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Hexane Extract from Squirrel-Tail Palm Fruit (*Wodyetia bifurcata*) as a Moisturizing Cream: Phytochemical Profile, Formulation, and Evaluation

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Abstract

Dry skin, characterized by excessive water loss from the outermost layer of the epidermis, is a common dermatological concern that can be addressed with topical moisturizers. This study aimed to formulate and evaluate a moisturizing cream based on the n-hexane extract of squirrel-tail palm fruit (*Wodyetia bifurcata*) and to identify its phytochemical profile. The dried fruit pulp was macerated in n-hexane, and the resulting extract was characterized using gas chromatography–mass spectrometry (GC–MS). Two cream formulations containing 5% (F1) and 15% (F2) of the extract, together with a base cream (F0) and a commercial cream (F+), were prepared as oil-in-water emulsions and evaluated for moisturizing effectiveness on the heels of six female volunteers (aged 35–50) over 14 days using a skin moisture analyzer. Physical properties of the creams were assessed using organoleptic, homogeneity, pH, spreadability, adhesion, irritation, and hedonic tests, along with a four-cycle stability test. GC–MS analysis identified 48 compounds dominated by fatty acids and their methyl esters, with 9-octadecenoic acid (Z)-, methyl ester (10.55%), l-(+)-ascorbic acid 2,6-dihexadecanoate (8.14%), and hexadecanoic acid, methyl ester (5.55%) as major constituents. The mean moisturizing effectiveness values were 13.46% for the crude extract, 19.48% for F1, and 25.83% for F2, indicating concentration-dependent moisturizing activity. All physical property results complied with the SNI 16-4399-1996 standard, and no skin irritation was observed. Overall, formulation F1 was identified as the optimal preparation in balancing physical stability, sensory acceptability, and moisturizing performance, supporting the cosmetic potential of *W. bifurcata* fruit as a natural moisturizing agent.

1. Introduction

The skin is the largest and outermost organ of the human body and serves as the primary barrier against environmental insults, including dehydration, microbial invasion, and physical abrasion. One of its principal functions is to limit transepidermal water loss, and any disruption of this regulatory role leads to dry skin, a condition characterized by excessive water loss from the stratum corneum [1]. Dry skin compromises both the aesthetic and functional integrity of the skin, resulting in a dull, inelastic appearance, scaling, itching, and irritation [2]. Sebum, the natural oil secreted by sebaceous glands, normally forms a thin protective film that retards moisture loss [3], while the skin's water content determines its overall hydration status [4]. Restoring

elasticity and preserving moisture in the epidermis are therefore central goals in the management of xerosis, and these aims can be achieved with topical moisturizers [5].

Moisturizing creams are among the most widely used cosmetic products today [6], owing to their capacity to soften the skin, support hydration, and reduce the perception of dryness [7, 8]. They act by retarding water evaporation from the skin surface while simultaneously replenishing the natural moisture of the epidermis [9], a feature that distinguishes them from many other cosmetic preparations [10]. The performance of a moisturizer is determined largely by the active ingredients it contains, which include humectants (such as hyaluronic acid, glycerin, amino acids, and aloe vera) that draw water from the surrounding environment, emollients (such as butter, cocoa butter, and fatty acids) that soften the skin, and occlusives (such as wax, olive oil, and mineral oil) that retard water evaporation [11]. Plant-derived oils and lipid-rich extracts are particularly attractive sources of these active ingredients because they combine emollient and humectant properties with a favorable consumer perception.

Squirrel-tail palm (*Wodyetia bifurcata*), a member of the Arecaceae family, has previously been examined chemically and pharmacologically. The *W. bifurcata* palm is a popular ornamental plant native to Queensland, Australia. It is a unique and attractive palm tree with a variety of practical and aesthetic benefits, making it a suitable choice for landscaping in suitable climates. The *W. bifurcata* palm is also often called the foxtail palm. The *W. bifurcata* palm belongs to the Arecaceae family and produces elliptical fruit, approximately 3 cm wide and 6 cm long, with orange and red flowers and a single seed. The *W. bifurcata* plant is very easy to cultivate and exhibits good drought tolerance, making it ideal for planting in temperate climates [12]. A previous study by Hilda reported that the ethanolic extract of *W. bifurcata* fruit contained a range of constituents, including 4H-pyran-4-one 2,3-dihydro-3,5-dihydroxy-6-methyl, hexadecanoic acid methyl ester, l-(+)-ascorbic acid 2,6-dihexadecanoate, pentadecanoic acid, methyl 9-cis-11-trans-octadecadienoate, methyl 6- and 11-octadecenoate, methyl stearate, linoelaidic acid, 17-octadecynoic acid, oleic acid, octadecanoic acid, squalene, and β-sitosterol [13]. Several of these compounds (linoleic acid, methyl stearate, and oleic acid) are known emollients, while squalene is a recognized humectant. Earlier work also documented heavy-metal toxicity considerations and triterpenoid–phenolic profiles for related *Wodyetia* preparations [14, 15], but the formulation of a moisturizing cream based on the n-hexane extract of the fruit, together with rigorous physical-property testing, has not yet been reported. The present study addresses this gap by characterizing the n-hexane extract of W. bifurcata fruit using GC–MS, formulating two oil-in-water moisturizing creams at extract concentrations of 5% and 15%, and evaluating their moisturizing effectiveness and physicochemical properties in six female volunteers over a 14-day application period.

