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Formulation and Assessment of Physical Characteristics of *Beta vulgaris* L Extract Body Lotion as a Moisturizer

Septiana L. Ramayani*, Muhammad Syaifuddin, Indri K. Dewi

Poltekkes Kemenkes Surakarta, Jl. Letjend. Sutoyo Mojosongo, Surakarta, Central Java 57127 Indonesia

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ABSTRACT

Lower-limb prostheses function as biomechanical substitutes that restore mobility in amputees. Despite their functional benefits, prolonged prosthesis use is often associated with adverse cutaneous reactions, including hyperkeratotic lesions, proliferative skin changes, cystic formations, and hypersensitivity responses. Friction and the accumulation of reactive oxygen species (ROS) aggravate these complications, collectively hindering the tissue healing process. The objective of this research was to formulate and assess a beetroot (*Beta vulgaris* L.) extract-based body lotion as an auxiliary therapy, utilizing its antioxidant potential to minimize oxidative stress and friction. Beetroot extract was obtained via maceration in 70% ethanol, and subsequently incorporated into a lotion base with appropriate excipients. The lotion's physical properties were examined through conventional stability and performance assessments, and antioxidant activity was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. While the formulation met cosmetic quality benchmarks, its adhesion performance was below the desired threshold. Antioxidant activity evaluation showed a very strong activity level, reflected by an IC_{50} value of 47.90 ppm. These findings suggest that beetroot extract body lotion holds promise as a supplementary skincare intervention for lower-limb amputees, potentially enhancing comfort and cutaneous resilience during prosthesis use.

Keywords: Beetroot, Body lotion, Physical quality, Antioxidant activity.

Introduction

Limb amputation is defined as the partial or complete removal of anatomical structures in the upper or lower limbs. Upper-limb amputations are predominantly caused by traumatic injuries, whereas lower-limb amputations are more commonly linked to peripheral arterial disease. Other etiological factors include congenital limb anomalies, neoplastic diseases, and chronic osteomyelitis.[1] The skin of amputees particularly in the residual limb is often subjected to xerosis or desquamation, rendering it more susceptible to frictional injury and moisture retention within the prosthetic socket. These factors compromise the skin barrier, predisposing it to inflammation, discomfort, and secondary infections. Moisturizers, such as body lotions, may help maintain skin integrity by enhancing hydration and improving epidermal resilience. Beetroot (*Beta vulgaris* L.) is a promising active ingredient owing to its high antioxidant potential, largely attributed to betacyanin pigments, with a reported IC_{50} value of 21.88 µg/mL.[2] Beside its antioxidant capacity, beetroot extract exhibits hydrating and antibacterial properties,[2,3] making it suitable for alleviating irritation and improving skin tolerance to prolonged prosthesis use. Body lotions are particularly suitable as delivery vehicles due to their spreadability, ease of absorption, and capacity to provide a protective, moisturizing layer on the skin surface.[4]Considering these factors, this study aimed to produce a topical beetroot extract-based body lotion and assess its physical characteristics and antioxidant capacity.

*Corresponding author. Email: septianaLR@gmail.com
Tel.: +6282138388871

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The novelty is rooted in both the elevated beetroot extract concentration and a re-engineered base formulation that now includes Liquid paraffin as an additional moisturizer alongside Stearic acid and Cetyl alcohol. Given that the earlier 2.5% formulation provided only moderate antioxidant activity (IC_{50} = 118.10ppm) [5], this strategic modification is expected to significantly boost the resultant antioxidant capacity. This formulation is specifically designed to treat oxidative stress and skin irritation resulting from prosthetic socket friction in lower limb amputees, a challenging and often-neglected clinical overlap between dermatology and prosthetics. Antioxidant capacity was measured using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging assay, chosen for its proven effectiveness in quantifying free radical inhibition and due to the recognized impact of reactive oxygen species (ROS) in slowing wound repair and aggravating skin inflammation, especially inside prosthetic socket settings.

Materials and Methods

Study location and duration

The experimental work was conducted at the Pharmacy Laboratory, Polytechnic of Health, Ministry of Health, Surakarta, Central Java, Indonesia, over a six-month period from January to July 2024.

