Development of Cream Serum from Mung Bean Hull Extract Derived from Industrial By-Product: Phenolic Content, Antioxidant Activity, and Formulation

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Abstract. Mung beans hull is by-product from food industry containing polyphenol compounds with antioxidant properties. It is often used in animal feed industry, as inexpensive raw material, but the use in cosmetic products is not yet widespread. This work aims to develop a skin cream serum from polyphenols by extracting the substance from mung bean hull by refluxing and determining the phenolic content by Folin-Ciocalteu method. Antioxidant properties were exhibited by using DPPH method. Subsequently, the formulation and stability test of cream serum were performed. The experimental results showed that the phenolic content was as high as 17.9 mg/g GAE and the IC_{50} free radical inhibition value was 381.9 ug/mL. Three formulas of cream serum were formulated and tested their stability. The comparison of pH, viscosity and CIE color values between the first day and the 30th day showed that those parameters of the three cream serum formulas in each condition did not change significantly. At the same time, no change of the cream serum texture was also observed. These findings could be value addition to mung beans hull by converting for health and beauty industry.

1 Introduction

The global agricultural processing industry generates substantial quantities of by-products that have traditionally been discarded as waste [1]. Recent study has recognized these materials as possible sources of bioactive chemicals with considerable commercial worth [2]. This paradigm shift toward sustainable valorization aligns with circular economy principles and addresses growing concerns regarding resource conservation [3]. Among these underutilized resources, mung bean (*Vigna radiata*) hulls, the outer coverings removed during seed processing which reported as one of the most by-product from legumes industry [4], have emerged as promising candidates for upcycling into high-value products [5].

Mung bean hulls contain a diverse array of phenolic constituents, including protocatechuic acid, isovitexin, vitexin, and various other flavonoids [6]. The average percentage composition of polyphenols in mung bean hull extracts was reported as 55.27 ± 1.14 mg gallic acid equivalent (GAE)/g of mung bean hull [7]. These compounds have demonstrated considerable antioxidant capacity through multiple mechanistic pathways, including free radical scavenging, metal chelation, and enhancement of endogenous antioxidant defence systems [8]. Recent investigations have further elucidated that specific phenolics extracted from mung bean hulls can effectively modulate cellular oxidative stress responses and autophagy pathways in dermal fibroblasts and keratinocytes, suggesting potential applications in combating photoaging and environmental skin damage [9].

Phenolic compounds in mung bean hulls can be extracted using both traditional and modern techniques. Conventional methods include maceration and Soxhlet extraction [10, 11]. For solvent selection, ethanol is commonly employed, though acetone also proves effective. More advanced extraction approaches include ultrasound-assisted extraction [9], pressurized liquid extraction [7], and microwave heating [12].

The cosmeceutical industry represents an ideal for such bioactive compounds, as it increasingly demands naturally-derived ingredients with demonstrable efficacy [13-15]. Several beans have emerged as a significant botanical ingredient in the cosmetic industry, particularly within the realm of skincare products. This legume, traditionally valued in Asian cuisines and folk medicine, has transitioned into contemporary cosmetic formulations due to its remarkable dermatological benefits [16-18]. However, specific commercial cosmetics solely made from mung bean hulls are quite limited and not widely available as standalone products in mainstream markets. Some products that incorporate mung bean hulls or extracts include exfoliating scrubs, face masks, and toners.

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Cream serums—hybrid formulations combining the penetrative capabilities of serums with the hydrating properties of creams—offer an optimal delivery vehicle for phenolic compounds due to their balanced lipophilic-hydrophilic character [19]. The development of such formulations requires consideration of extract stability, ingredient compatibility, rheological properties, and sensory attributes to ensure both efficacy and consumer acceptance [20].

Herein, we investigate the systematic development of a cream serum incorporating phenolic-rich mung bean hull extract derived from industrial by-products. Our methodology encompasses extraction optimization, phenolic content quantification, antioxidant activity assessment, and formulation development with stability evaluation. The work aims to demonstrate not only the functional benefits of this cosmeceutical for skin protection but also its contribution to sustainable product innovation and waste valorization strategies. The findings presented provide a comprehensive framework for transforming agricultural processing residues into efficacious skincare ingredients.

2 Materials and methods

Mung bean hull powder was provided by Thai Wah Public Company, Bangkok, Thailand. Ethanol, Folin-Ciocalteu solution, sodium carbonate, DPPH solution, ascorbic acid, and EDTA were analytical grade from Sigma-Aldrich, Missouri, USA. All formulation ingredients, including glycerin 99.9 % USP, Silsense DW-18, Schercemol 318 Ester, 1,3 – butylene glycol, carbopol ultrez 30 polymer, and phenoxyethanol, were cosmetic grade and purchased from Namsiang Co., Ltd., Bangkok, Thailand.

