

The effect of sodium metabisulfite concentration on the physicochemical stability of an L-Ascorbic Acid face mist formulation

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DOI: <https://doi.org/10.29303/sjp.v6i2.623>

Article Info

Received : 2025-08-28
Revised : 2025-10-10
Accepted : 2025-10-10

Abstract: Face mist is a cosmetic that is included in skin fresheners, is more practical to use, and has the potential to add antioxidants. Vitamin C is one source of antioxidants. Although water-soluble, vitamin C is an antioxidant that oxidizes readily. Sodium metabisulfite must be added to prevent oxidized vitamin C from becoming unstable. Topical treatments containing 0.01–1.0% sodium metabisulfite act as antioxidants. Therefore, a face mist preparation was made with variations in the concentration of sodium metabisulfite, namely 0.25%, 0.5%, and 1%. This study aims to see an increase in the stability of vitamin C face mist preparations with an increase in the concentration of sodium metabisulfite through physicochemical stability testing under real-time storage conditions for 28 days. The parameters to be observed in the stability test include organoleptic test, pH, specific weight, viscosity, and vitamin C levels. The F1 formula with the smallest concentration of sodium metabisulfite (0.25%) has been able to maintain the stability of vitamin C face mist preparations for 28 days of storage.

Keywords: L-Ascorbic Acid; Vitamin C; Sodium Metabisulfite; Face Mist; Oxidative Stability; Cosmetic Formulation.

Citation: Anastasia, D. S., Desnita, R., Yuswar, M. A. & Halim, C. M. (2025). The effect of sodium metabisulfite concentration on the physicochemical stability of an L-Ascorbic Acid face mist formulation. *Sasambo Journal of Pharmacy*, 6(2), 108-114. doi: <https://doi.org/10.29303/sjp.v6i2.623>

Introduction

As the skin is the body's largest organ, it acts as the primary protective shield of the body against various external physical and biological factors (D.-Q. Wang et al., 2023). However, it also undergoes considerable stress as a result of its exposure to ultraviolet (UV) radiation, as well as to smoke and other airborne pollutants (Teng et al., 2025). These stressors constitute the primary source of free radicals, which are unstable molecules with unpaired electrons. In their attempts to become more stable, free radicals react with vital cell components and, in the process, initiate a damaging chain reaction known as oxidative stress. This process, often referred to as the oxidative cascade, weakens the skin barrier, enhancing the breakdown of structural

proteins like collagen and elastin, and precipitating the more visible effects of aging, particularly the premature aging of skin (photoaging), which manifests as wrinkle formation, loss of elasticity, and fine lines (Chmielewski & Lesiak, 2024; Lyu et al., 2022).

To combat oxidative stress, the cosmetic and dermatological industries have increasingly integrated antioxidant compounds into topical formulations. These molecules protect the skin by counteracting further damage and bolstering repair mechanisms (Budzianowska et al., 2025). Naturally derived antioxidants are becoming more popular because of their efficacy and the increasing consumer demand for sustainable, plant-based, and "clean" beauty products (Sharma et al., 2023).

Face mists hydrate the skin and deliver active

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cosmetic ingredients with the convenience of a spray bottle. Like other skincare products, face mists are liquids applied to the skin using fine sprayers. Although face mists are often confused with toners, they serve different purposes. While toners are meant to be applied after skin cleansing to remove leftover dirt, residues, and balance skin pH, face mists are more versatile and meant for use any time during the day (Pal et al., 2025). They are especially useful when one needs a quick dose of hydration and nutrition for the skin and can be applied even over makeup without alteration to its deposition or appearance. The use of fine mist sprayers is crucial to the product's appeal, as they provide a uniform and lightweight application and gentle, skin-friendly delivery, which enhances the user experience. The gentle sprayers ensure a lightweight and uniform application and enhance the user experience of the product. Today, face mists are popular and significant in the market as a means to deliver active cosmeceutical ingredients because of the pleasant and convenient spray delivery system (Pal et al., 2025; Sethi et al., 2024).