Plant collection and identification

Fresh beetroot specimens were sourced from Batur Village, Semarang Regency, Central Java, Indonesia in January 2023. The plant material was taxonomically verified by Mrs. Isna Jati Aisyah at the Center for Research and Development of Medicinal Plants and Traditional Medicine, Tawangmangu, Central Java, Indonesia with voucher number KM.04.01/2/342/2023. The raw plant material was washed thoroughly, sliced, dried, pulverized, and sieved through a 40-mesh filter to obtain a uniform, fine powder suitable for extraction.

Extraction of beetroot

Beetroot powder (300 g) was macerated in 3 L of 70% ethanol in a sealed glass vessel wrapped in aluminum foil to protect from light. The mixture was kept at 25-30°C for 72 hours, with intermittent agitation to

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enhance solvent penetration and extraction efficiency. The macerate was initially filtered through flannel cloth to remove coarse particulates, followed by filtration through standard filter paper to obtain a clear liquid extract. The filtrate was evaporated over a water bath at 50°C until a thick, viscous extract was obtained. The viscous extract was weighed, and its percentage yield was determined against the initial dry weight of beetroot powder to assess extraction efficiency.

Formulation of beetroot-based body lotion

The lotion formulation followed a modified procedure from a previously established method.[5] The ingredients used in the formulation and their proportions are listed in Table 1. The oil phase, containing liquid paraffin, cetyl alcohol, and stearic acid, was melted in a porcelain dish at 50°C on a water bath. At the same time, the aqueous phase comprising propylene glycol, triethanolamine, methylparaben, and propylparaben was prepared at the same temperature to ensure compatibility prior to emulsification.

Table 1: Formula for the beetroot body lotion

Ingredient	Concentration (%)	Function
Beetroot extract	25	Active ingredient
Cetyl alcohol	4	Emulsifier
Propylene glycol	5	Preservative
Liquid paraffin	7	Emollient
Stearic acid	4	Emulsifier
Triethanolamine	1	Buffer
Methyl paraben	0.12	Preservative
Propyl paraben	0.1	Preservative
Distilled water	Ad 60	Solvent

Once both phases were at the same temperature, the aqueous phase was added slowly to the oil phase while stirring continuously to achieve emulsification and form a stable lotion base. The concentrated *Beta vulgaris* L. extract was then added at the predetermined concentration and mixed thoroughly until a homogeneous formulation was achieved.

Quality evaluation of beetroot-based body lotion

a. Sensory evaluation (visual and tactile)

The visual characteristics of the lotion including colour, odour, consistency, and phase separation were assessed by five trained panelists under standardized lighting conditions. Texture was evaluated using a 5-point hedonic scale.[7]

b. Uniformity assessment

One gram of lotion was evenly spread on a glass slide and examined under a 10× hand-held magnifying glass. The presence of coarse particles or phase separation was recorded.[7]

c. pH measurement

pH was measured with an HI8424 pH meter calibrated using pH 4.01 and 7.00 buffer standards. Twenty grams of lotion were mixed into 20 mL of distilled water, stirred for five minutes, and allowed to be stable before the pH measurement was taken.[8]

d. Viscosity measurement

Viscosity was evaluated using a Brookfield DV-II+ Pro viscometer, spindle No. 4, at 60 rpm and 25°C. Approximately 100 g of lotion was placed beneath the spindle, and readings (cP) were taken after 30 seconds.[9]

e. Adhesion test

A 0.1 g lotion sample was positioned between two glass slides (25 mm × 75 mm), secured, and a 50 g weight was applied for five minutes. The time (seconds) required for the slides to separate under gravitational force was recorded.[7]

f. Spreadability test

A 0.5 g lotion sample was positioned between two glass slides (diameter 20 mm). The initial spread diameter was measured after 1 minute without load. Weights of 50, 100, 150, and 200 g were applied sequentially for one minute each, and the resulting spread diameters (mm) were documented.[7]