2.1 Extraction of polyphenol from mung bean hull

The extraction was modified according to a previous report [7]. To a suspension of 10 g of mung bean hull powder in a 250 mL round-bottom flask using 100 mL of ethanol-water solution (40:60) as the solvent for reflux at 80ºC for 1, 2, and 3 hours, respectively. Then each suspension was filtered with Whatman filter paper no. 1 and centrifuged at 4000 rpm for 20 minutes, after which it was evaporated using a rotary evaporator to remove ethanol, leaving polyphenol in water.

2.2 Determination of total phenolic content by Folin-Ciocalteu colorimetric assay

Determination of total phenolic content (TPC) by Folin-Ciocalteu colorimetric assay was modified according to a previously reported procedure [9]. Pipette 0.5 mL of diluted extract solution into a 10-mL test tube. Then add 4.5 mL of distilled water followed by 0.2 mL of Folin-Ciocalteu solution. Then add 0.5 mL saturated sodium carbonate and then add 4.3 mL distilled water. Mix well with a vortex mixer and leave the solution in the dark at room temperature (RT: 32 ± 3ºC) for 30 minutes. Measure an absorption at 765 nm with a UV-Vis spectrophotometer.

2.3 Antioxidant activity test using DPPH radical scavenging assay

The antioxidant activity test using the DPPH radical scavenging assay was modified according to a previously reported procedure [21]. Pipette 0.5 mL of diluted extract solution into a 10-mL test tube. Then add 1.5 mL of distilled water and 2 mL of DPPH solution. Mix well with a vortex mixer and leave the mixed solution in the dark at RT (32 ± 3 ºC) for 30 minutes. Measure an absorption at 517 nm with a UV-Vis spectrophotometer. Ascorbic acid was used as a standard for testing.

2.4 Formulation of cream serum

The formulation of cream serum was performed by varying concentration of glycerin (Table 1). The method for preparing the cream serum products was mixing the substances in Part A; DI water, 2Na EDTA, glycerin 99.9 % USP, 1,3–butylene glycol, and carbopol ultrez 30 polymer using T 25 Ultra-Turrax® homogenizer (IKA Works (Thailand) Co., Ltd., Bangkok, Thailand) at 10,000 rpm for 5 min. at RT (32 ± 3ºC), followed by the substances in Part B, C and D. Then the substances in Part E; phenoxyethanol and polyphenol extract from mung bean hull were added. The mixture was then stirred until homogeneous and packaged.

Table 1. The formulation of cream serum.

Part	Ingredients	Formulation (%w/w)		
	INCI name	F_1	F_2	F_3
A	DI water	86.40	87.40	86.90
	Carbopol Ultrez 30 Polymer	0.15	0.15	0.15
	2 Na EDTA	0.1	0.1	0.10
	Glycerin 99.9% USP	3.00	2.00	2.50
	1,3-Butylene Glycol	5.00	5.00	5.00
B	Silsense 318 Ester	1.50	1.50	1.50
C	Schercemol 318 Ester	1.50	1.50	1.50
D	NaOH (18% Solution)	0.15	0.15	0.15
E	Phenoxyethanol	2.00	2.00	2.00
	Polyphenol extract from mung bean hull	0.20	0.20	0.20

2.5 Stability tests of formulated cream serum

Three cream serum formulations (F1, F2, F3) were prepared and divided into two parts for testing under two storage conditions: RT (32 ± 3ºC) and 4 °C refrigeration. The assessments at the first day (D0) include phase separation, pH measurement, viscosity determination using Brookfield DV2T, and color analysis in the CIE system using Hunter Lab Colorflex: EZ 45-0 (LAV). For colorimetry, in CIE L*a*b* color space:

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

Where, L = Lightness (0=black, 100=white)
a = Red (+) to Green (-)
b = Yellow (+) to Blue (-)

After 30 days of storage (D30), the same parameters were reassessed to compare with D0. Comparative analysis between D0 and D30 measurements involves calculating delta values (Δ) for pH and viscosity, while color changes were quantified using the ΔE value.