2. Materials and Methods

2.1. Materials

The plant material used in this study was the fruit of *Wodyetia bifurcata*. The reagents and excipients comprised stearic acid (Merck, 57-11-4), triethanolamine (Merck, 102-71-6), glycerin (Merck, 56-81-5), distilled water, methylparaben (Merck, 99-76-3), ethanol (Merck, 64-17-5), n-hexane (Merck, 110-54-3), phytochemical reagents (Liebermann–Burchard, Dragendorff, Mayer, and Wagner), glyceryl monostearate (Croda Pte Ltd, Singapore), propylene glycol (Dow Chemical Pacific, Singapore), and propylparaben (Amresco, LLC). All chemicals were of analytical grade and used without further purification.

2.2. Plant Collection and *Phytochemical Screening*

W. bifurcata fruits were collected from Tapaktuan-Meulaboh National Road, Kuta Baro, Meukek district, South Aceh, Aceh Province (3.456805, 97.059604). Dr. Saida Rasnovi identified the sample, number 13/UN11.1.8.4/TA.00.03/2023, at the Herbarium, Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala.

Phytochemical screening of the n-hexane extract was performed following the procedures described in A Guide to Modern Techniques of Plant Analysis [16]. The presence of alkaloids, flavonoids, terpenoids, steroids, saponins, and tannins was assessed using Liebermann–Burchard, Dragendorff, Mayer, and Wagner reagents, and the reactions were interpreted based on standard color and precipitation reactions.

2.3. Extraction of W. bifurcata Fruit Pulp

The fruits of *W. bifurcata* were cleaned and split into two parts, and the fruit was then separated into the mesocarp and kernel. The fruit's mesocarp was collected, dried, and mashed. Three kilograms of dried, powdered W. bifurcata fruit pulp were macerated with n-hexane for 3 × 24 h at room temperature. The macerate was filtered through a Buchner funnel, and the resulting filtrate was concentrated under reduced pressure on a rotary

Table 1. Formulation of the *W. bifurcata* fruit extract cream preparation.

Material	Composition (%)			
	Negative control	**F1**	**F2**	**Function of Materials**
W. bifurcata fruit extract	-	5.00	15.0	Active ingredients
Stearic acid	12.0	12.0	12.0	Emulsifying agent
Glycerin	5.00	5.00	5.00	Humectant
Propylene glycol	3.00	3.00	3.00	Humectant and occlusive
Glyceryl monostearate	3.00	3.00	3.00	Emulgator
Triethanolamine (TEOA)	1.00	1.00	1.00	Emulsifying agent
Methyl paraben	0.18	0.18	0.18	Preservative
Propyl paraben	0.02	0.02	0.02	
Aqua dest	Ad 100	Ad 100	Ad 100	Solvent

Note:
F1: Cream preparation formulation 1 (extract: 5%)
F2: Cream preparation formulation 2 (extract: 15%)
Ad: Until (Ad 100 = made 100)

evaporator to obtain a dark-green concentrated extract of 19.151 g (0.63%), using 20 liters of hexane.

The crude extract was used directly in the moisturizing activity assay and characterized by GC–MS before incorporation into the cream formulations. Each cream preparation was subsequently evaluated for moisturizing activity and physical properties, including pH, homogeneity, spreadability, adhesion, organoleptic, hedonic, and irritation responses, as well as stability over four cycles.

2.4. Moisturizer Formulation

Moisturizing creams containing the n-hexane extract of *W. bifurcata* fruit were prepared on an oil-in-water (o/w) base, following the study by Sutrisno with slight modifications [17]. Two formulations were prepared with extract concentrations of 5% (F1) and 15% (F2). A base cream without the extract was prepared as a negative control (F0), and a commercially available moisturizing cream was used as a positive control (F+). Briefly, the oil phase, comprising stearic acid, glyceryl monostearate, and propylparaben, was heated to approximately 70°C; the aqueous phase, containing distilled water, glycerine, propylene glycol, triethanolamine, and methylparaben, was heated separately to the same temperature. The aqueous phase was gradually added to the oil phase under continuous stirring until a homogeneous emulsion was obtained, after which the n-hexane extract was incorporated and the mixture was stirred while cooling to room temperature.

The preparation of moisturizer cream from *W. bifurcata* fruit extract/subfraction was carried out based on research [18], using a modified method. The cream formula for the *W. bifurcata* fruit extract moisturizer preparation is presented in Table 1.

The moisturizing preparation of *W. bifurcata* fruit was formulated from hexane extract by first creating 2 distinct phases: an oil phase and a water phase. The oil phase consists of stearic acid and glyceryl monostearate, while the water phase consists of triethanolamine (TEOA), glycerin, and propylene glycol. Then, in another container, a preservative mixture was made consisting of methyl paraben and propyl paraben dissolved in propylene glycol. After that, both phases were heated to 70°C. The oil and water phases were then mixed into a heated mortar and ground until homogeneous. The thick ethanol extract of *W. bifurcata* fruit was prepared at 2 concentrations: 5% and 15%. Meanwhile, *W. bifurcata* extract with a concentration of 5% was added slowly to the base cream that had been made as formula 1 (F1), while W. bifurcata extract with a concentration of 15% was added to the base cream that had been made as formula 2 (F2). F1 and F2 were each stirred until homogeneous.

2.5. Moisturizing Activity Test

The moisturizing activity of the *W. bifurcata* fruit extract and its cream formulations was evaluated according to the method of Aryani, with slight modifications [5]. Approval was obtained from the Ethics Committee of the Faculty of Medicine, Universitas Syiah Kuala. Six female volunteers aged 35–50 years, with comparable daily activities (homemakers) and mild-to-moderate dry, cracked skin on the heels of both feet, were recruited. Volunteers agreed to apply the test product only once daily at night for the duration of the study and to refrain from using other moisturizing products during the study period. The 14-day extract test was conducted first, in which the crude extract was applied to each volunteer's heel. After completion, formulations F1 and F2 were tested concurrently for 14 days, with F1 applied to the right heel and F2 to the left heel. One week after this phase, the negative control (F0) and positive control (F+) were tested for a further 14-day period. Skin moisture was measured before and after product application each

day using a portable skin moisture analyzer, and changes were recorded with a 12-megapixel camera.