L-ascorbic acid or L Vitamin C is one of the most potent and researched antioxidants in dermatology. Its L form is water-soluble and thus is the most highly sought after. Vitamin C is crucial in neutralizing a number of reactive oxygen species (ROS) that may cause harm. Going beyond its antioxidant properties, L-ascorbic acid serves as a cofactor for prolyl and lysyl hydroxylase and thus for collagen biosynthesis. This allows Vitamin C to aid in improving the firmness of the skin, enhancing structural integrity, and promoting skin wound repair (Chugaeva et al., 2023; Piersma et al., 2017). As beneficial as L-ascorbic acid is, it is greatly unstable, especially in water. Commonly, face mists are aqueous in nature and thus would aid in their oxidative degeneration. L-ascorbic acid is prone to rapid oxidative degeneration due to common factors oxygen, light, heat, or higher pH levels. This conversion, especially if L-ascorbic acid is exposed to light, will cause a yellow or brown discoloration (Li et al., 2016; Mešić Macan et al., 2019).

The inclusion of "sacrificial" antioxidants serves as a primary and effective approach for L-ascorbic acid preservation from premature degradation. These antioxidants, also referred to as oxygen scavengers, possess a higher oxidation rate than L-ascorbic acid. They work by preferentially reacting to and consuming any oxygen in the formulation, which, in turn, prevents the oxygen from triggering the degradation cascade of the primary active ingredient (Gérard et al., 2019). A common preservative, sodium metabisulfite, serves as a strong reducing agent and oxygen scavenging preservative. In the presence of water, it reacts with dissolved molecular oxygen to form sodium sulfate, thus preserving the efficacy and potency of L-ascorbic

acid (Okamoto et al., 2020).

The increase in demand for face mist delivery systems, combined with the widely accepted Vitamin C dermatological uses, highlights the clinical and market need for stable, effective formulations in this product category. The chemically unstable nature of L-ascorbic acid poses a considerable formulation hurdle to overcome to ensure quality and potency throughout the shelf-life of the product (Song et al., 2024).

This research was conducted to meet the challenge by studying the effects of sodium metabisulfite (0.25%, 0.5%, and 1.0%) on the physicochemical stability of a formulated face mist with L-ascorbic acid. The formulation stability was evaluated over a period of 28 days at room temperature. The main goal was to establish the best formulary concentration of sodium metabisulfite that would preserve the product's structure, therapeutic value, and visually appealing features.

Materials and Methods

Materials and Reagents

Purified water (Aquadest), DMDM hydantoin, glycerin (PT. Wilmar Nabati Indonesia), disodium edetate (Na₂EDTA), sodium metabisulfite, polyvinylpyrrolidone (PVP), strawberry fragrance (PD. Sahabat Jaya Cemerlang), triethanolamine (TEA) (Petronas Chemicals Marketing Ltd.), and L-ascorbic acid (Vitamin C) (CSPC Weisheng Pharmaceutical Co., Ltd.) were used as received.

Equipment

The following equipment was utilized: aluminum foil, glass stirring rods (Pyrex), spray bottles, glass funnels (Pyrex), beaker glasses (Pyrex), graduated cylinders (Pyrex), filter paper, volumetric flasks (Pyrex), micropipettes (Nesco Dragon Lab), a pH meter (Xing Wei Qiang), a pycnometer (Pyrex), dropper pipettes, spatulas, a UV-Vis spectrophotometer (Shimadzu), an analytical balance (Fujitsu FS-AR), and a viscometer (Brookfield).

Formulation of Vitamin C Face Mist

Three distinct face mist formulations were prepared, varying only in the concentration of sodium metabisulfite, as detailed in **Table 1**. The manufacturing procedure was as follows: PVP, sodium metabisulfite, and Na₂EDTA were dissolved in a portion of the purified water until a homogenous solution was formed. Glycerin and DMDM hydantoin were subsequently added and mixed until uniform. L-ascorbic acid was then incorporated into the mixture and stirred until fully dissolved. The pH of the solution was measured and adjusted to a target of 5.4 using TEA. Once the target pH

was achieved, the strawberry fragrance was added, followed by the addition of purified water to the final volume. The final solution was mixed until homogeneous and then filled into spray bottles.

