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ation of Hydroxypropyl Methylcellulose Stearoxy Ether as a Fragrance-Boosting Agent

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1. Introduction

In recent years, consumer interest in fragrance within the skincare market has grown substan-tially, accompanied by a corresponding expansion in market size. Consumers in-creasingly seek cosmetic and fragrance products offering pleasant and long-lasting scents. To be perceived, fragrance compounds must efficiently evaporate from surfaces and dis-perse through the air. Consequently, these volatile substances are typically characterized by high vapor pressures, which promote diffusion but simultaneously shorten the duration of de-tectable scent over time[1].

To enhance fragrance persistence in cosmetic formulations, strategies such as increasing the concentration of fragrance components or selecting inherently long-lasting fragrance in-gredients have been explored. However, higher fragrance loading may elevate production costs and reduce consumer acceptance due to overly intense scents, while narrowing in-gredient choices can limit fragrance diversity.

To address these limitations, various delivery systems based on chemical and physical inter-actions have been developed to control the release of volatile compounds. Chemical systems, or profragrances, release scent molecules via covalent bond cleavage from non-volatile precursors [1,2]. Physical systems—such as microcapsules and polymer matrices—prolong fragrance longevity by allowing gradual diffusion through encapsulating structures [1,3].

Recent studies have shown that cellulose-derived polymers, including microcrystalline cellulose, nanocellulose, and modified cellulose ethers, can effectively regulate fragrance volatility and release kinetics. These polymers form hydrated networks or encapsulating structures that retain volatile molecules and slow their diffusion, thereby extending scent perception. For instance, functionalized cellulose nanocrystals have demonstrated sustained release properties and applicability in both fabric and topical systems [4–6], supporting the use of cellulose-based systems as effective fragrance-holding matrices in water-based formulations.

Based on previous studies, hydroxypropyl methylcellulose stearoxy ether (HPMC-SE) was selected as a potential booster, and its effects on fragrance persistence and intensity were experimentally evaluated.

2. Materials and Methods

2.1 Preparation of Samples

To assess the fragrance-boosting efficacy of hydroxypropyl methylcellulose stearoxy ether (HPMC-SE), test formulations were prepared. Each sample contained denatured ethanol, fragrance, purified water, and an antioxidant (pentaerythrityl tetra-di-t-butyl hydroxyhydrocinnamate). A control sample (without HPMC-SE) and a treatment sample (containing 0.1% HPMC-SE pre-dispersed in purified water) were prepared. The compositions for the two samples are shown in Table 1. Each sample (0.3 g) was applied to test paper and left to stand for 1 and 8 hours under normal indoor conditions to simulate typical usage.

Table 1. Compositions of the treatment and control samples.

Ingredient	Trearment sample (HPMC-SE)	Control
Purified Water	24.89	24.99
Denatured Ethanol	70	70
Hydroxypropyl Methylcellulose Stearoxy Ether	0.1	-
Pentaerythrityl Tetra-di-t-butyl Hydroxyhydrocinnamate	0.01	0.01
Fragrance	5	5
Total	100	100

2.2 Sample Processing and Analysis

Volatile compounds were extracted using solid-phase microextraction (SPME) with a PDMS/DVB StableFlex fiber (Supelco Corp., Bellefonte, PA, USA). The SPME fiber was inserted into a sealed 10 mL glass vial containing the treated test paper and allowed to absorb the headspace volatiles for 20 minutes at 100°C.

Gas chromatography (GC) analysis was performed using an Agilent 7890A/5975C system (Agilent Technologies, Palo Alto, CA, USA) equipped with a VF-WAXms capillary column. The oven temperature was initially set at 50°C for 5 minutes and ramped to 220°C at 2°C/min. The injector temperature was maintained at 220°C, and the total run time was 120 minutes. Helium was used as the carrier gas at a flow rate of 1 mL/min. Fragrance components were identified via GC-MS using the Wiley 10th edition library.