2.6. Evaluation of Physical Properties

The cream preparations were evaluated for pH [19], homogeneity [20], spreadability [21], adhesion [19], organoleptic and hedonic responses [19], skin irritation [19], and stability over four cycles [22]. The procedures used for each evaluation are summarized below.

Homogeneity testing is performed to determine whether the base ingredients in the moisturizer and its additives are evenly mixed during formulation. A moisturizer is considered homogeneous if there are no clumps on the container's surface.

A pH test is performed to determine the safety of a moisturizer preparation during use and to ensure it does not cause skin irritation. The pH test is performed by measuring the moisturizer's pH with a pH meter. Approximately 1 g of moisturizer is weighed and diluted with approximately 10 mL of distilled water. The pH meter is inserted into the dissolved moisturizer, and the pH reading is read on the device's monitor. A good moisturizer should be close to the skin's physiological pH, which is 4.5-6.5

A spreadability test is performed to determine a moisturizer's ability to spread on the skin surface. The criteria for good spreadability for topical preparations are 5-7 cm. Spreadability testing can be performed by weighing approximately 0.5 g of moisturizer and placing it on a cup. The cup is then covered and inverted, left for approximately 1 minute, and the diameter of the spread moisturizer is measured. Then, loads of 50, 100, and 250 g are applied in stages, left for 1 minute, and the diameter is measured again with each additional load.

An irritation test is a preparation test intended to determine whether a cream preparation can cause skin irritation. The technique used in this irritation test is an open-sample test on the inner forearm of 10 respondents. This test can be performed three times a day for three consecutive days. The observed irritation reaction is typical of eczema in the test area, namely itching. This symptom appears as edema in the red skin area. If blisters also occur, it indicates primary irritation. If moderate erythema occurs, the test is repeated the following day. If the erythema appears pale within 24 hours, it is considered evidence of no allergic reaction.

A hedonic test is an organoleptic sensory analysis method used to determine the magnitude of differences in quality among several similar products by providing an assessment or score of certain product properties, and to determine the level of liking for a product. This level of liking is called a hedonic scale, for example, really like, like, somewhat like, somewhat dislike, dislike, really dislike, and so on. The principle of the hedonic test is that respondents are asked for their personal responses to their likes or dislikes of the commodity being assessed, including levels of liking or dislike on a hedonic scale [23]. Stability test. The cream preparations underwent four cycles of stability testing, during which organoleptic and pH changes were monitored.

3. Results and Discussion

3.1. Identification of Chemical Components by GC–MS

Chemical compound examination of the hexane extract of *W. bifurcata* fruit was carried out in the Instrumentation Laboratory, Faculty of Mathematics and Natural Sciences, using a Thermo Fisher Scientific GC-MS with electron impact ionization (70 eV). This tool is equipped with a TG-5MS capillary column (30 m x 0.2 mm, 0.25 µm thickness). The temperature was programmed from 60-150°C for 4 minutes, then increased to 150-210°C and maintained at 210°C for 10 minutes. The carrier gas was Helium (He), with an injector temperature of 250°C and a flow rate of 1.35 mL/minute. The compound components of the ethanol extract of W. bifurcata fruit seeds were injected automatically using the split method. This tool is controlled by a computer system equipped with a data library and compared with published standard data [24].

Gas chromatography–mass spectrometry was used to characterize the constituents of the n-hexane extract of *W. bifurcata* fruit. The total ion chromatogram is presented in Figure 1, and 48 peaks were resolved across the chromatographic run, of which 8 compounds reached a similarity index of ≥99% against the reference library.

Table 2 summarizes the identification, retention times, peak areas, and similarity indices for the 48 detected compounds. The extract is dominated by fatty acids and their methyl esters, with the three most abundant constituents being 9-octadecenoic acid (Z)-, methyl ester (methyl oleate, $C_{19}H_{36}O_2$; 10.55%; 99.67% similarity), l-(+)-ascorbic acid 2,6-dihexadecanoate (ascorbyl palmitate, $C_{38}H_{68}O_8$; 8.14%; 99.3% similarity), and hexadecanoic acid, methyl ester (methyl palmitate, $C_{17}H_{34}O_2$; 5.55%; 99.6% similarity). The chemical structures of the three major constituents are presented in Figure 2.

These three compounds collectively account for the principal moisturizing activity of the extract. They contribute to skin hydration through complementary mechanisms, including emollient action, occlusive film