Table 1. Composition of the Experimental Face Mist Formulations (F1-F3)

Ingredient	Function	F1 (%)	F2 (%)	F3 (%)
L-Ascorbic Acid	Active Antioxidant	1	1	1
Sodium Metabisulfite	Stabilizer	0,25	0,50	1,00
Glycerin	Humectant	5	5	5
PVP	Film Former	5	5	5
DMDM Hydantoin	Preservative Chelating Agent	0,1	0,1	0,1
Na ₂ EDTA	Agent	0,1	0,1	0,1
TEA	pH Adjuster	0,5	0,5	0,5
Strawberry Fragrance	Fragrance	q.s.	q.s.	q.s.
Purified Water	Vehicle	to 100	100	100

q.s. = quantum sufficit (quantity sufficient)

Stability Study Protocol

This study specifically aimed to evaluate product stability over time and under real-time storage conditions. All three formulations (F1, F2, and F3) were kept in their final plastic spray bottle packaging and stored at room temperature (25±2°C) for a period of 28 days. Sample evaluation was performed on days 1, 7, 14, 21, and 28, and these time points were used for evaluation to check the physicochemical properties of the samples. This methodology is in accordance with the industry standard for determining the stability and shelf life of cosmetic products (Mascarenhas-Melo et al., 2023).

Physicochemical Evaluation Parameters

- Organoleptic Evaluation:** All assessment was performed visually and olfactorily to identify any color, scent, and clarity changes over time.
- pH Measurement:** The pH for each formulation was measured with a previously calibrated pH meter with standard buffer solutions of pH 4, 7, and 10.
- Specific Gravity (SG):** SG was measured by means of a pycnometer and analytical balance. The weights of the empty pycnometer, the pycnometer filled with the sample, and the pycnometer filled with purified water were recorded (P1, P2, P3). The specific gravity was calculated with the formula: $SG = (P2 - P1) / (P3 - P1)$.
- Viscosity:** Each formulation's viscosity was

analyzed with a Brookfield viscometer. A sample of 50 mL was taken, placed in the sample cup, and then analyzed using spindle number 2 at 100 rpm. The spindle's reading was taken in centipoise (cPs).

Analytical Method Verification for Vitamin C Quantification

The stability study was preceded by the verification of the UV-Vis spectrophotometric method for Vitamin C quantification. A standard series of L-ascorbic acid standard solutions prepared at 3, 5, 7, 9, and 11 ppm was created. Each standard's absorbance was recorded at the predetermined λ_{max} of 265.4 nm. The method underwent verification for the following criteria: linearity, accuracy, precision, LOD (Limit of Detection), and LOQ (Limit of Quantitation) with 3 replicates.

Analysis for Vitamin C Quantification

At every stability time point, 90 μ L of sample was taken from each face mist formulation and diluted to 100 mL with purified water in a volumetric flask. The absorbance was measured using a UV-Vis spectrophotometer at 265,4 nm, and Vitamin C concentration was determined by the absorbance value using the linear regression equation obtained from the standard curve.

Statistical Analysis

The pH, specific gravity, viscosity, and Vitamin C content data were subjected to One-Way Analysis of Variance for each formulation to assess whether any changes occurring over the 28-day storage period were significant ($p < 0.05$).

Results and Discussion

The formulation face mist's rationale for the selection of the excipients.

The selection of face mist formulation's excipients is critical in determining the stability, physicochemical and microbiological activity, and the overall quality of the formulation (Dănilă et al., 2024). Preservative (DMDM Hydantoin): Considering the formulation contains water, the formulation is at risk for microbial contamination, which means a robust preservative system is mandatory. DMDM Hydantoin was selected due to its wide-spectrum antimicrobial activity. Its action is based on the slow release of small amounts of formaldehyde, a known bactericidal, yeasticidal, and moldicidal agent. Preservation is provided through the slow release of formaldehyde, which incessantly inhibits the growth of bacteria, yeast, and mold through collagen breakdown. Its safety is minimal risk on product preservative safety, especially in low concentrations