2.3 Sensory Evaluation

A panel of six trained evaluators from the cosmetics industry conducted sensory assessments. To simulate real-life conditions, panelists applied each sample to their forearms. A 5-point Likert scale was used to evaluate fragrance intensity, with 0 representing very weak and 5 representing very strong intensity. Evaluations were performed at multiple time points to assess fragrance persistence. Statistical analysis was performed using one-way analysis of variance (ANOVA), and statistical significance was set at $p < 0.05$.

2.4 Dynamic light scattering

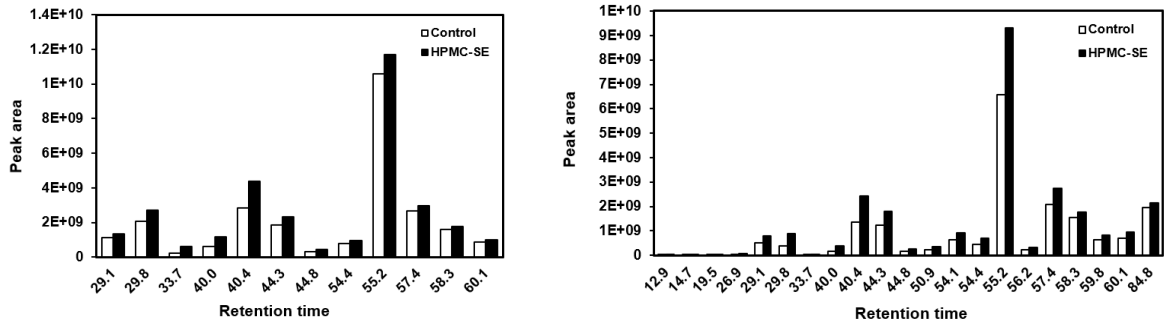
Dynamic light scattering (DLS) measurements were conducted to characterize particle formation in the control and treatment formulations using a Zetasizer Pro (Malvern Panalytical, UK) with ZS Xplorer software.

3. Result

3.1 Volatile Fragrance Intensity

To assess fragrance intensity, GC-MS analysis was conducted for both samples at 1 and 8 hours. At 1 hour, 12 fragrance compounds exhibited more than a 10% increase in peak area in the treated sample compared to the control (Table 2(a), Figure 1(a)). At 8 hours, 22 fra-

grance compounds demonstrated more than a 10% increase in peak area (Table 2(b), Figure 1(b)).



(**a**) Peak area at 1-hour (**b**) Peak area at 8-hour

Figure 1. Comparative GC-MS peak areas of volatile fragrance compounds between the control and treatment samples at 1 and 8 hours. (a) Peak areas of volatile fragrance compounds in the control and treatment samples at 1 hour; (b) Peak areas of volatile fragrance compounds in the control and treatment samples at 8 hours. The treatment sample exhibited higher peak areas compared to the control at both time points, indicating enhanced fragrance persistence.

Table 2(a). Comparison of peak areas and relative differences in volatile fragrance compounds between control and treatment samples at 1 hour. Relative difference (%) was calculated as: (Treatment Peak Area – Control Peak Area) divided by Control Peak Area, multiplied by 100.

No.	Compound list	Retention time	Peak area		Relative Difference (%)
			Control	HPMC-SE	
1	Linalool	29.1	1104580704	1355199311	22.69
2	Linalyl acetate	29.8	2072228165	2704884593	30.53
3	Thujopsene	33.7	227066895	594091355	161.64
4	Geranyl acetate	40.0	588306857	1150068570	95.49
5	Citronellol	40.4	2853498983	4379005336	53.46
6	Geraniol	44.3	1869992007	2340886634	25.18
7	3-Methyl-5-propyl-2-cyclohexen-1-one	44.8	298141191	452065271	51.63
8	Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl-	54.4	794772361	937221843	17.92
9	Ethanone, 1-(1,2,3,5,6,7,8,8a-octahydro-2,3,8,8-tetramethyl-2-naphthalenyl)-	55.2	10600037214	11711243064	10.48
10	Cedrol	57.4	2653694265	2961941595	11.62
11	2-Ethyl-4-(2,2,3-trimethyl-3-cyclo-penten-1-yl)-2-buten-1-ol	58.3	1587216304	1761725546	10.99
12	Patchouli alcohol	60.1	870105513	1001976122	15.16