Assessment of antioxidant activity

The antioxidant activity of both the beetroot extract and its lotion formulation was determined using the 2,2-diphenyl-1-picryl hydrazyl (DPPH) radical scavenging assay. Sample solutions were prepared in methanol at concentrations of 2, 4, 8, and 10 ppm. For each concentration, 2 mL of sample solution was combined with 2 mL of 0.1 mM DPPH solution in methanol, mixed thoroughly, and kept in the dark at room temperature for 15 minutes to avoid photodegradation. Absorbance readings were taken at 517 nm using an Innova C-5000 UV–Vis spectrophotometer. Percentage radical inhibition was computed following Equation 1, and the IC_{50} value was derived through linear regression (Equation 2):[10]

$$\%\, I = \frac{Abs\ control - Abs\ sample}{Abs\ control}\ x\ 100 \quad \text{..... (Eq. 1)}$$

Where:
Abs = absorbance

$$y = bx + a \quad \text{..... (Eq. 2)}$$

Where:
y = absorbance of the sample
x = concentration corresponding to the IC_{50} value (ppm)
a = regression constant (intercept)
b = regression coefficient (slope)

Statistical analysis

All tests were carried out in triplicate (n = 3), and results were presented as mean ± standard deviation (SD) to reflect central tendency and variability. Statistical analysis was performed using IBM SPSS Statistics 26 (IBM Corp., Armonk, NY, USA; 2019). Data normality was assessed using the Shapiro–Wilk test. An independent samples t-test was performed to compare the antioxidant IC_{50} values between the beetroot extract and its lotion formulation. A p-value below 0.05 was regarded as statistically significant.

Results and Discussion

Physical characteristics of beetroot-based body lotion

The principal physicochemical properties of the beetroot extract-based body lotion are presented in Table 2. Across all tested formulations, the product exhibited satisfactory homogeneity, pH, viscosity, and spreadability, meeting the standard requirements for topical cosmetic preparations.

Table 2: Physical quality characteristics of beetroot extract body lotion

Parameter		Result	Standard
Sensory characteristics	Form	Semi-solid	-
	Smell	Typical of beetroot	-
	Colour	Slightly brown	-
Uniformity		Homogeneous	Homogeneous
pH		4	4 - 7
Viscosity (cP)		2854	2000 – 50.000
Adhesion (seconds)		2.64	> 4
Spreadability (cm)	50 g	5.13	5 -7
	100 g	5.33	
	150 g	5.53	
	200 g	5.6	
	250 g	5.6	

The incorporation of beetroot extract did not compromise the lotion's structural integrity or functional performance; however, the formulation did not meet the minimum adhesion standard. The pH of the lotion (4.0)

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falls within the physiological range of the skin's acid mantle (4.0 - 7.0), aligning with dermatological safety parameters, thus reducing the likelihood of irritation.[11,12] The measured viscosity (2,854 cP) lies within the recommended range for lotion emulsions (2,000 - 50,000 cP), ensuring appropriate rheological behaviour for dermal application.[13]

Viscosity is a fundamental physicochemical property in emulsion-based cosmetic formulations, particularly lotions, as it influences rheological behaviour, ease of application, and overall sensory perception. In hydrocolloid-based systems, viscosity is affected by multiple compositional and processing factors, including polymer concentration, processing temperature, dispersion uniformity, sulfate group content, manufacturing technique, and the presence of hydrophilic colloidal agents.

According to established cosmetic standards, lotion formulations should exhibit viscosity values within the range of 2,000 – 50,000 centipoise (cP).[13] The beetroot extract-based body lotion developed in this study demonstrated viscosity values within this range, confirming its suitability in terms of consistency, physical stability, and appropriateness for dermal application.

Adhesion testing, measured as the time two glass slides remained adhered under a 50 g load, yielded an average of 2.64 s, which is below the desirable threshold of > 4 s.

Adhesion, defined as the duration a topical product remains in contact with the skin, is crucial for ensuring sufficient absorption and therapeutic action. The adhesion test results indicated that the formulation did not meet the minimum standard of >4 seconds. This indicates a shorter residence time on the skin surface, potentially limiting the formulation's capacity for prolonged contact and sustained action, hence, the need for formulation optimization.