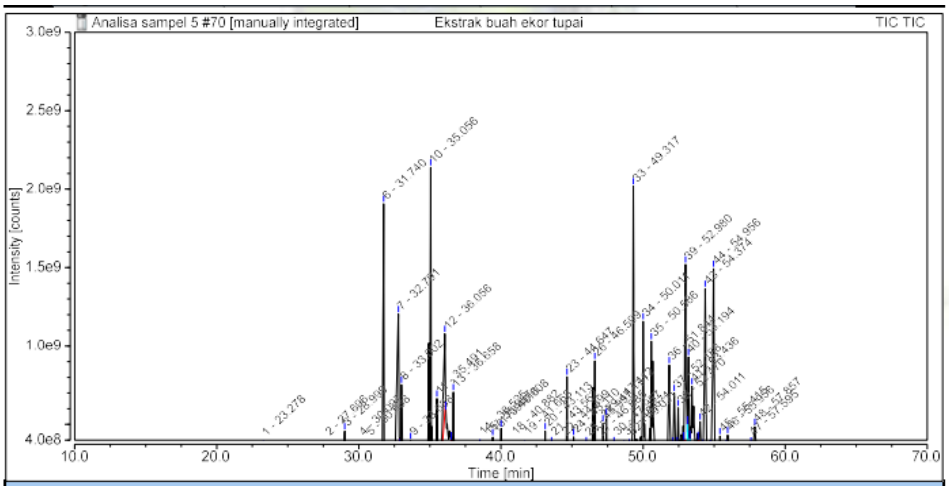

Figure 1. GC chromatogram of the n-hexane extract of *W. bifurcata* fruit.

Table 2. Compounds identified by GC–MS in the n-hexane extract of *W. bifurcata* fruit.

No.	Compound	Class	Rt (min)	Area (%)	Sim. (%)
1	2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-, (R)-	Terpenoid	23.27	0.91	99.5
2	1H-Indene, 1-ethylideneoctahydro-7a-methyl-, cis	Terpenoid	27.69	0.45	95.11
3	E-7-Octadecene	Alkene	28.99	0.92	96.2
4	Z-8-Octadecen-1-ol acetate	Fatty acid ester	30.09	0.73	100
5	Estra-1,3,5(10)-trien-17β-ol	Steroid	30.63	0.38	98.1
6	Hexadecanoic acid, methyl ester	Fatty acid ester	31.74	5.55	99.6
7	l-(+)-Ascorbic acid 2,6-dihexadecanoate	Ascorbic acid derivative	32.79	8.14	99.3
8	1-Heneicosyl formate	Fatty acid ester	33	1.18	88.6
9	Octadecanoic acid, 2-(2-hydroxyethoxy)ethyl ester	Fatty acid ester	33.638	1.54	98.9
10	9-Octadecenoic acid (Z)-, methyl ester	Fatty acid ester	35.05	10.55	99.67
11	Heptadecanoic acid, 10-methyl-, methyl ester	Fatty acid ester	35.49	1.33	98.1
12	cis-Vaccenic acid	Fatty acid	36.05	4.64	98.6
13	trans-13-Octadecenoic acid	Fatty acid	36.65	1.03	97.56
14	Methyl 9-eicosenoate	Fatty acid ester	38.52	0.5	96.95
15	Oxiraneundecanoic acid, 3-pentyl-, methyl ester, cis	Fatty acid ester	38.95	0.41	98.7
16	7-Methyl-Z-tetradecen-1-ol acetate	Ester	39.41	0.63	98.3
17	1-Hexadecanol, 2-methyl-	Fatty alcohol	40	0.83	99.2
18	2H-Pyran, tetrahydro-2-(12-pentadecynyloxy)-	Terpenoid	40.88	0.41	98.4
19	7-Methyl-Z-tetradecen-1-ol acetate	Fatty alcohol acetate	41.66	0.5	97.7
20	Z-8-Methyl-9-tetradecenoic acid	Fatty acid	43.11	0.68	97.7
21	2-Butoxyethyl oleate	Fatty acid ester	43.56	0.86	99.02
22	trans-13-Octadecenoic acid	Fatty acid	44.39	0.41	94.8
23	Tritetracontane	Alkane	44.64	1.65	98.3
24	Tetracosanoic acid, methyl ester	Fatty acid ester	45.11	0.63	95.8
25	6-Octadecenoic acid	Fatty acid	45.99	0.53	97.6
26	Ethanol, 2-(9-octadecenyloxy)-, (Z)-	Fatty alcohol ether	46.59	3.38	97.2
27	3-[3-Bromophenyl]-7-chloro-3,4-dihydro-10-hydroxy-1,9(2H,10H)-acridinedione	Acridine	46.88	0.66	98.5
28	Dihydroxanthin	Flavonoid glycoside	47.17	1.24	91.9
29	Octadecane, 3-ethyl-5-(2-ethylbutyl)-	Alkane	47.41	0.94	99.2
30	1-Heptatriacotanol	Fatty alcohol	47.95	0.61	98.2
31	Ethyl iso-allocholate	Ester	48.67	0.46	99.3
32	1-Heptatriacotanol	Fatty alcohol	49.02	0.76	98.2
33	Dotriacontanal	Aldehyde	49.31	6.88	97.9
34	Tritetracontane	Alkane	50.01	3.07	93.9
35	Vitamin E	Terpenoid	50.58	5.11	98.2
36	9-Octadecene, 1,1'-[1,2-ethanediylbis(oxy)]bis-, (Z,Z)-	Alkene	51.84	2.93	95.6
37	Stigmasterol	Steroid	52.18	1.23	93.9
38	Oleic acid, 3-(octadecyloxy)propyl ester	Fatty acid ester	52.47	0.77	95.2
39	β-Sitosterol	Steroid	52.98	6.06	98.7

No.	Compound	Class	Rt (min)	Area (%)	Sim. (%)
40	Lupeol	Triterpenoid	53.19	2.15	98.4
41	Lupeol	Triterpenoid	53.43	2.92	98.1
42	Ethyl iso-allocholate	Ester	54.01	0.36	97.07
43	D:C-Friedo-B':A'-neogammacer-9(11)-ene, 3-methoxy-, (3β)-	Terpenoid	54.37	5.28	92.8
44	β-Sitostenone	Triterpenoid	54.95	6.75	93.03
45	Ethyl iso-allocholate	Ester	55.41	0.42	96.5
46	9,19-Cyclolanostane-3,7-diol	Triterpenoid	55.95	0.37	97.7
47	Spirost-8-en-11-one, 3-hydroxy-, (3β,5α,14β,20β,22β,25R)-	Steroid	57.59	0.4	95.2
48	17-(1,5-Dimethyl-hexyl)-4,4,9,13,14-pentamethylhexadecahydrocyclopenta[a]phenanthren-3-one	Steroid	57.85	1.83	96.7