found in cosmetic products is safe because of safety and scientific panels' approval (Halla et al., 2018; Murphy et al., 2021) Humectant (Glycerin): Glycerin was included in the formulation to assist in nourishing the face mist's hydrating benefits. Glycerin exerts its humectant action by attracting water to the stratum corneum from the environment and from the deeper skin layers. This process improves the hydration of the skin while also reinforcing the barrier function of the skin. Its efficacy and safety profile make it one of the most widely used moisturizing agents in cosmetics (Becker et al., 2019; Madnani et al., 2024). Chelating Agent (Na₂EDTA): Disodium EDTA was incorporated as a crucial co-stabilizer. This substance serves chiefly as a chelating and binding agent, which combines with and isolates trace metal ions (e.g., iron, copper) as contaminants that could be introduced during the processing stage via either the raw materials used, or the equipment employed during processing. These metal ions can act as catalysts, significantly accelerating oxidative degradation of Vitamin C. EDTA's ability to make these ions nonreactive not only counters the oxidation but, in conjunction with the primary antioxidant, works to improve the synergistic effects and enhance overall formulation stability (Temova Rakuša et al., 2021; M. Wang et al., 2019). pH Adjuster (Triethanolamine - TEA): TEA was utilized in fine-tuning the formulation pH to the desired value of 5.4. TEA, the suggested pH value, is critical since the stability of L-ascorbic acid is very pH dependent, and this figure is an optimal compromise between chemical stability and the biocompatibility with the skin's acid mantle. TEA is an effective pH adjuster; however, its use in cosmetics is regulated due to concerns of TEA being a skin irritant. More importantly, TEA, when used with nitrosating agents, can form N-nitroso compounds (Aboul-Einien et al., 2020; Gérard et al., 2019).

Validation of the UV-Vis Spectrophotometric Method

The analytical method developed for the quantification of L-ascorbic acid was validated in accordance with the standard guidelines, and the validation is presented in the results. The validation was as expected, and the method is suitable for its intended purpose. The validation parameters were met for the calculation of the L-ascorbic acid concentration in the samples. The significant validation parameters were the correlation coefficient of 0,999, which indicates the method registration was near in the range, the percent recovery values of 99-101%, and the percent relative standard deviation (precision) of 0.7-1.8%. These validation results confirm that the quantitative data generated throughout the stability study on Vitamin C, in regard to its content, is reliable and accurate.

Table 2. Results of Analytical Method Verification

Parameter	Acceptance Criteria	Result	Conclusion
Linearity (r)	$r \geq 0.997$	0,999	Pass
Accuracy (% Recovery)	98-102%	99-101%	Pass
Precision (% RSD)	$\leq 2\%$	0.7-1.8%	Pass
LOD	-	0.267 ppm	-
LOQ	-	0.810 ppm	-

Physicochemical Stability of the Face Mist Formulations

Organoleptic Properties

Throughout the 28 days, none of the three formulations (F1, F2, F3) lost any of their pleasing strawberry fragrances or their clear, colorless liquid, which is of great importance regarding the stabilization of the formulation. It is known that the oxidation of L-ascorbic acid leads to the formation of yellow to brown colored degradants. Not changing color, especially in the context of stabilization, is noteworthy for a Vitamin C product. The lack of opalescence and odor together support that stability has been attained within the formulation. The equilibrium observed indicates that sufficient control is achieved over significant deterioration through the antioxidant system incorporated (Gérard et al., 2019; Santos et al., 2022).

pH Stability and Its Implications for Skin Compatibility

Formulations A, B, C, D, and E, as seen in Table 3, have a constant pH of 5.20 to 5.47 over the 28 days. This pH stability is significant for two reasons. First, protective of L-ascorbic acid, no chemical reactions occurred that would increase or decrease any acidity. Also, the pH of 5.20 to 5.47, albeit not, is still lower than the skin pH of 4.5-6.0, thus lowering the skin irritation risk and assisting in the maintenance of skin barrier function. Looking at the data for all the formulations, all significant pH changes over time were corroborated by the ANOVA results.

Table 3. pH Values of Face Mist Formulations During 28-Day Storage

Storage Time	F1 (0.25%)	F2 (0.5%)	F3 (1.0%)
Day 1	5.42±0.01	5.45±0.02	5.47±0.01
Day 7	5.38±0.02	5.40±0.01	5.41±0.02
Day 14	5.31±0.01	5.35±0.02	5.36±0.01
Day 21	5.25±0.02	5.28±0.01	5.30±0.02
Day 28	5.20±0.01	5.22±0.02	5.25±0.01

Values are presented as mean ± standard deviation (n=3).

Specific Gravity and Viscosity

Specific gravity and viscosity showed no statistically significant changes across all formulations over the 28-day study period. The unchanged specific gravity values (Table 4) suggest that no significant physical alterations, for example, the precipitation of ingredients, occurred. The consistent low viscosity of about 23.2 cP (Table 5) measured over time is advantageous for this product as it will enable easier atomization into a fine, uniform mist with the spray pump mechanism, which is crucial for product application and user experience.

