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Effect of Patchouli Oil Concentration on Fragrance Longevity of Eau de Parfum

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ABSTRACT

Background. Perfumes are cosmetic products which its quality determined not by scent, also by longevity when applied to skin. Patchouli oil is a natural fixative, an effect attributed to its low-volatility sesquiterpenes and patchouli alcohol. Research on its optimal concentration in Eau de Parfum (EDP) remains limited. This study aimed to determine the effect of patchouli oil concentration on fragrance longevity and the physicochemical characteristics of EDP. Method. This experimental study used a Completely Randomized Design with four formulas (F0 0%, F1 4%, F2 6%, and F3 7% patchouli oil) in a 96% ethanol base (total fragrance oil 8-15%), bergamot oil as top note and rose oil as the middle note. Evaluations included organoleptic testing, specific gravity, pH, fragrance longevity via blotter and skin application tests at 0-8 hour intervals by 25 panelists using 0-5 sensory intensity scale, analyzed with Levene's Test and One-Way ANOVA followed by Games-Howell test. Result. All formulas met to SNI 16-4949-1998 quality requirements, appearing as clear, homogeneous liquids, uniform specific gravity (0.782; p=0.642), pH 5-6. Aroma intensity decreased over time across all formulas, formula F3 (7% patchouli oil) showed the longest fragrance longevity at 8 hours (blotter score 2.60; skin score 2.20). One-Way ANOVA showed highly significant effect of patchouli oil concentration on fragrance longevity (blotter: F=94.910; skin: F=117.532; both p<0.001) with large effect sizes (η^2 = 0.75 and 0.79 and the Games-Howell post hoc test confirmed all four formulas differed significantly from one another in both the blotter and skin tests (p<0.05), forming fully distinct, non-overlapping subsets. Increasing patchouli oil concentration also associated with stronger woody note and darker color. Conclusion. Among the concentrations tested, patchouli oil at 7% was the best-performing natural fixative in enhancing sensory-rated EDP fragrance longevity. Total fragrance oil increased, effect reflects the whole formulation; skin safety was not assessed.

Keyword: *patchouli oil; fixative; eau de parfum; fragrance longevity*

Introduction

Perfumes are cosmetic products which it's quality determined not by the scent produced but also by its longevity once applied to the skin (Iin Hardiyati et al., 2020). Eau de Parfum (EDP) is one of the most popular perfume types, generally containing 15-20% aromatic (fragrance oil) concentration (Surburg & Panten, 2020). The high volatility of essential oil components is often a major challenge in perfume formulation, as it causes the fragrance to dissipate quickly (Iin Hardiyati et al., 2020), making a fixative agent that slows the evaporation rate of aroma components necessary.

Patchouli oil is a commonly used essential oil that serves as both a natural fixative and a base note in perfume formulation (Chairunnisa et al., 2023a), a property attributed to its patchouli alcohol and sesquiterpene content, which are relatively low in volatility 27/10/2026 22.12.00. Nevertheless, research on the

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concentration of patchouli oil that best enhances EDP fragrance longevity remains limited. Research by Khairan et al. (2025) demonstrated that a low concentration of patchouli oil (up to 0.75%) improved longevity in a general liquid perfume, a value far below the 15-20% total fragrance oil range typically used for EDP (Surburg & Panten, 2020). A concentration that is too low does not provide a significant fixative effect, whereas an excessive concentration may dominate and mask the primary fragrance profile (Chairunnisa et al., 2023; Khairan et al., 2025).