3 Results and discussion

3.1 Determination of polyphenol extract yield

Sample extractions were performed under reflux conditions which utilizes controlled heating under condensation to maintain constant solvent volume [22]. The 40-50 % ethanol-water blend provides the right balance of polarity, solubility, and synergistic action to efficiently extract a broad spectrum of phenolic compounds from mung bean hulls while being a practical and safe choice of solvent [7].

Analysis of polyphenol extracts yield using reflux method at different times; 1, 2, and 3 hours in 40 % or 50 % ethanol as the solvent was exhibited in Tables 2. The experimental result demonstrated a relationship between ethanol concentration, extraction duration, and polyphenol yield. When comparing the extraction conditions, it was found 50% ethanol mostly produced higher yields than 40% ethanol, with one notable exception. The highest overall yield (170.9 mg/g dried-based mung bean hull) was achieved using 50% ethanol with a 1-hour extraction time, contradicting the general expectation that longer extraction times produce higher yields.

Table 2. Yield of polyphenol extracts using reflux method.

Conditions		mg/g of dried-based seed coat
%EtOH	Time (h)	
40	1	87.1 ± 0.5
	2	97.6 ± 0.3
	3	108.9 ± 0.4
50	1	170.9 ± 0.5
	2	92.5 ± 0.4
	3	103.9 ± 0.2

The results indicated that solvent polarity plays a crucial role in the extraction efficiency of polyphenols [23]. The 50% ethanol solution provided an optimal balance of polar and non-polar characteristics that effectively solubilizes a broader spectrum of polyphenolic compounds from the mung bean hull matrix. This intermediate polarity appeared effective for the initial extraction phase (1 hour), suggesting that shorter extraction times are preferred to minimize the degradation of polyphenols [9].

3.2 Determination of total phenolic content by Folin-Ciocalteu colorimetric assay

The Folin-Ciocalteu colorimetric assay, widely recognized for quantifying total phenolic content (TPC) in various matrices [9, 24], was employed to identify optimal parameters for maximizing phenolic yield using gallic acid as a standard. The result revealed a clear trend regarding ethanol concentration and extraction duration (Figure 1.). First, 50% ethanol consistently outperformed 40% ethanol across all time points, yielding significantly higher phenolic content values. This suggests that the increased polarity of the 50% ethanol solution provided a more favorable environment for extracting the target phenolic compounds from the sample matrix [25]. Second, a notable inverse relationship was observed between extraction duration and phenolic yield, with the 1-hour extraction consistently producing superior results compared to longer extraction periods (2 and 3 hours).

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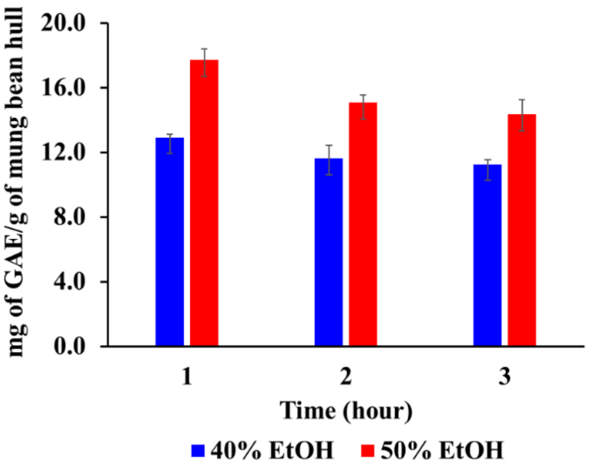


Figure 1. Total phenolic content of mung bean hull extracts.

The highest TPC of 17.9 mg GAE/g of mung bean hull was achieved using 50% ethanol with a 1-hour reflux duration, however, it was lower than the previous report [7]. This signified a 37% increase over the best-performing 40% ethanol condition. The progressive decrease in phenolic content with extended extraction times observed in both ethanol concentrations suggested potential degradation of phenolic compounds during prolonged thermal exposure which would be a critical consideration for optimizing extraction protocols [26].

3.3 Antioxidant activity using DPPH assay

According to the optimal duration and solvent concentration for the extraction procedure, a 1-hour period and 50% ethanol were then selected to assess antioxidant activity utilizing the DPPH assay.

The 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assay represents one of the most widely utilized methodologies in natural product research for quantifying free radical scavenging capacity. This spectrophotometric assay offers several advantages including operational simplicity, rapid results, and high reproducibility, making it an essential tool for preliminary screening of potential antioxidant compounds from plant extracts [27].