Table 2(b). Comparison of peak areas and relative differences in volatile fragrance compounds between control and treatment samples at 8 hour. Relative difference (%) was calculated as: (Treatment Peak Area – Control Peak Area) divided by Control Peak Area, multiplied by 100.

No.	Compound list	Retention time	Peak area		Relative Difference (%)
			Control	HPMC-SE	
1	Limonene	12.9	18400350	35897243	95.09
2	Gamma-terpinene	14.7	2366494	5969583	152.25
3	Rose oxide	19.5	14952707	28964824	93.71
4	Menthone	26.9	46898892	86266430	83.94
5	Linalool	29.1	516687771	784304578	51.79
6	Linalyl acetate	29.8	401503168	884892167	120.39
7	Thujopsene	33.7	14342962	51842395	261.45
8	Geranyl acetate	40.0	163470632	391140303	139.27
9	Citronellol	40.4	1362200022	2414623257	77.26
10	Geraniol	44.3	1227805305	1815944018	47.90
11	3-Methyl-5-propyl-2-cyclohexen-1-one	44.8	152964640	267520727	74.89
12	3-Methyl-5-(2,2,3-trimethylcyclopent-3-enyl)pentan-2-ol	50.9	241129520	340590781	41.25
13	(Ethoxymethoxy)cyclododecane	54.1	623012476	912210134	46.42
14	Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl-	54.4	454543549	696060291	53.13
15	Ethanone, 1-(1,2,3,5,6,7,8,8a-octahydro-2,3,8,8-tetramethyl-2-naphthalenyl)-	55.2	6569441899	9323126309	41.92
16	4-Penten-1-ol, 2-methyl-4-(2,2,3-trimethyl-3-cyclopenten-1-yl)-	56.2	243105799	316399838	30.15
17	Cedrol	57.4	2069307798	2734530857	32.15
18	2-Ethyl-4-(2,2,3-trimethyl-3-cyclo-penten-1-yl)-2-buten-1-ol	58.3	1539839476	1769361435	14.91
19	1,5,5,9-Tetramethyl-13-oxatricyclo(8.3.0.0(4,9))tridecane	59.8	623250213	812280505	30.33
20	Patchouli alcohol	60.1	697897387	938711907	34.51
21	Ethylene brassylate	84.8	1952601493	2154202444	10.32
22	Patchouli alcohol	`60.1	870105513	1001976122	15.16

3.2 Volatile Fragrance persistence

The persistence of volatile fragrance compounds was evaluated by measuring the change in peak area at 1 hour and 8 hours for both the control and treatment samples. The rate of change in peak area was calculated, and fragrance components showing a difference of 5% or greater were screened. Nineteen fragrance compounds in the treated sample exhibited enhanced fragrance persistence compared to the control (Figure 2, Table 3).