Table 4. Specific Gravity of Face Mist Formulations During 28-Day Storage

Storage Time	F1 (0.25%)	F2 (0.5%)	F3 (1.0%)
Day 1	1.041±0.001	1.043±0.001	1.045±0.002
Day 28	1.041±0.001	1.043±0.001	1.045±0.001

Values are presented as mean ± standard deviation (n=3).

Table 5. Viscosity (cPs) of Face Mist Formulations During 28-Day Storage

Storage Time	F1 (0.25%)	F2 (0.5%)	F3 (1.0%)
Day 1	23.20±0.00	23.20±0.00	23.20±0.00
Day 28	23.20±0.00	23.20±0.00	23.20±0.00

Values are presented as mean ± standard deviation (n=3).

Chemical Stability: Vitamin C Content Over 28 Days The Protective Effect of Sodium Metabisulfite

As shown in Table 6, the most noteworthy result from this study was the L-ascorbic acid's remarkable chemical stability in all three formulations tested over 28 days. Vitamin C concentration was maintained in all formulations, as shown by the statistical analysis performed using ANOVA. This, in turn, illustrates the effectiveness of sodium metabisulfite as an oxygen scavenger within the system. This compound—and particularly in this case—exhibits the ability to bind preferentially to dissolved oxygen, which effectively thwarts the oxidative degradation pathway of L-ascorbic acid and preserves its chemical potency (Choi et al., 2020; Cimino et al., 2018)

Table 6. Remaining Vitamin C Content (%) in Face Mist Formulations During 28-Day Storage

Storage Time	F1 (0.25%)	F2 (0.5%)	F3 (1.0%)
Day 1	100.15±0.12	100.05±0.15	100.25±0.10
Day 7	99.85±0.10	99.95±0.11	100.10±0.13
Day 14	99.60±0.13	99.70±0.12	99.85±0.11
Day 21	99.35±0.11	99.50±0.10	99.65±0.12
Day 28	99.10±0.12	99.25±0.13	99.40±0.10

Values are presented as mean ± standard deviation (n=3).

Impact of Varying Stabilizer Concentrations

From the data, the most striking observation is the absence of a protective effect that is dependent on the dose among all three concentrations of sodium metabisulfite tested. The formulation of the lowest dose met stabilizer in F1 (0.25%) showed a level of Vitamin C stability that did not differ significantly from the formulations that contained double (F2, 0.5%) and quadruple (F3, 1.0%) doses of stabilizer. This indicates that the 0.25% concentration stabilizer is likely sufficient to neutralize the amount of dissolved oxygen in the formulation as well as counter any minimal oxygen ingress into the sealed container during the 28 days of the study. This excerpt exemplifies 'sufficient stabilization'. In these particular storage conditions, once the oxygen, the leading cause of deterioration, is sufficiently scavenged, further additions of sodium metabisulfite become useless, and the protective effect caps. This result is especially relevant and practical for cosmetic formulators. It disproves the stabilizer concentration assumption, where increasing the concentration of the stabilizer always improves stability. It emphasizes that the concentration of stabilizer needs to be below the effective dose for achieving the desired shelf life. Such an approach is beneficial in many ways, such as these: focusing on sulfite sensitivity minimizes skin sensitivity, reduces the raw material and overall chemical burden of the product, and facilitates easier compliance with the rising consumer demand for efficacious products with straightforward, uncomplicated formulations.

Conclusion

All three face mist formulations containing Vitamin C, preserved with sodium metabisulfite at 0.25%, 0.5%, and 1.0% respectively, demonstrated excellent physicochemical stability over 28 days at room temperature. Organoleptic properties, pH, specific gravity, viscosity, and the concentration of the active ingredient reinforced the evaluation of the formulation and were all within acceptable limits. Most importantly, the results of this study showed that sodium metabisulfite at a concentration of 0.25% was stable enough to preserve L-ascorbic acid. Higher preservative concentrations did not provide any additional stability under the conditions tested. These results suggest that stable and effective Vitamin C face mist formulations can be developed with a minimal approach to preservative additions, maximizing formulation safety and minimizing potential irritation. This is beneficial for formulation scientists seeking to minimize the number of ingredients in their formulations while ensuring the safety, sensitivity, and modern demands of consumers.

Acknowledgements

We would like to express our gratitude to the Faculty of Medicine, Tanjungpura University.

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