Other research by Hardiyati et al. (2020) has only examined the physicochemical characteristics of patchouli oil without applying it to perfume formulation, while other patchouli-based studies have generally focused on Eau de Toilette preparations (Chairunnisa et al., 2023) or on alcohol-free/water-based fragrance systems (Mahalaxme et al., 2025). The novelty of the present study, therefore, is not simply the use of patchouli oil as a fixative, which is already well established, but the systematic comparison of specific patchouli oil concentrations (0%, 4%, 6%, and 7%) within an EDP system, evaluated through both blotter and skin sensory tests. This study aimed to formulate and compare these patchouli oil concentrations as a fixative in an ethanol-based EDP, to identify which concentration among those tested most effectively enhances fragrance longevity, while also evaluating the physicochemical characteristics of the resulting preparations. The concentrations were chosen so that the base note accounted for about one-third to nearly one-half of the total fragrance oil, while the total fragrance oil remained at or below 15%, the upper limit of the EDP range reported by Putri et al. (2023). Because the total fragrance oil increases with patchouli oil in this design, the observed effects are interpreted as those of the formulation as a whole rather than of patchouli oil alone.

Research Methods

This study was a laboratory experimental study using a one-factor Completely Randomized Design, with patchouli oil concentration as the treatment factor, consisting of four formulas (F0 as the control without patchouli oil, and F1, F2, F3 with increasing concentrations). The study was conducted at the Pharmacy Research Laboratory of Universitas 17 Agustus 1945 Jakarta.

Raw Material Characterization

Cosmetic-grade patchouli oil (of Indonesian origin, accompanied by a Certificate of Analysis) was characterized through organoleptic testing (form, color, odor) according to SNI 16-4949-1998, along with physicochemical examination comprising specific gravity (Farmakope Indonesia Edisi VI, 2020), solubility in 90% ethanol (Standar Nasional Indonesia, 1998) and refractive index using an Abbe refractometer, referencing the SNI 06-2385-2006 (Standar Nasional Indonesia, 2006) quality standard.

Eau de Parfum Formulation

The EDP preparations were made in a 30 mL volume using bergamot oil as the top note (3%), rose oil as the middle note (5%), and patchouli oil as the base note/fixative (0%, 4%, 6%, 7% for F0-F3), resulting in a total fragrance oil content ranging from 8% (F0) to 15% (F3). This places the present formulation at the lower end of, or slightly below, the 15-20% concentration range typically used for EDP (Surburg & Panten, 2020), this is acknowledged as a design limitation, since a total fragrance oil load closer to the conventional EDP range may further influence the absolute longevity values reported here. BHT (0.05%) was added as an antioxidant, and 96% ethanol was used as the solvent to complete the formula to 100%. All concentrations are expressed as %v/v of the 30 mL batch, except BHT, which is expressed as %w/v. The base note concentration was designed to comprise 33-47% of the total fragrance oil, referring to the recommended minimum of 30-35% for an effective fixative effect. As a result, the total fragrance oil increased from 8% (F0) to 15% (F3) as patchouli oil increased, so patchouli oil concentration and total fragrance oil load varied together and could not be separated in this design. The complete composition of each formula is presented in Table 1.

Table 1. Complete composition of the four Eau de Parfum formulas per 30 mL batch.

Ingredient	F0	F1	F2	F3
Bergamot oil (3%, top note)	0.90 mL	0.90 mL	0.90 mL	0.90 mL
Rose oil (5%, middle note)	1.50 mL	1.50 mL	1.50 mL	1.50 mL
Patchouli oil (base note/fixative)	0.00 mL (0%)	1.20 mL (4%)	1.80 mL (6%)	2.10 mL (7%)
BHT (antioxidant)	0.015 g (0.05%)	0.015 g (0.05%)	0.015 g (0.05%)	0.015 g (0.05%)
96% ethanol, ad	27.585 mL	26.385 mL	25.785 mL	25.485 mL
Total batch volume	30 mL	30 mL	30 mL	30 mL

Ingredients were added in the order of patchouli oil, rose oil, and bergamot oil, following the olfactory pyramid from base to top note, with gentle manual stirring using a glass rod at an approximate speed of 60 rpm for 1 minute after each addition. BHT was first dissolved separately in approximately 5 mL of 96% ethanol until fully dissolved, then combined with the fragrance oil mixture and stirred gently for 5 minutes until homogeneous. The remaining ethanol was then added gradually to bring the total volume to 30 mL, and the solution was visually inspected to confirm the absence of turbidity or precipitate. The mixture was transferred into an airtight, light-protected 30 mL amber glass bottle, labeled with the formula code, preparation date, and replicate number, and matured in the dark

at room temperature for 14 days, with gentle swirling three times daily without vigorous shaking; any precipitate formed during maturation was removed by filtration before the preparation was transferred into the final 30 mL amber spray bottle. The interval between preparation and sensory testing was standardized at 14 days (the maturation period) for all formulas and replicates (n=3 per formula).

