pomelo peel is particularly rich in limonene and contains other terpenoid components such as α -pinene, β -pinene, sabinene, and β -phellandrene (Myung et al., 2008). The bitter constituents of pomelo—primarily neohesperidin and naringin—are concentrated in the albedo (inner peel) and the segmental membranes, and exhibit biological activities relevant to antioxidant and anti-inflammatory pathways (Tripoli et al., 2007).

An expanding body of evidence demonstrates that pomelo peel extract possesses potent antibacterial properties against foodborne and clinical pathogens such as *Staphylococcus aureus*, *Bacillus cereus*, *Listeria monocytogenes*, and *Escherichia coli* (Fisher & Phillips, 2006). Limonene, the major essential oil component, has been widely studied for its antioxidant, antimicrobial, and cytoprotective functions (Hirota & Roger, 2010), whereas limonin has shown biological activity associated with dermal cell activation and stimulation of the hair follicle anagen phase (Kang et al., 2022). Collectively, these findings underscore the potential of pomelo peel as a multifunctional bioactive material with promising applications across the cosmetic, pharmaceutical, and functional food industries (Muangmoon et al., 2024).

Within Thailand, research emerging from Suan Sunandha Rajabhat University (SSRU) has highlighted innovative uses of pomelo peel in environmentally friendly household cleaning products, biodegradable materials, and community-based sustainability initiatives (Boonchoo, 2024; Matichon, 2023; Utharasakul, n.d.). Additional SSRU studies examining entrepreneurship and supply chain dynamics of pomelo-based agricultural products emphasize the fruit's socio-economic relevance in both local industry and rural livelihoods (Unknown Author, n.d.). Despite increasing interest in the valorization of pomelo peel, limited research has investigated its incorporation into contemporary cosmetic formulations—particularly liquid cleansing products—where natural antioxidant activity and skin-compatible properties are desirable alternatives to synthetic additives.

This study aims to address this research gap by evaluating the antioxidant activity of pomelo peel extract and exploring its application in the development of a value-added liquid body soap. The broader objective is to support sustainable resource utilization while providing a natural functional ingredient capable of enhancing product performance and contributing to local economic development.

1.2 Objectives

This study aimed to:

1. Evaluate the antioxidant activity of pomelo peel extract.
2. Develop liquid body soap formulations containing pomelo peel extract.
3. Assess consumer satisfaction with the formulated products.

2. Methodology

2.1 Materials

DPPH, α -tocopherol, Folin-Ciocalteu reagent, and all analytical-grade chemicals were obtained from standard suppliers (Sigma, USA; Merck, Germany).

2.2 Extraction of Pomelo Peel

Pomelo peels were collected from Ban Bang Phlap, Samut Songkhram province. The peels were macerated in ethanol, filtered, and the extracts were stored at 4 °C until further analysis.

2.3 Determination of Total Phenolic Content

Total phenolic content was quantified using the Folin-Ciocalteu method. Extracts (0.1–5.0 mg/mL) were mixed with Folin-Ciocalteu reagent and sodium carbonate, followed by incubation for 30 minutes. Absorbance was measured at 765 nm and expressed as mg gallic acid equivalents (GAE) per g of dried extract.

2.4 DPPH Radical Scavenging Assay

Extracts (0.1–5 mg/mL) were mixed with 1 mM DPPH solution and incubated for 30 minutes. Absorbance was measured at 517 nm. Methanol served as the negative control and vitamin E as the positive control. Radical scavenging activity and IC₅₀ values were calculated.

2.5 Formulation of Liquid Body Soap

Four liquid body soap formulations (F1–F4) were prepared by incorporating pomelo peel extract at concentrations of 0%, 1%, 3%, and 5%. Other formulation components included surfactants, moisturizers, thickeners, preservatives, and fragrance.

Table 1. Formulations of Liquid Body Soap Containing Pomelo Peel Extract

Phase	Ingredient (% w/w)	F1	F2	F3	F4	Function
A	Deionized Water	49.05	48.05	46.05	44.05	Diluent
	Sodium Laureth Sulfate	15.00	15.00	15.00	15.00	Primary surfactant
	Cocamidopropyl Betaine	10.00	10.00	10.00	10.00	Secondary surfactant
	Glycerin	15.00	15.00	15.00	15.00	Moisturizer
	Citric Acid	0.20	0.20	0.20	0.20	pH adjuster
B	Sodium Chloride	0.25	0.25	0.25	0.25	Thickener
	Cocamide DEA	2.50	2.50	2.50	2.50	Thickener/Foam booster
	Pomelo Peel Extract	0.00	1.00	3.00	5.00	Active ingredient
	Pearlizing Agent	5.00	5.00	5.00	5.00	Pearlescent appearance
C	SciWis Megacare PHE	1.00	1.00	1.00	1.00	Preservative
D	Fragrance	2.00	2.00	2.00	2.00	Scent
Total		100	100	100	100	

Note: *F1 contains no pomelo peel extract, while F2–F4 contain increasing extract concentrations for comparative evaluation.*

This table presents the formulation components of four liquid body soap prototypes containing different concentrations of pomelo peel extract. The increasing extract concentration from F1 to F4 enables evaluation of dose-response effects on Stability, physicochemical characteristics, and user acceptance.