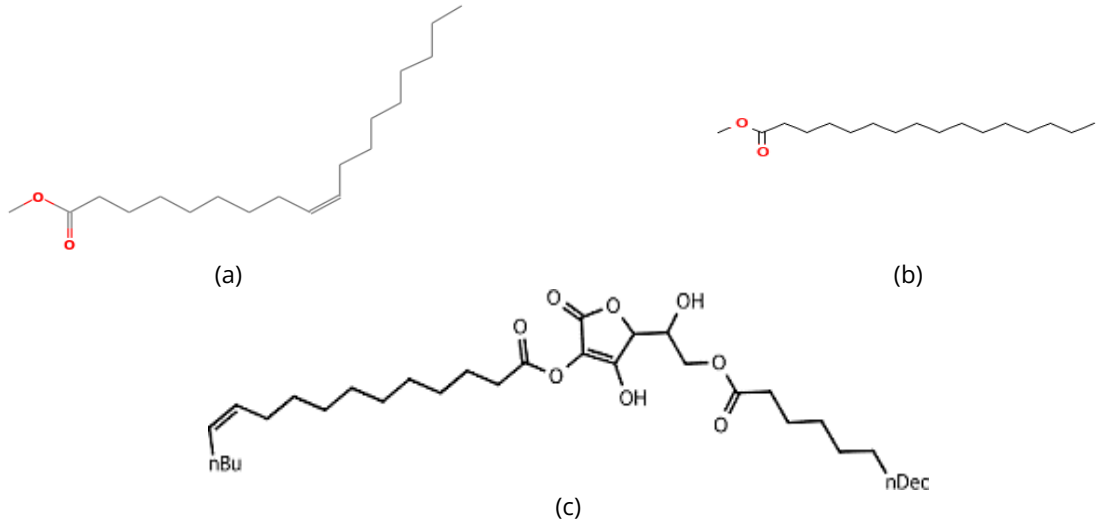

Figure 2. Chemical structures of the major compounds identified in the n-hexane extract of *W. bifurcata* fruit: (a) 9-octadecenoic acid (Z)-, methyl ester (methyl oleate); (b) hexadecanoic acid, methyl ester (methyl palmitate); and (c) l-(+)-ascorbic acid 2,6-dihexadecanoate (ascorbyl dipalmitate). Source: pubchem.ncbi.nlm.nih.gov.

formation, and humectant activity. Salim et al. reported that fatty acid–rich extracts exhibit pronounced moisturizing activity, supporting skin elasticity and helping to prevent premature aging [25]. Fatty acids function as emollients that hydrate the skin and reinforce the cutaneous barrier; their long hydrocarbon chains and unsaturation impart hydrophobicity, allowing them to interact with the lipid matrix of the stratum corneum and traverse the stratum corneum to reach deeper epidermal strata. The carboxylic acid head group simultaneously confers hydrophilic character through hydrogen bonding with water molecules, accounting for their amphipathic behavior [26]. Lulu et al. further reported that ascorbic-acid derivatives, exemplified here by ascorbyl palmitate, enhance skin elasticity, reduce fine lines and wrinkles, brighten skin tone, increase hydration, and act synergistically with sunscreen agents [27]. The mass spectrum of the most abundant compound, 9-octadecenoic acid (Z)-, methyl ester, is shown in Figure 3.

3.2. Phytochemical Profile of the Extract

Phytochemical screening of the n-hexane extract of *W. bifurcata* fruit indicated the presence of secondary metabolites of the terpenoid and steroid classes. Other classes of secondary metabolites were not detected, which is consistent with the moderate polarity of the n-hexane solvent and may reflect either the absence of these constituents in the fruit pulp or their concentration below the detection limit of the screening assay. This phytochemical profile is consistent with the GC–MS results, which identified β-sitosterol, stigmasterol, lupeol, and β-sitostenone as among the most prominent steroid and triterpenoid constituents.

3.3. Moisturizing Activity of the Crude Extract

The moisturizing activity of the crude n-hexane extract was assessed to evaluate its inherent capacity to enhance skin hydration. The mean increase in skin moisture across the six volunteers was 13.46% over the 14-day testing period, indicating an appreciable but moderate moisturizing effect (Figure 4). The activity is attributable to the fatty-acid-rich composition of the extract, which combines emollient, humectant, and occlusive properties; the value falls below the 20-25% benchmark for a fully effective skin moisturizer, which suggests that