Preparation Evaluation

The physicochemical properties of each preparation were evaluated through organoleptic testing (form, color, odor) based on SNI 16-4949-1998 , specific gravity testing using the pycnometer method (Gunawan & Rahayu, 2021) , for which the preparation had to comply with the specific gravity requirement of 0.7-1.2 (Standar Nasional Indonesia, 1998) , and pH testing using a universal pH indicator, in which the resulting color change corresponds to a pH value on the 0-14 scale. Because the preparations are ethanol-based (non-aqueous), conventional aqueous pH measurement may be affected by the medium. The indicator was therefore used only as a simple, semi-quantitative screening, and the values reported are apparent pH values for comparing formulas, not absolute pH.

Fragrance longevity was evaluated through blotter and skin tests. Both methods assessed aroma intensity at intervals of T0 (0 minutes), T1 (2 hours), T2 (4 hours), T3 (6 hours), and T4 (8 hours) using a 0-5 scale (0 = not detected to 5 = very strong), performed by 25 trained/semi-trained healthy panelists with no history of skin allergy who did not use other scented products during testing. The four formulas were coded with random three-digit codes, and the order of presentation was randomized or counterbalanced for each panelist, with a rest interval between samples to minimize order and carry-over effects. For the blotter test, one spray of each formula was applied to a labeled perfume blotter strip, and panelists evaluated the aroma at a standardized distance of approximately 2-3 cm from the nose. For the skin test, one spray of each formula was applied directly to the wrist of each panelist, with the test area cleaned beforehand and the same site used consistently for each formula and time point within a panelist; the aroma was likewise evaluated at a standardized distance of approximately 2-3 cm from the skin, and panelists avoided water contact and the application of other scented products or skincare on the test area throughout the evaluation period. Potential confounding factors such as ambient temperature, relative humidity, individual skin type, sweating, and skin pH were not separately measured in this study and are acknowledged as limitations that may have contributed to inter-panelist variability in the skin test results, consistent with the somewhat higher scores observed in the blotter test relative to the skin test.

This in vivo test was approved by the ethics commission of the Faculty of Pharmacy, Universitas 17 Agustus 1945 Jakarta, No. 237/KEPK-

UTA45JKT/EC/EXP/8/2026, and testing on human panelists was conducted after obtaining informed consent from each panelist.

Data Analysis

Data were analyzed using a variance homogeneity test (Levene's Test) followed by One-Way ANOVA to examine the effect of patchouli oil concentration on the observed parameters; when variances were not homogeneous, the Games-Howell post hoc test was used. Data were presented in tabular form using Microsoft Excel and processed using SPSS. Because the same panelists evaluated all formulas and time points, the observations are not fully independent. The One-Way ANOVA reported here treated the formulas as independent groups, which is acknowledged as a limitation; repeated-measures or linear mixed-effects models with panelist as a random effect are more appropriate for this design (Barr et al., 2013; Bates et al., 2015; Kuznetsova et al., 2017). The 0-5 intensity scores were treated as approximately interval data (Norman, 2010). Effect size was expressed as eta squared (η^2), calculated from the F statistic and its degrees of freedom (Lakens, 2013), because statistical significance alone does not indicate the magnitude of an effect (Sullivan & Feinn, 2012).

Results and Discussion

1.1. *Raw Material Characteristics*

The patchouli oil was a viscous liquid, reddish-brown in color, with a strong woody-earthy aroma, in accordance with SNI 06-2385-2006 requirements (Standar Nasional Indonesia, 2006). Physicochemical examination showed a specific gravity of 0.961, a refractive index of 1.5073, and clear solubility in 90% ethanol (1:10), all consistent with the SNI standard and the Certificate of Analysis, indicating good raw material purity without meaningful dilution or contamination.