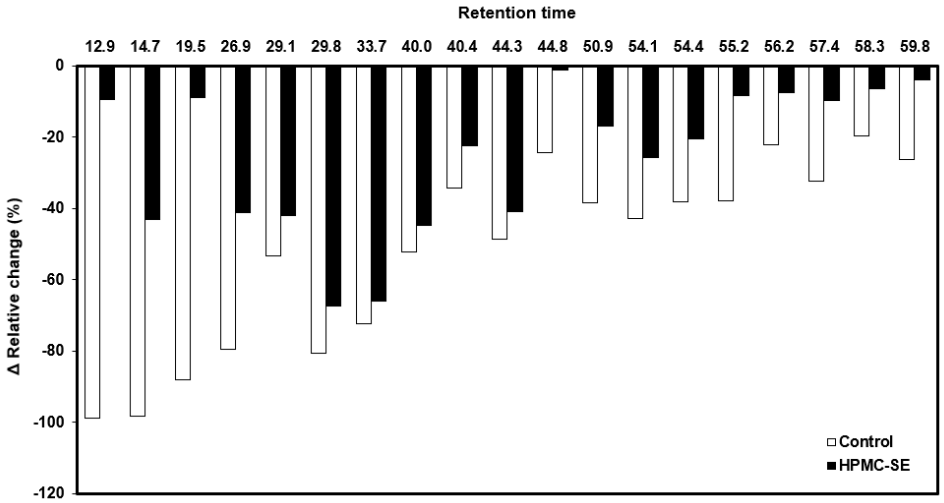


Figure 2. Relative change in volatile fragrance compound peak areas from 1 to 8 hours. The treated sample exhibited a lower reduction in fragrance compound peak areas compared to the control, indicating improved fragrance persistence.

Table 3. Relative change in volatile fragrance compound peak areas over the 1–8 hour period.

No.	Compound list	Retention time	Relative Difference on peak area over 1-8 hour period (%)		Change in Relative Difference(HPMC-SE - Control)
			Control	HPMC-SE	
1	Limonene	12.9	-98.78	-9.60	89.18
2	Gamma-terpinene	14.7	-98.26	-43.07	55.20
3	Rose oxide	19.5	-87.92	-8.85	79.07
4	Menthone	26.9	-79.43	-41.30	38.13
5	Linalool	29.1	-53.22	-42.13	11.10
6	Linalyl acetate	29.8	-80.62	-67.29	13.34
7	Geranyl acetate	40.0	-72.21	-65.99	6.22
8	Citronellol	40.4	-52.26	-44.86	7.40
9	Geraniol	44.3	-34.34	-22.42	11.92
10	3-Methyl-5-propyl-2-cyclohexen-1-one	44.8	-48.69	-40.82	7.87
11	3-Methyl-5-(2,2,3-trimethylcyclopent-3-enyl)pentan-2-ol	50.9	-24.40	-1.29	23.11
12	(Ethoxymethoxy)cyclododecane	54.1	-38.30	-16.83	21.48
13	Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl-	54.4	-42.81	-25.73	17.08
14	Ethanone, 1-(1,2,3,5,6,7,8,8a-octahydro-2,3,8,8-tetramethyl-2-naphthalenyl)-	55.2	-38.02	-20.39	17.63
15	4-Penten-1-ol, 2-methyl-4-(2,2,3-trimethyl-3-cyclopenten-1-yl)-	56.2	-37.93	-8.42	29.51
16	Cedrol	57.4	-22.02	-7.68	14.34
17	1,5,5,9-Tetramethyl-13-oxatricyclo(8.3.0.0(4,9))tridecane	59.8	-32.39	-9.81	22.58

18	Patchouli alcohol	60.1	-19.79	-6.31	13.48
19	Ethylene brassylate	84.8	-26.30	-3.95	22.35

3.3 Sensory Evaluation

Fragrance intensity was evaluated on a 0–5 scale immediately after application, and at 1, 2, and 4 hours post-application. While initial intensity was similar between the samples, the control exhibited a rapid decline, whereas the treated sample demonstrated significantly improved persistence. The treated sample showed fragrance persistence improvements of 29.6%, 58.1%, and 74.1% at 1, 2, and 4 hours, respectively (Table 4, Figure 3). Statistical analysis by one-way ANOVA indicated no significant difference at 1 hour ($p > 0.05$), but significant differences were observed at 2 and 4 hours ($p < 0.05$). Relative improvement (%) was calculated as: (Treatment intensity – Control intensity) divided by Control intensity, multiplied by 100.