Spreadability testing, conducted to evaluate the ability of the lotion to distribute evenly over the skin, showed favorable results. The result produced an average spread diameter of 5.44 cm, with values increasing proportionally with the applied load, a behaviour characteristic of water-rich emulsions, which are known for their ease of dispersion across the skin surface.[11,14]

The measured spread diameters varied between 5 and 7 cm, satisfying the accepted standards for effective topical dispersion.[14]

Comparative antioxidant efficacy between beetroot extract and its lotion-based delivery system

The antioxidant potential of the beetroot extract and its lotion formulation was analyzed using the DPPH radical scavenging assay, with absorbance measured at 517 nm. This method is widely recognized for its simplicity, rapid execution, and minimal sample requirements, making it appropriate for assessing the free radical neutralizing ability of antioxidants.[15] The DPPH assay operates by measuring the capability of antioxidant molecules to donate electrons or hydrogen atoms to stabilize the DPPH radical, causing a measurable drop in absorbance and a visible colour change. The extent of discoloration reflects the radical scavenging capacity of the sample. A key parameter derived from this assay is the half-maximal inhibitory concentration (IC_{50}), representing the amount of antioxidant needed to reduce the initial DPPH radical level by 50%.[16] Lower IC_{50} values correspond to greater antioxidant potency. In this study, both the beetroot extract and its lotion formulation demonstrated measurable antioxidant activity, as indicated by their respective IC_{50} values. These results confirm the potential utility of beetroot-derived ingredients in topical cosmetic formulations aimed at mitigating oxidative stress and enhancing skin protection.

As shown in Table 3, the IC_{50} value of the beetroot extract (31.55 ± 4.68 ppm) was lower than that of the beetroot-based body lotion (47.60 ± 9.92 ppm), suggesting that the pure extract exhibited greater antioxidant potency than the formulated lotion.

Table 3: IC_{50} values and antioxidant classification of beetroot samples

Sample	IC_{50} (ppm)	Category
Beetroot extract	31.55 ± 4.68	Very strong
Beetroot-extract lotion	47.60 ± 9.92	Very strong

This reduction in potency may be attributed to the presence of excipients in the lotion matrix, which could partially restrict the interaction between active antioxidant compounds and DPPH radicals.[17,18] An independent samples t-test produced a p-value of 0.064, showing that the antioxidant activities of the raw extract and the lotion formulation were not significantly different. The modest increase in IC_{50} for the lotion likely reflects minor interactions between phytochemicals and excipients that reduce radical accessibility without substantially compromising antioxidant strength.

Antioxidant strength is quantitatively determined by IC_{50} values. According to established criteria[16] and as presented in Table 4, antioxidant strength is categorized into specific ranges, with values below 50 ppm considered very strong. Both the beetroot extract and its lotion formulation exhibited IC_{50} values within this range, confirming their classification as very strong antioxidants. This result highlights the notable radical-scavenging capacity of beetroot-derived compounds and supports their suitability for incorporation into antioxidant-rich cosmetic formulations designed to protect the skin from oxidative stress.

Table 4: Antioxidant strength based on IC_{50} value

Category	IC_{50} Range (ppm)
Very Strong	< 50
Strong	50 - 100
Moderate	101 - 250
Weak	251 - 500
Very Weak	> 500

Conclusion

Physical evaluation of the beetroot (*Beta vulgaris* L.) extract-based lotion demonstrated that the formulation met key cosmetic quality standards, including homogeneity, pH stability, viscosity, and spreadability. The measured IC_{50} value of 47.60 ppm indicates strong antioxidant capacity, confirming its suitability for topical applications and highlighting its potential therapeutic relevance. These findings support the lotion's prospective use as a moisturizing agent for amputee prosthetic sockets, where antioxidant-mediated protection may help maintain residual limb skin health and resilience. Future research should investigate the long-term dermatological effects, biocompatibility with various prosthetic materials, and scalability of production. Additional work on formulation optimization particularly enhancing stability and adhesion alongside comparative trials across diverse amputee populations, would further strengthen the evidence base for its clinical and cosmetic application.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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