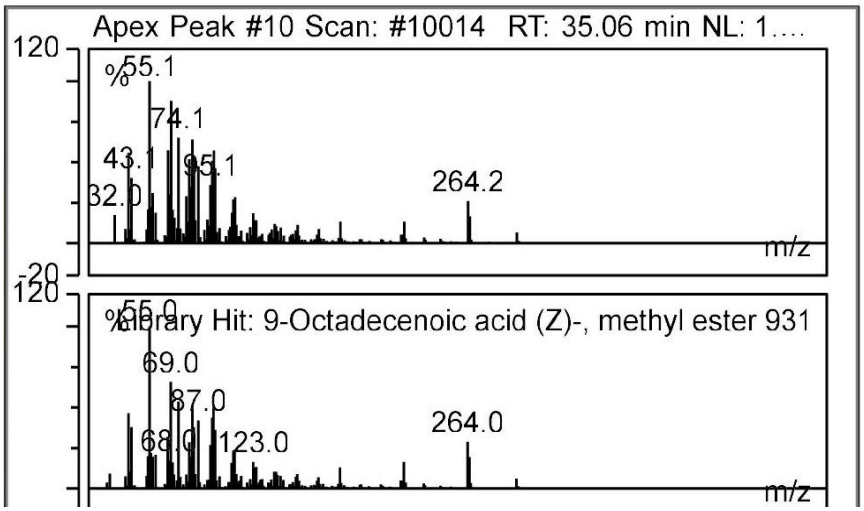

Figure 3. Mass spectrum of 9-octadecenoic acid (Z)-, methyl ester from the n-hexane extract of *W. bifurcata* fruit.

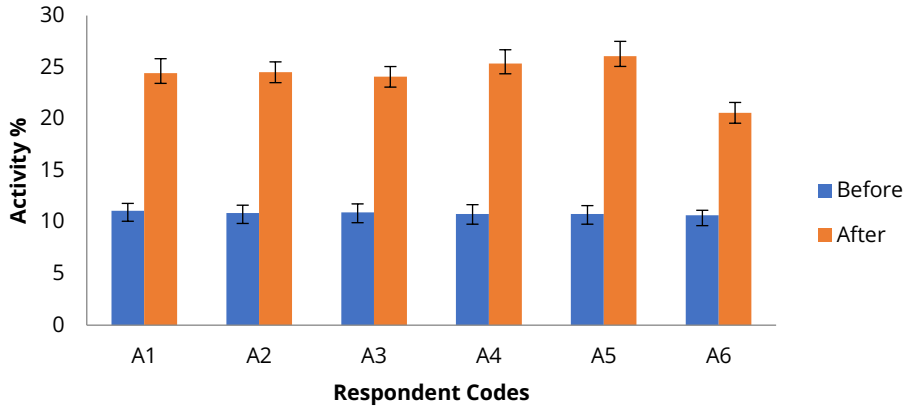

Figure 4. Moisturising effectiveness of the n-hexane extract of *W. bifurcata* fruit on volunteer heel skin (before vs. after 14 days of application).

the crude extract requires formulation in a suitable cream base to deliver optimal performance.

3.4. Effectiveness of the Cream Formulations (F1 and F2)

The two cream formulations containing 5% (F1) and 15% (F2) of the n-hexane extract were assessed for moisturizing effectiveness over 14 days. F1 was applied to the right heel and F2 to the left heel of each volunteer, and the percentage increase in skin moisture was measured each morning. Mean effectiveness values were 19.48% for F1 and 25.83% for F2, indicating a clear concentration-dependent improvement in moisturizing performance (Figure 5). The 25.83% increase produced by F2 falls within the 20–25% range identified by Rahayu et al. as indicative of good moisturizing efficacy [28].

3.5. Comparison with Positive and Negative Controls

One week after the F1/F2 testing phase, the negative control (F0, base cream without extract) and the positive control (F+, commercial moisturizing cream) were tested under identical conditions for an additional 14 days. F+ was applied to the right heel and F0 to the left heel. This phase aimed to benchmark the formulations against an established commercial product and to estimate the contribution of the cream base alone to the observed moisturizing activity. As shown in Figure 6, F2 exhibited moisturizing effectiveness closest to that of the positive control, indicating that the 15% extract formulation replicated the performance of a commercial reference product. The base cream alone (F0) showed a relatively low effectiveness of 10.36%, which is below the 13.46% recorded for the unformulated extract; this comparison indicates that the moisturizing activity is primarily attributable to the *W. bifurcata* fruit extract rather than to the excipients.

Organoleptic evaluation of F0, F1, and F2 before and after the four-cycle stability test showed no perceptible changes in color, shape, or odor. F1 was lighter in color than F2, reflecting the lower extract concentration in F1. Homogeneity testing showed that F0 and F1 were uniform in color and texture and free from visible particles before and after stability testing, whereas F2

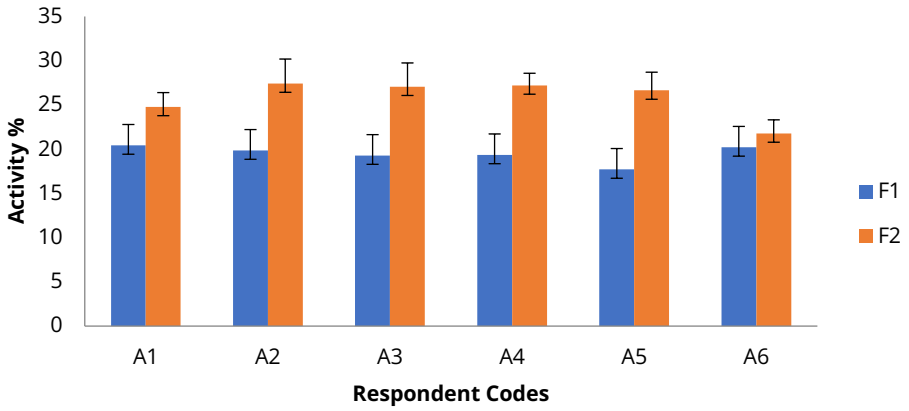

Figure 5. Mean moisturising effectiveness of cream formulations F1 and F2 across the six volunteers over 14 days.