Table 4. Fragrance intensity and relative improvement rates of the control and treatment samples at each time point.

Time after application	Control	HPMC-SE	Relative Improvement (%)
0 h	3.67	4.17	13.62
1 h	2.75	3.83	39.27
2 h	1.50	2.58	72.0
4 h	0.83	1.75	110.84

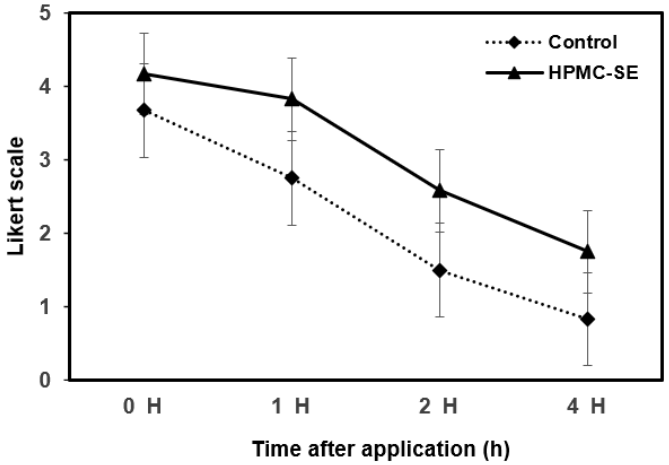


Figure 3. Fragrance intensity of the control and treatment samples at each time point.

3.4 Dynamic light scattering (DLS)

DLS analysis of the control sample showed two distinct particle populations at 1.424 nm and 327.7 nm, indicating the coexistence of molecularly dissolved fragrance components and self-aggregated domains. In the treated sample containing HPMC-SE without fragrance, the primary particle size was observed at 508.6 nm. In the treated sample containing both HPMC -SE and fragrance, the major peak shifted to 897.3 nm, and an additional minor peak was detected at 129.2 nm (Table 5, Figure 4).

Table 5. DLS analysis results for the treatment sample. Size measurements of Control, HPMC-SE without fragrance and HPMC-SE with fragrance by DLS.

Parameter	Peak 1 Diameter(nm)	Peak 2 Diameter(nm)
Control	1.414	327.7
HPMC-SE without Fragrance	508.6	-
HPMC-SE with Fragrance	897.3	129.2

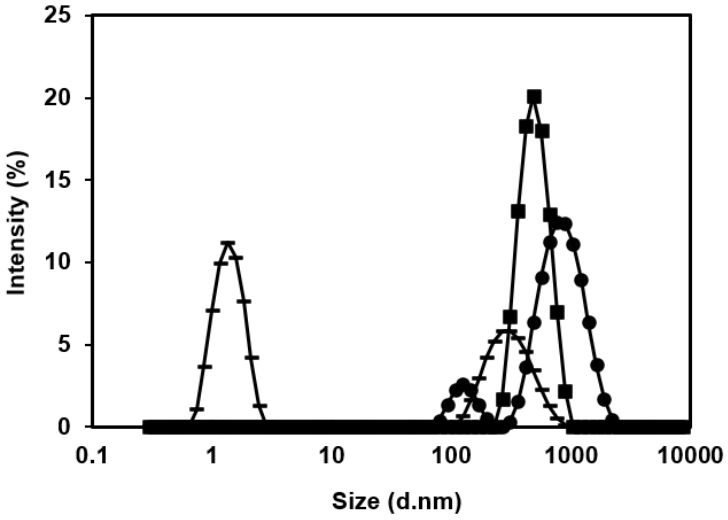


Figure 4. Size measurements of Control(**--**), HPMC-SE without fragrance(■) and HPMC-SE with fragrace(●) by DLS.