In our investigation, the relationship between inhibition percentage and extract concentration was analyzed by plotting inhibition percentage against the logarithm of concentration (Figure 2.). Our result demonstrated that extraction yielded the antioxidant activity with an IC_{50} value of 381.9 µg/mL, which was higher than the previous report [28]. While this value was approximately 12.5 times higher than that of ascorbic acid or vitamin C (30.6 µg/mL), it represents antioxidant potential for a crude plant extract. This IC_{50} value represents a moderate antioxidant activity when compared to values reported in existing literature [29, 30].

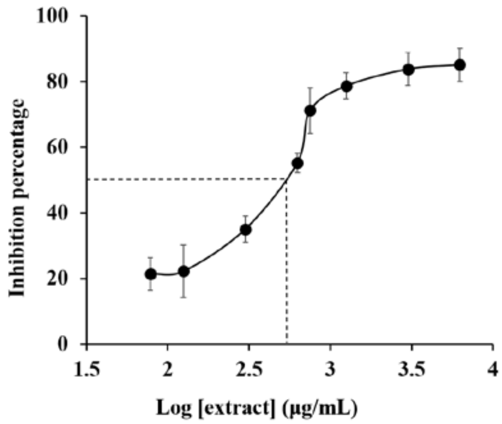


Figure 2. Plot of inhibition percentage against log concentration of mung bean hull extract.

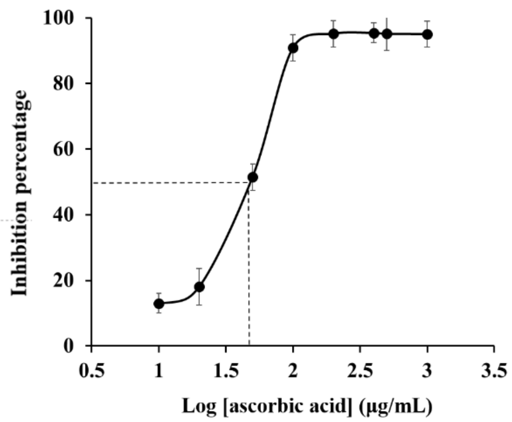


Figure 3. Plot of inhibition percentage against log concentration of ascorbic acid.

3.4 Stability tests of formulated cream serum

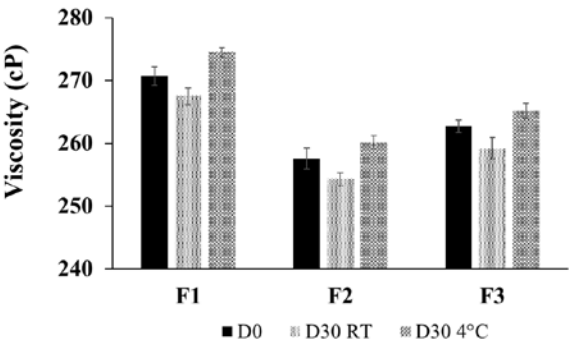


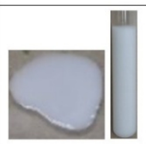
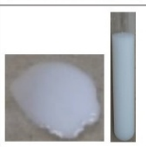
Figure 4. Viscosity of cream serum formulations over the 30-day storage period at RT (32 ± 3ºC) and 4°C.

The physical stability of three cream serum formulations was rigorously evaluated through multiple parameters under two storage conditions: RT (32 ± 3ºC) and refrigeration (4°C). This comprehensive analysis provides critical insights into the formulations' behavior under typical storage conditions over a 30-day period.

Visual inspection of the cream serum formulations from D0 to D30 revealed stability in terms of consistency. All three formulations maintained homogeneous textures without any noticeable changes in appearance when stored at RT (32 ± 3ºC) (Table 3.). The serums preserved their white color and maintained an appealing texture throughout the testing period. At 4°C, while a slight increase in opacity was observed, the formulations remained homogeneous with no significant changes in their application characteristics.

Phase separation analysis demonstrated excellent stability across all formulations. No evidence of layer separation or sedimentation was observed in any of the samples at either storage condition. This stability aligns with the reported quality standards, which emphasize that cream and serum formulations should maintain phase integrity regardless of storage conditions or temperature variations [31, 32].

Table 3. Visual inspection and phase separation of cream serum formulations.

Formulation	D0	D30	
		RT	4°C
F1			
F2			
F3			

Viscosity analysis of the cream serum formulations revealed minimal changes over the 30-day storage period (Figure 4.). At RT (32 ± 3ºC), the viscosity changes were 3.2 cP, 3.3 cP, and 3.5 cP for formulations F1, F2, and F3, respectively. Under refrigeration at 4°C, the formulations exhibited slightly higher viscosity values compared to RT (32 ± 3ºC) samples due to reduced molecular kinetic energy at lower temperatures, which increases flow resistance. However, the changes from initial values remained minimal at 3.8 cP, 2.6 cP, and 2.5 cP for F1, F2, and F3, respectively.