1.2 *Physicochemical Characteristics of the Preparations*

All formulas produced clear, homogeneous liquids free of turbidity or sediment, satisfying the SNI 16-4949-1998 quality requirements (Table 2). This indicates that 96% ethanol was able to fully dissolve all fragrance oil components (bergamot, rose, and patchouli oil) and BHT, resulting in a physically stable mixture. Product color showed a positive correlation with patchouli oil concentration, from pale yellow in F0 to deep brownish-orange in F3, consistent with the natural yellowish-to-brownish color of patchouli oil (Khairan et al., 2025).

Table 2. Organoleptic characteristics of the Eau de Parfum preparations.

Formula	Form	Color	Aroma
F0	Clear, homogeneous liquid	Pale yellow	Fresh citrus-floral (no woody note detected)
F1	Clear, homogeneous liquid	Yellow-orange	Floral-citrus with a slight woody nuance
F2	Clear, homogeneous liquid	Brownish-orange	Floral-citrus with a woody nuance
F3	Clear, homogeneous liquid	Deep brownish-orange	Floral-citrus with a dominant woody note

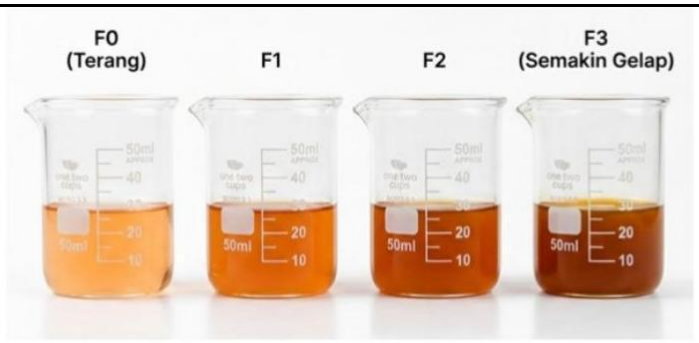


Figure 1. The result of the organoleptic test of the four formulas

The aroma profile followed consistently with the role of patchouli oil as both a base note and a fixative agent. F0, the control without patchouli oil, displayed only a fresh citrus-floral character derived from bergamot oil (top note) and rose oil (middle note), with no woody nuance detected. As patchouli oil concentration increased in F1, F2, and F3, a woody nuance became increasingly noticeable, becoming the most dominant characteristic in F3, paralleling the strengthening woody note that increasingly overlaid the citrus-floral character at higher patchouli oil concentrations.

The specific gravity of all four formulas fell within 0.782 (SD 0.000-0.003), meeting the SNI 16-4949-1998 quality requirement (specific gravity 0.7-1.2). Levene's Test indicated homogeneous variance in specific gravity among formulas ($p=0.596>0.05$), so the One-Way ANOVA result ($F=0.583$; $p=0.642>0.05$) could be interpreted directly without a specific post hoc test, showing no significant differences in specific gravity among formulas (Figure 2).

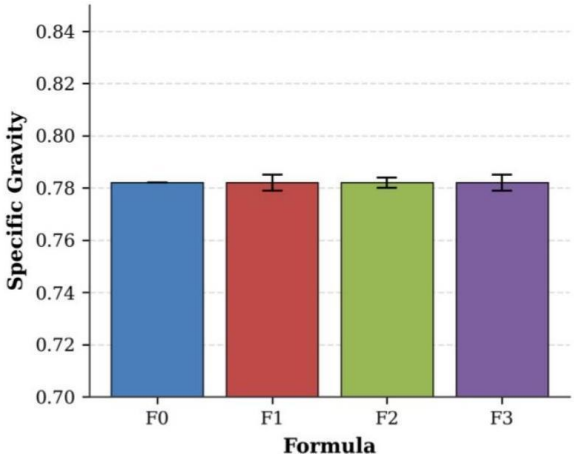


Figure 2. Specific gravity of the four Eau de Parfum formulas (mean ± SD, n=3)