4. Discussion

This study demonstrates that hydroxypropyl methylcellulose stearoxy ether (HPMC-SE) can enhance both the persistence and intensity of fragrance compounds in cosmetic formulations. Interpretation of the GC-MS results revealed that the treated sample containing HPMC-SE showed increased peak area values for multiple fragrance components at both 1 hour and 8 hours post-application. Specifically, peak areas increased for 12 fragrance components at 1 hour and for 22 components at 8 hours, indicating a notable enhancement in fragrance intensity.

Additionally, the rate of decline in peak area over time (from 1 to 8 hours) was analyzed to assess fragrance persistence. A total of 19 volatile compounds exhibited lower reduction rates in the treated sample compared to the control, suggesting improved retention of these components over time.

Importantly, the fragrance components exhibiting enhanced intensity and persistence included a broad range of low- to medium-molecular-weight compounds, covering top and middle notes. This suggests that HPMC-SE is broadly effective across different volatility profiles.

The dynamic light scattering (DLS) results suggest that cellulose-based polymeric assemblies exhibit two contrasting structural behaviors depending on the size and state of the fragrance molecules. In the control sample, two distinct particle populations were observed at

approximately 1.4 nm and 327.7 nm, corresponding to molecularly dissolved fragrance components and self-aggregated domains formed via hydrophobic interactions, respectively.

In the HPMC-SE-treated sample without fragrance, the primary particle size was detected at 508.6 nm, which is interpreted as the formation of spontaneously hydrated polymeric networks. When fragrance was incorporated into the HPMC-SE matrix, the major peak shifted to 897.3 nm, and an additional minor peak appeared at around 129.2 nm.

These findings indicate that two opposing fragrance–polymer interaction behaviors coexist within the polymeric network. One involves the entrapment of very small hydrophobic fragrance molecules between polymer chains, leading to slight compaction of the assembly due to increased chain interactions and structural tightening. The other involves the inclusion of relatively large pre-aggregated fragrance clusters into the polymeric matrix, resulting in core expansion of the assembly. This suggests that the presence of fragrance induces structural enlargement of the network, depending on its aggregation state.

Sensory evaluation results reinforced these findings. The treated sample exhibited up to a 110.84% improvement in fragrance intensity compared to the control at 4 hours post-application, consistent with the GC-MS data and confirming the sensory relevance of the physicochemical evidence.

Taken together, these results highlight the potential utility of HPMC-SE as a functional fragrance booster, capable of enhancing both the perceived intensity and persistence of fragrances in formulations.

5. Conclusion

This study confirms that hydroxypropyl methylcellulose stearoxy ether (HPMC-SE) is a promising enhancer of fragrance persistence for cosmetic formulations. Through quantitative GC-MS analysis, sensory evaluation, and particle characterization, the treated samples exhibited significantly improved fragrance intensity and persistence over time compared to the control.

These enhancements are attributed to the formation of a hydrated polymeric network capable of physically interacting with volatile, hydrophobic fragrance compounds and slowing their evaporation. Importantly, HPMC-SE demonstrated effectiveness across a broad range of fragrance compounds, including top and middle notes with low to medium molecular weights, suggesting broad applicability across different volatility profiles. Beyond its impact on fragrance persistence, HPMC-SE also contributes to formulation stability, making it particularly attractive for applications requiring reduced fragrance concentrations and long-lasting sensorial effects.

The two distinct structural behaviors observed upon the application of HPMC-SE suggest that the microstructure of polymer–fragrance complexes may vary depending on the molecular weight, hydrophobicity, and aggregation tendency of the fragrance molecules. These structural differences are closely related to fragrance persistence, release rate, and formulation stability, indicating the necessity of quantitatively considering the relationship between polymer properties and the physicochemical characteristics of the fragrance in future formulation design.

Future research could expand upon these findings by investigating the effects of HPMC-SE in various formulation types, such as emulsions, and by characterizing long-term fragrance retention under diverse environmental conditions. Furthermore, mechanistic studies focusing on the interactions between stearoxy ether branches and specific classes of fragrance molecules—particularly those identified in this study—could further elucidate the structure–function relationships underlying its performance.

6. References

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