2.6 Stability Testing

Stability was assessed immediately after preparation and after one week by observing color, odor, texture, and phase separation. Accelerated Stability testing was conducted using Heating-Cooling Cycles (4 °C for 24 h followed by 40 °C for 24 h), repeated for six cycles. Post-test observations included pH, color, odor, texture, and phase separation.

2.7 Safety and Satisfaction Evaluation

A Closed Patch Test was conducted on 20 volunteers aged 20–30 years. Patches containing each formulation were applied to the volar forearm for 24 hours. Sites were observed after a 2-hour recovery period for signs of irritation.

For the satisfaction evaluation, volunteers used assigned formulations for four weeks and completed a structured questionnaire assessing cleansing performance, texture, fragrance, skin compatibility, and overall satisfaction.

3. Results

3.1 Antioxidant Activity

Pomelo peel extract demonstrated potent antioxidant capacity, with an IC_{50} value of 0.49 ± 0.09 $\mu\text{g/mL}$, significantly more effective than vitamin E (133.27 ± 13.97 $\mu\text{g/mL}$).

3.2 Product Development and Stability

All four liquid soap formulations displayed consistent Stability during accelerated temperature cycling.

- **pH values:** 5.70–5.75
- **Appearance:**
 - F1 & F2: white
 - F3 & F4: yellowish-opaque
- **Odor:** odorless with mild extract scent
- **Texture:** liquid and uniform
- **Phase separation:** none observed

3.3 User Satisfaction Evaluation

Consumer satisfaction was assessed using an 8-item Likert scale evaluating cleansing ability, sensory properties, moisturizing effect, and overall acceptance.

Table 2. Average Satisfaction Scores of Liquid Body Soap Formulations

Evaluation Criteria	(Mean \pm SD)			
	F1	F2	F3	F4
Skin tolerance / No irritation	3.8 \pm 0.84	4.4 \pm 0.55	4.6 \pm 0.55	4.6 \pm 0.55
Effective cleansing	4.2 \pm 0.84	3.4 \pm 0.55	4.8 \pm 0.45	4.2 \pm 0.55
Maintains skin moisture	3.4 \pm 0.55	3.4 \pm 0.55	4.6 \pm 0.55	3.4 \pm 0.55
Attractive color	4.4 \pm 0.55	5.0 \pm 0.15	3.4 \pm 0.55	3.0 \pm 0.75
Pleasant fragrance	2.8 \pm 0.45	3.0 \pm 0.13	3.2 \pm 0.45	4.8 \pm 0.45
Easy to rinse off	4.6 \pm 0.55	4.6 \pm 0.55	5.0 \pm 0.15	4.8 \pm 0.45
Smooth texture	4.8 \pm 0.45	4.6 \pm 0.55	5.0 \pm 0.05	4.6 \pm 0.55
Overall satisfaction	3.2 \pm 0.45	3.4 \pm 0.55	5.0 \pm 0.10	4.0 \pm 0.10
Total Satisfaction Score	4.0 \pm 0.59	4.0 \pm 0.41	4.2 \pm 0.46	4.0 \pm 0.41
Level of Satisfaction	High	High	High	High

Note: F3 (3% extract) yielded the highest acceptance in cleansing efficiency, fragrance, rinsability, texture smoothness, and overall satisfaction.

3.3 Consumer Safety and Satisfaction

No irritation or allergic reactions were observed in the Closed Patch Test. Satisfaction scores (1–5 scale) indicated high acceptance as shown in F1 (4.00 \pm 0.59), F2 (4.00 \pm 0.41), F3 (4.20 \pm 0.46) and F4 (4.00 \pm 0.41).

Formulation 3 received the highest ratings, particularly for ease of rinsing (5.0 \pm 0.15), smooth texture (5.0 \pm 0.05), overall satisfaction (5.0 \pm 0.10) and moisturizing effect.

This table summarizes satisfaction scores from 20 volunteers for four formulations. Parameters include skin tolerance, cleansing efficiency, moisturization, appearance, fragrance, rinsability, texture quality, and overall satisfaction. The formulation containing 3% pomelo peel extract (F3) consistently demonstrated the highest satisfaction across multiple categories.

4. Discussion

The exceptionally low IC₅₀ value of pomelo peel extract highlights its strong antioxidant potential, likely attributed to its flavonoid-rich composition. Incorporation into surfactant-based formulations showed no adverse interactions that would compromise Stability, as confirmed by consistent pH and the absence of phase separation.

The favorable consumer response aligns with previous findings regarding citrus-derived phytochemicals enhancing sensory and functional properties of cosmetic formulations. The absence of irritation supports its safety for topical application.

5. Conclusion

Pomelo peel extract demonstrates strong antioxidant activity and can be efficiently incorporated into liquid body soap formulations. All formulations were stable under accelerated conditions and safe for use, with high user satisfaction. Pomelo peel shows promise as a natural, value-added cosmetic ingredient that supports sustainable utilization of agricultural by-products.

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