The pH measurements showed that F0 had an average pH of 6, while F1, F2, and F3 consistently had an average pH of 5 across all three replicates. This pattern indicates a decrease in pH associated with the addition of patchouli oil to the formula: F0, as the control without patchouli oil, produced the highest pH, whereas the three patchouli oil-containing formulas produced the same pH despite their different concentrations. This suggests that the pH reduction is most likely caused by the presence of patchouli oil itself rather than by the magnitude of the concentration added, since F1, F2, and F3 did not show a graded pH decrease proportional to their increasing fixative concentration. Overall, the pH values obtained (5-6) indicate that all four EDP formulas exhibited stable and uniform pH characteristics across replicates, close to the slightly acidic pH of the skin surface (Lambers et al., 2006) (Figure 3). These are apparent pH values obtained with an indicator in an ethanol-based medium and are insufficient on their own to establish skin safety, because no irritation or sensitization test was performed.

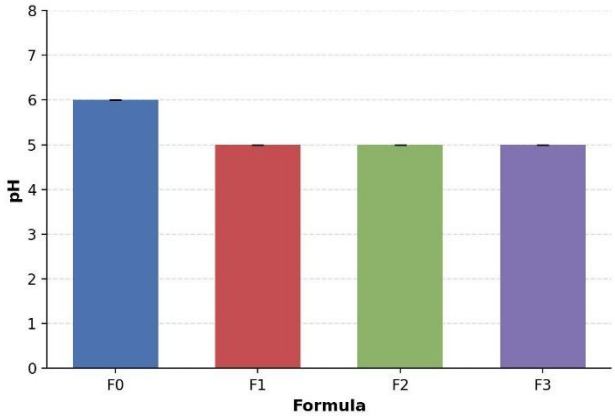


Figure 3. pH of the four Eau de Parfum formulas (mean ± SD, n=3)

1.3 ***Fragrance Longevity Results***

Aroma intensity declined consistently across all formulas from T0 (score 5.00) to T4, with a consistent longevity ranking of F0 < F1 < F2 < F3 at every time point, in both the blotter test and skin test. At the 8-hour application, F0 had nearly lost its

entire aroma, while F3 retained the longest-lasting scent, consistent with the role of patchouli oil as a fixative agent with low volatility characteristics in perfume.

The skin test showed the same result as the blotter test. F0 lost its scent almost completely by T4, while F1, F2, and F3 retained progressively higher scores in line with their patchouli oil content. By 8 hours of skin application, the scent of the perfume was fading or gone for the lower formulas, while F3 was the longest-lasting, with the scent still detectable after 8 hours of skin application.

The blotter test may better reflect the intrinsic volatility of the fragrance material itself, while the skin test more realistically represents fragrance performance under actual use conditions. The differences between the blotter and skin test results were likely affected by enzymatic activity, natural skin oils, and moisture on the skin surface, factors not present on the paper medium of the blotter test.

Table 3. Mean aroma intensity scores in the blotter test and skin test (0-5 scale, n=25).

Formula	T0 (0 h)	T1 (2 h)	T2 (4 h)	T3 (6 h)	T4 Blotter	T4 Skin
F0	5.00	3.00 / 2.76	1.72 / 1.68	0.76 / 0.48	0.04	0.00
F1	5.00	3.76 / 3.12	2.68 / 2.16	1.60 / 1.32	1.04	0.64
F2	5.00	4.20 / 3.80	3.20 / 2.80	2.48 / 1.84	1.68	1.20
F3	5.00	4.36 / 4.16	3.68 / 3.16	3.16 / 2.48	2.60	2.20