The viscosity range of 200-270 cP observed across all formulations was optimal for serums, providing the lightweight, non-sticky texture that characterizes high-quality serum products [33]. This highlighted the lightweight texture and quick absorption as distinctive properties of effective serums.

The pH stability analysis discovered exceptional consistency across all formulations during the 30-day storage period (Figure 5.). At RT (32 ± 3ºC), the pH changes were minimal at 0.01, 0.03, and 0.05 units for formulations F1, F2, and F3, respectively. Under refrigeration at 4°C, the formulations exhibited slightly higher pH values compared to RT samples, which can be attributed to decreased hydrogen molecule solubility at lower temperatures, leading to slightly increased alkalinity. However, the changes from initial values remained negligible at 0.01, 0.01, and 0.04 pH units for F1, F2, and F3, respectively.

Importantly, all formulations maintain pH values within the optimal range of 4-6, which is ideal for skin application. This is an importance of maintaining appropriate pH levels to protect the skin's natural hydrolipid film barrier [34]. Excessive alkalinity can disrupt this protective barrier, leading to moisture loss and skin dryness.

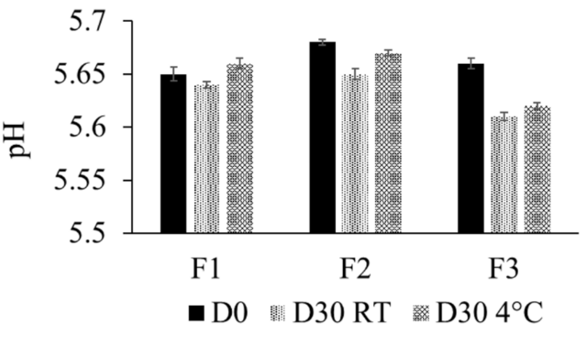


Fig. 5. pH of cream serum formulations over the 30-day storage period at RT (32 ± 3ºC) and 4°C.

Color stability analysis using the CIE color system demonstrated excellent stability, particularly at RT (32 ± 3ºC) (Table 4.). The color difference values (ΔE) for RT samples were 0.92, 0.90, and 0.97 for formulations F1, F2, and F3, respectively. Since these values are less than 1.0, the color changes are invisible to the human eye, indicating good color stability.

Table 4. Color in the CIE system of cream serum formulations over the 30-day storage period at RT (32 ± 3ºC) and 4°C.

Color (L*, A*, B*)			
Formulation	Day/state		
	D0	D30	
		ΔE (RT)	ΔE (4°C)
F1	(92.88, -1.11, 1.02)	0.92	1.29
F2	(91.71, -1.37, -0.58)	0.90	1.17
F3	(91.57, -1.33, 0.52)	0.97	1.32

Under refrigeration at 4°C, slightly higher color difference values were observed: 1.29, 1.17, and 1.32 for F1, F2, and F3, respectively. These values exceed 1.0, suggesting that the color changes might be just perceptible to the human eye. This was visually confirmed as a slight increase in opacity in the refrigerated samples. The increased opacity is a visual indicator of changes at the molecular or microscopic level within the cream serum, primarily driven by the reduced temperature affecting ingredient solubility, viscosity, and emulsion stability. Nevertheless, these changes were minimal and did not significantly affect the overall appearance or quality of the formulations.

4 Conclusion

This research successfully demonstrates the potential of mung bean hull, an industrial by-product, as a valuable source of bioactive compounds for cosmetic applications. The study systematically developed a cream serum formulation incorporating phenolic-rich extracts from mung bean hulls, addressing both sustainability concerns and consumer demand for naturally-derived skincare ingredients. The extraction optimization revealed that 50% ethanol with a 1-hour reflux duration yielded the highest total phenolic content (17.9 mg GAE/g) and demonstrated significant antioxidant activity with an IC_{50} value of 381.9 µg/mL in the DPPH assay. Three cream serum formulations were developed and subjected to comprehensive stability testing over a 30-day period under both RT (32 ± 3ºC) and refrigerated conditions. All formulations exhibited excellent stability in terms of physical appearance, phase separation, viscosity, pH, and color. This provides a comprehensive framework for transforming agricultural processing residues into efficacious skincare ingredients, contributing to sustainable product innovation and waste valorization strategies.

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