

Deodorants on the European market: quantitative chemical analysis of 21 fragrances

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Deodorants are one of the most frequently used types of cosmetics and side-effects from them are common. Recent studies relate perfume allergy to this type of product. 73 deodorants were analyzed by gas chromatography – mass spectrometry for the determination of the contents of 7 well-known fragrance allergens from the fragrance mix and 14 other commonly used fragrance materials. The deodorants were purchased at retail outlets in 5 European countries. It was found that in general, fragrance mix ingredients were more frequently present in vapo- and aerosol sprays than in roll-on products. The levels of the fragrance mix substances ranged from 0.0001–0.2355%. The products investigated contained cinnamic aldehyde and isoeugenol less frequently (17% and 29% respectively), and eugenol and geraniol most frequently (57% and 76% respectively). The 14 other fragrance materials were found in 40–97% of the deodorants, with hedione and benzyl acetate the most frequently found substances. The concentration of these 14 substances ranged from 0.0001–2.7%. It is concluded that the levels of cinnamic aldehyde and isoeugenol found in the deodorants could prove to be relevant for elicitation of contact dermatitis. No conclusions could be drawn about the other fragrance mix constituents, as threshold levels in sensitized individuals have not been investigated. Furthermore, all of the fragrance materials investigated were frequently found in deodorants and, apart from the fragrance mix ingredients, the extent of problems with sensitization to these fragrance materials is largely unknown.

Key words: contact allergy; deodorants; fragrances; fragrance mix; chemical analysis; cosmetics.
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Allergic contact dermatitis is among the more severe unwanted effects arising from the use of cosmetics. The majority of allergic reactions to cosmetics can be attributed to the perfume in the product (1). Deodorants are one of the most widely used types of cosmetic products (2) and there is evidence to suggest that deodorants play a particular important rôle in allergic contact dermatitis from perfumes (3, 4). In one study, a significant correlation was found between axillary eczema and perfume allergy in 1016 consecutive eczema patients (3). Furthermore, deodorant sprays were

more often the cause of first-time rash in perfume-allergic individuals, as compared to other eczema patients and individuals from the general population (4).

Perfumes are composed of 10–300 fragrance substances, which are chosen from among thousands of fragrances. The composition of perfumes is kept a trade secret by the fragrance industry, which means that important information regarding exposure is not available for risk assessment.

In the present study, quantitative analysis was performed on 73 deodorants by gas chromatogra-

phy – mass spectrometry. The contents of 21 fragrance substances, which are well-known fragrance allergens and/or commonly used fragrance substances, were established in 3 different product types, vapo-sprays, aerosol sprays and roll-on products.

Materials and Methods

Deodorant samples

The study included 73 deodorant products, comprising 23 vapo-spray, 22 aerosol spray, 27 roll-on products and 1 deostick. The samples represented both the well-known international cosmetic/perfume companies, based in Europe and the USA, and the local small/medium, sized cosmetic companies in Denmark, England, France, Germany and Sweden. The samples were purchased in 1996 at retail outlets in the above-mentioned 5 countries. 3 of the products investigated (1 vapo-spray and 2 roll-on) were labelled “not perfumed”, and one vapo-spray was labelled “perfume for babies”.

Target fragrance substances

The 21 target fragrance substances (Table 1) included the 7 chemically-defined substances of the fragrance mix, cinnamic aldehyde, cinnamic alcohol, α -amylcinnamic aldehyde, eugenol, geraniol, hydroxycitronellal, isoeugenol, and 14 other substances that in previous studies (unpublished data from studies reported in ref. 5–8) were found to be frequently present in perfumes and cosmetics. The following criteria were considered while selecting

these 14 fragrance substances: (i) they have been shown to be allergenic fragrance materials, and/or (ii) they are chemically similar to the known fragrance allergens, and/or (iii) they are produced and used in large amounts in perfumes, and/or (iv) they are present in relatively high concentrations in essential oils used for compounding the perfumes.

Analysis

A previously-described gas chromatography – mass spectrometric (GC-MS) method (9) was used for the analysis. As a routine, target fragrance substances were identified by GC-MS, and the determination of the substances identified was performed by GC-FID (flame ionization detection). The sample preparation methods for the analysis of fragrance substances in various types of cosmetic products have been described previously (9). All of the target fragrance substances were analyzed at a detection limit of approximately 1 ppm (0.0001%). The relative standard deviation of the determination of all of the substances was within 10%.

Results

The GC-MS method used for the analysis of the 21 target fragrance substances resolved all of these substances from each other, though some samples contained substances that interfered with the detection/quantification of benzyl alcohol, Lilial®, Hedione® and α -amylcinnamic aldehyde. Thus, the identification of benzyl alcohol in many aerosol