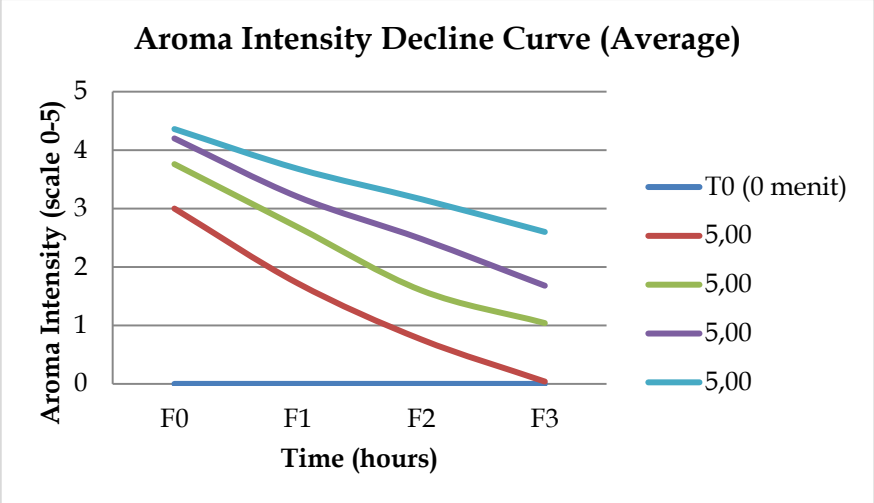


Figure 4. Aroma intensity decline curve for the blotter test

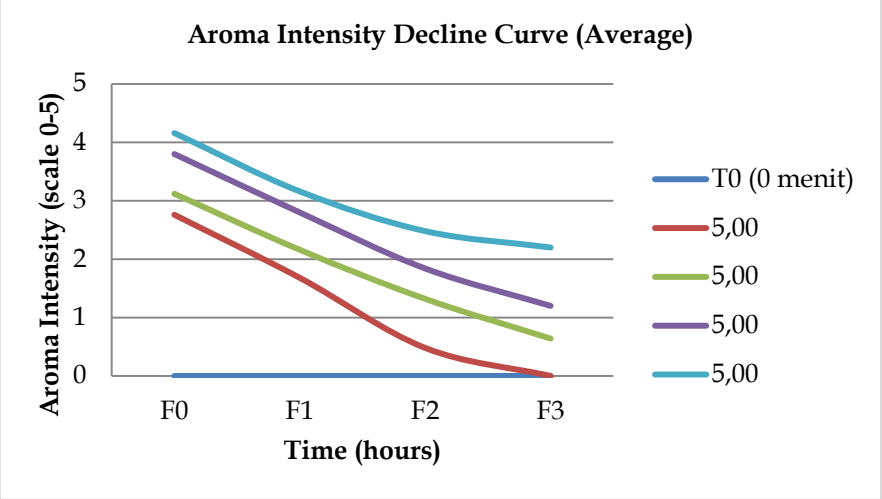


Figure 5. Aroma intensity decline curve for the skin test

Table 3 shows that at T0 all formulas started from the maximum score (5.00), as the fragrance concentration was still at its fullest immediately after application. The sharpest decline occurred in F0 between T0-T2 (dropping from 5.00 to below 2.00 within 4 hours), indicating that the top and middle note components evaporated quickly without a retaining agent. In contrast, F3 maintained a much more gradual decline, with scores still above 2.0 at the 6- and 8-hour marks in both the blotter and skin tests, a pattern consistent with the proposed mechanism by which patchouli oil, as a fixative, slows the evaporation rate of the more volatile aroma components; this mechanism was inferred from the observed sensory decline curves and was not directly measured by an independent volatility assay. Because the total fragrance oil also increased with patchouli oil, the higher scores of F3 may partly reflect its greater total fragrance oil content.

1.4 ***Statistical Analysis of Fragrance Longevity***

Levene's Test indicated non-homogeneous variance in longevity scores ($p<0.001$ for both methods), so the Games-Howell post hoc test was used rather than Tukey HSD, which requires homogeneous variance. Nevertheless, One-Way ANOVA still showed a highly significant effect of patchouli oil concentration (blotter: $F=94.910$; skin: $F=117.532$; both $p<0.001$), and large effect sizes ($\eta^2 = 0.75$ for the blotter test and 0.79 for the skin test, calculated from F with df = 3, 96) since a violation of variance homogeneity primarily affects pairwise comparison tests rather than the overall validity of the F-test (Field, 2013).