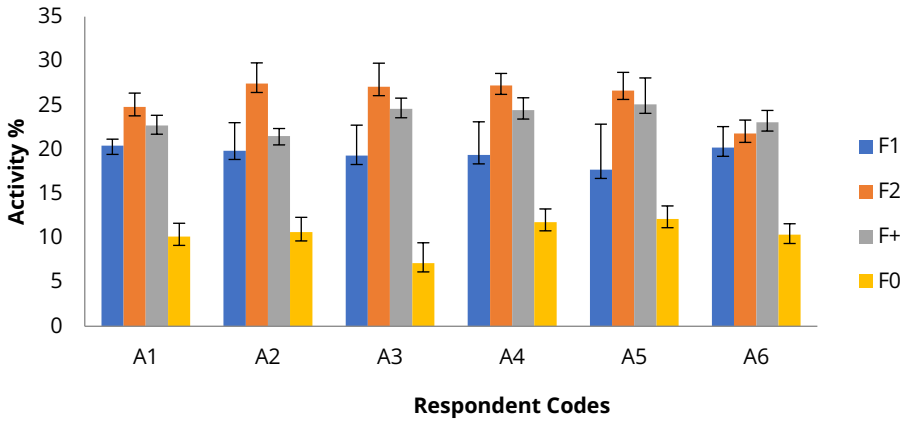

Figure 6. Mean moisturising effectiveness of cream preparations F1, F2, F+, and F0.

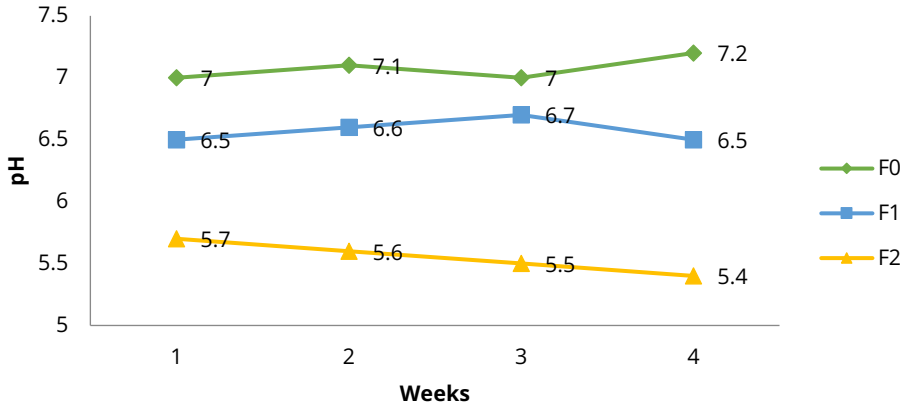

Figure 7. Weekly pH values of cream preparations F0, F1, and F2 over four weeks. Measured values ranged from 5.4 to 7.2.

exhibited a less homogeneous appearance with fine grains still discernible after stability testing, attributable to the higher extract loading.

The pH test is carried out to determine the safety of the moisturizer preparation when used, ensuring it does not cause skin irritation. The pH measurement was performed weekly over four weeks (Figure 7). F0 maintained the highest pH, whereas F1 and F2 trended towards more acidic values, consistent with the carboxylic acid contribution of the fatty-acid-rich extract; pH values declined modestly in both formulations as extract concentration increased. All three preparations remained within the SNI 16-4399-1996 acceptance range and showed thermal stability across the cycling test.

A spreadability test is performed to determine a moisturizer's ability to spread when applied to the skin surface. The criteria for good spreadability for topical preparations are 5-7 cm [21]. Spreadability of the three

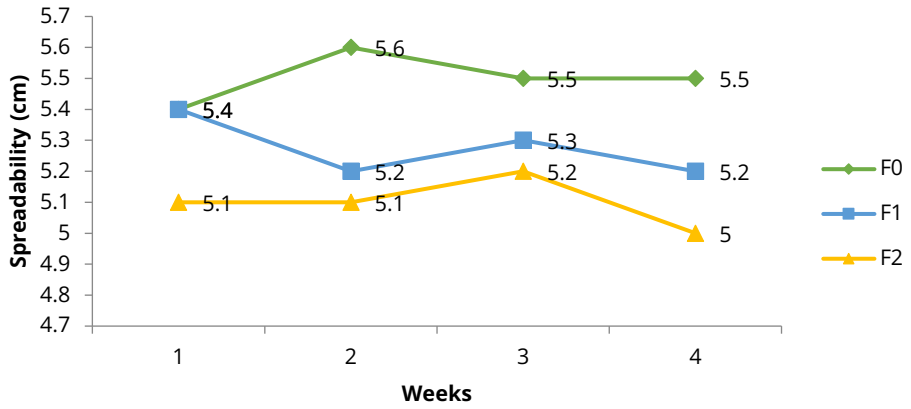

Figure 8. Spreadability of cream preparations F0, F1, and F2 across four weeks of stability testing.

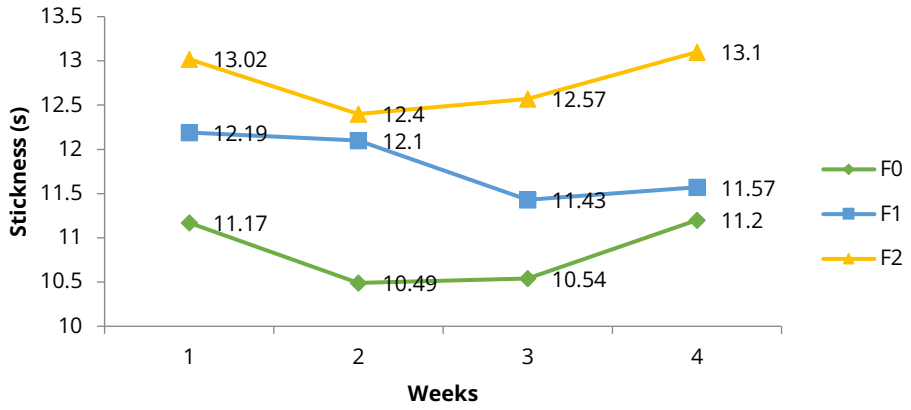

Figure 9. Adhesion of cream preparations F0, F1, and F2 across four weeks of stability testing.