Different letters (a, b, c, d) in Table 4 indicate significant differences among formulas (Games-Howell, $p<0.05$). Welch's F-test is a robust alternative when variances are unequal (Delacre et al., 2019), and 95% confidence intervals should accompany the effect sizes in a re-analysis of the raw panelist data. All four formulas formed fully distinct, non-overlapping subsets in both the blotter and skin tests, which, according to Field (2013), indicates a consistent separation among the formulas, although this should be interpreted cautiously because the same panelists

rated all formulas. These findings are consistent with the role of patchouli oil as a fixative through its patchouli alcohol content, which has low volatility (Ginting et al., 2021; Mahalaxme et al., 2025).

Table 4. Games-Howell post hoc results

Formula	Blotter Test Score	Skin Test Score
F0	0.04 b,c,d	0.00 b,c,d
F1	1.04 a,c,d	0.64 a,c,d
F2	1.68 a,b,d	1.20 a,b,d
F3	2.60 a,b,c	2.20 a,b,c

Subsets of aroma longevity scores among formulas.
a: significantly different from F0; b: from F1; c: from F2; d: from F3.

1.5 Limitatons

Several limitations should be considered. First, the total fragrance oil increased from 8% (F0) to 15% (F3) as patchouli oil increased, so the differences in longevity reflect the combined effect of patchouli oil concentration and total fragrance oil load and cannot be attributed to patchouli oil concentration alone. Second, longevity was assessed only by panelist sensory scoring, and fragrance volatility was not measured instrumentally (e.g., by gas chromatography); the fixative mechanism is therefore inferred rather than demonstrated. Third, the same 25 panelists evaluated all formulas and time points, creating a repeated-measures structure that the One-Way ANOVA did not model; re-analysis with a repeated-measures or mixed-effects model (Barr et al., 2013; Bates et al., 2015) is needed to confirm the results. Fourth, only 0%, 4%, 6%, and 7% patchouli oil were tested, so concentrations between 6% and 7% and above 7% remain unevaluated. Finally, no skin irritation, sensitization, or other dermatological safety assessment was performed, and essential oils can cause skin reactions in some individuals (Bakkali et al., 2008; Herman & Herman, 2015), so the pH results cannot by themselves establish skin safety.

Conclusion

Patchouli oil was associated with significantly longer sensory-rated fragrance longevity of Eau de Parfum in a concentration-dependent manner: the higher the concentration (from F0 to F3), the longer the fragrance persisted. Because the total fragrance oil also increased with patchouli oil (from 8% to 15%), this effect reflects the formulation as a whole rather than patchouli oil concentration alone. Among the three patchouli oil concentrations tested (4%, 6%, and 7%), formula F3 (7%) showed the best performance in both the blotter and skin tests; because concentrations between 6-7% and above 7% were not investigated, this finding

indicates that 7% was the best-performing concentration among those tested, rather than establishing it as an absolute optimum. The resulting Eau de Parfum preparations also met the SNI 16-4949-1998 quality requirements, appearing as clear, homogeneous liquids with uniform specific gravity (mean 0.782; not significantly different among formulas, p=0.642) and a pH of 5-6, although skin irritation and sensitization were not evaluated, so skin safety cannot be concluded from pH alone.

Recommendations

Future studies are recommended to test a broader range of patchouli oil concentrations, including values between 6-7% and above 7%, to determine the true optimal concentration. The proposed fixative mechanism, whereby patchouli oil slows the evaporation rate of volatile aroma components, should also be confirmed through instrumental analysis, such as gas chromatography, to complement the sensory evaluation results. . Future studies should also use designs that separate patchouli oil from total fragrance oil load (for example, by keeping the total fragrance oil constant), apply repeated-measures or mixed-effects analysis with effect sizes and confidence intervals, and include skin irritation and sensitization testing before any safety claim is made. For perfume manufacturers, a patchouli oil concentration of 7% may be considered as a preliminary reference for EDP formulations based on bergamot and rose, while remaining attentive to fragrance balance so that the woody nuance does not overwhelm the product's citrus-floral character.

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