cream preparations is shown in Figure 8. F0 exhibited the highest spreadability throughout the testing period, whereas F1 and F2 produced lower values consistent with their higher extract concentrations; spreadability decreased monotonically with increasing extract loading. After stability testing, all three preparations showed a slight increase in spreadability, indicating that the cream base did not fully retain water under cycling stress and that the formulations became thinner. Spreadability values for all preparations remained within the 5–7 cm acceptance range specified in SNI 16-4399-1996 [29].

The adhesion test is conducted to determine the level of durability of the moisturizer cream preparation on the skin. The optimal time for the two glasses to detach is at least 4 seconds. Research conducted by Kurnianingrum and Zulkarnain stated that a semi-solid preparation is considered good if it has an adhesion of more than 10 seconds [30]. Poor adhesion can result in less-than-optimal penetration of the moisturizer into the skin. However, if the adhesion is too high, it can disrupt the skin's respiration process [31]. Adhesion testing showed that the formulations containing the n-hexane extract exhibited longer adhesion times than the base cream, with adhesion increasing as extract concentration rose (Figure 9). Greater adhesion correlates with prolonged residence on the skin, which favors sustained release of active ingredients into the cream base and onto the skin surface. Adhesion is inversely related to spreadability, and the observed pattern is consistent with the higher viscosity associated with greater extract loading. All three preparations exceeded the 4-second minimum adhesion specified in SNI 16-4399-1996, with measured adhesion times ranging from 10.49 to 13.10 s.

Irritation testing of all three cream preparations (F0, F1, F2) on the skin of healthy volunteers produced no observable erythema, edema, or pruritus, indicating that increasing the concentration of the n-hexane extract of *W. bifurcata* fruit did not compromise dermal tolerability. The hedonic test indicated that the base cream (F0) and F1 received the highest mean preference scores, with values corresponding to the 'like' rating. In contrast, F2 received a lower mean score corresponding to the 'dislike' rating, primarily due to its darker color and stronger odor at the higher extract concentration. The hedonic profile is summarised in Figure 10.

Taken together, the physical-property results indicate that all three cream preparations exhibited acceptable

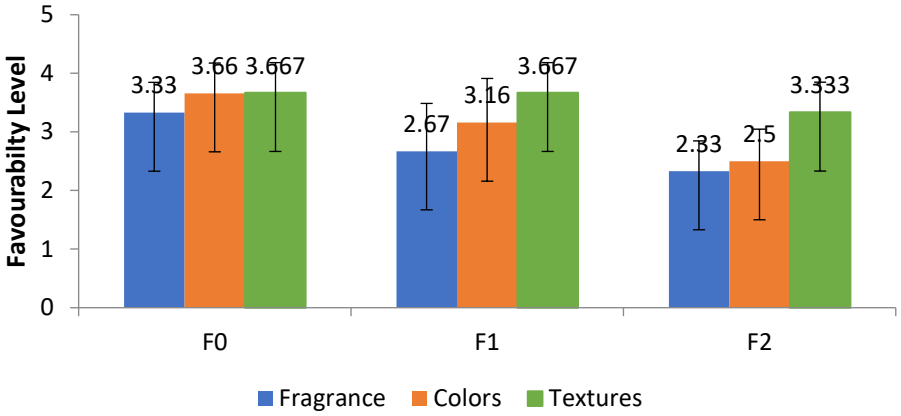

Figure 10. Mean hedonic scores for moisturising cream preparations F0, F1, and F2.

stability over the four-week test period, met the SNI 16-4399-1996 quality criteria, and caused no skin irritation. F1 emerged as the optimal preparation in terms of the balance between moisturizing performance, physical-property stability, and sensory acceptability. However, F2 delivered superior moisturizing effectiveness at the cost of reduced homogeneity and lower hedonic acceptance.

4. Conclusions

The n-hexane extract of *Wodyetia bifurcata* fruit was characterized by GC–MS as a fatty-acid-rich preparation in which 9-octadecenoic acid (Z)-, methyl ester (10.55%), l-(+)-ascorbic acid 2,6-dihexadecanoate (8.14%), and hexadecanoic acid, methyl ester (5.55%) were the three principal constituents. Phytochemical screening confirmed the presence of terpenoid and steroid classes consistent with the GC–MS profile. Two oil-in-water moisturizing cream formulations containing 5% (F1) and 15% (F2) of the extract were prepared and tested on the heels of six female volunteers over 14 days. Mean moisturizing effectiveness values were 13.46% for the crude extract, 19.48% for F1, and 25.83% for F2, indicating concentration-dependent improvement and confirming the extract's moisturizing potential. All three cream preparations satisfied the SNI 16-4399-1996 quality requirements for organoleptic, homogeneity, pH, spreadability, adhesion, irritation, hedonic, and stability parameters. F1 was identified as the optimal formulation when the balance among moisturizing effectiveness, homogeneity, and consumer preference is considered. These findings support the cosmetic potential of *W. bifurcata* fruit as a natural source of moisturizing agents and warrant further investigation into long-term efficacy, comparative performance against benchmark commercial products, and scale-up of the formulation for industrial production.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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