Table 1. Target fragrance substances

Trivial/trade name	CAS – reg.nr.	Chemical name
α -amylcinnamic aldehyde *	122-40-7	2-phenylmethylene heptanal
benzyl acetate	140-11-4	acetic acid phenylmethyl ester
benzyl alcohol	100-51-6	α -hydroxytoluene
benzyl benzoate	120-51-4	benzoic acid phenylmethyl ester
benzyl salicylate	118-58-1	2-hydroxybenzoic acid phenylmethyl ester
cinnamic aldehyde*	104-55-2	3-phenyl-2-propenal
cinnamic alcohol*	104-54-1	3-phenyl-2-propen-1-ol
citronellol	106-22-9	3,7-dimethyl-6-octen-1-ol
coumarin	91-64-5	2H-1-benzopyran-2-one
eugenol*	97-53-0	2-methoxy-4-(2-propenyl) phenol
geraniol*	106-24-1	3,7-dimethyl-2,6-octadien-1-ol
α -hexylcinnamic aldehyde	101-86-0	2-phenylmethylene octanal
Hedione®	24851-98-7	methyl(3-oxo-2-pentylcyclopentyl)acetate
hydroxycitronellal*	107-75-75	7-hydroxy-3,7-dimethyl octanal
isoeugenol*	97-54-1	2-methoxy-4-(1-propenyl) phenol
Lilial®	80-54-6	2-methyl-3-(4-tert-butylphenyl) propanal
linalool	78-70-6	3,7-dimethyl-1,6-octadien-3-ol
linalyl acetate	115-95-7	3,7-dimethyl-1,6-octadien-3-yl acetate
Lyrall®	31906-04-4	4-(4-hydroxy-4-methylpentyl)-3-cyclohexene carboxaldehyde
α -iso-methylionone	127-51-5	4-(2,6,6-trimethylcyclohex-2-en-1-yl)-3-methylbut-3-en-2-one
piperonal	120-57-0	1,3-benzodioxole-5-carboxaldehyde

*Present in the fragrance mix.

Table 2. Contents of target fragrance substances in 23 vapo-sprays

Fragrance substance	Products containing the substance		Concentration range (g/100 ml)	Mean (g/100 ml)	Median (g/100 ml)
	no.	%*			
α -amylcinnamic aldehyde	10	45	0.0001–0.0617	0.0130	0.0068
benzyl acetate	20	91	0.0001–2.6960	0.1876	0.0339
benzyl alcohol	10**		0.0011–0.0629		
benzyl benzoate	21	95	0.0012–0.1075	0.0179	0.0113
benzyl salicylate	12	55	0.0016–1.8758	0.2371	0.0512
cinnamic alcohol	13	59	0.0006–0.1169	0.0222	0.0040
cinnamic aldehyde	4	18	0.0001–0.0046	0.0022	0.0019
citronellol	20	91	0.0017–0.1392	0.0275	0.0146
coumarin	17	77	0.0011–0.1170	0.0310	0.0112
eugenol	15	68	0.0006–0.2355	0.0327	0.0065
geraniol	21	95	0.0001–0.1178	0.0207	0.0048
Hedione®	19	86	0.0024–1.7587	0.1898	0.0288
α -hexylcinnamic aldehyde	18	82	0.0015–0.1684	0.0363	0.0110
hydroxycitronellal	18	82	0.0001–0.1023	0.0183	0.0041
isoeugenol	9	41	0.0001–0.0458	0.0129	0.0098
Lilial®	15	68	0.0025–0.1452	0.0314	0.0212
linalool	22	100	0.0009–0.1927	0.0511	0.0284
linalyl acetate	16	73	0.0001–0.1810	0.0505	0.0413
Lyrall®	13	59	0.0001–0.1874	0.0595	0.0387
α -iso-methylionone	15	68	0.0020–0.2235	0.0627	0.0458
piperonal	11	50	0.0001–0.0526	0.0139	0.0072

*The fragrance free vapo-spray did not contain any of the target fragrances. The % of products containing the fragrance is, therefore, calculated on the basis of 22 perfumed products. **Due to interference by dipropylene glycol, identification of benzyl alcohol was not possible in 7 products, and hence the % of products containing benzyl alcohol, mean and median values is not calculated.

Table 3. Contents of target fragrance substances in 22 aerosol sprays

Fragrance substance	Products containing the substance		Concentration range (g/100 ml)	Mean (g/100 ml)	Median (g/100 ml)
	no.	%			
α -amylcinnamic aldehyde	6	27	0.0001–0.0198	0.0052	0.0026
benzyl acetate	21	95	0.0001–0.0517	0.0205	0.0199
benzyl alcohol	2*		0.0045, 0.0575		
benzyl benzoate	21	95	0.0001–0.0187	0.0049	0.0032
benzyl salicylate	11	50	0.0001–0.1537	0.0488	0.0422
cinnamic aldehyde	6	27	0.0001–0.0424	0.0072	0.0002
cinnamic alcohol	10	46	0.0016–0.0184	0.0056	0.0028
citronellol	22	100	0.0005–0.5585	0.0377	0.0090
coumarin	11	50	0.0030–0.0260	0.0118	0.0102
eugenol	17	77	0.0006–0.0632	0.0165	0.0094
geraniol	20	91	0.0001–0.0206	0.0053	0.0031
Hedione®	19	86	0.0001–0.2409	0.0367	0.0182
α -hexylcinnamic aldehyde	19	86	0.0002–0.0422	0.0164	0.0080
hydroxycitronellal	14	64	0.0012–0.0815	0.0228	0.0128
isoeugenol	9	41	0.0001–0.0104	0.0031	0.0024
Lilial®	12	55	0.0065–0.3732	0.1009	0.0620
linalool	22	100	0.0009–0.1028	0.0223	0.0094
linalyl acetate	20	91	0.0009–0.1119	0.0300	0.0149
Lyrall®	17	77	0.0006–0.1606	0.0295	0.0210
α -iso-methylionone	15	68	0.0018–0.1942	0.0457	0.0287
piperonal	13	59	0.0001–0.0612	0.0116	0.0028

*Due to interference by dipropylene glycol, identification of benzyl alcohol was not possible in 19 products.

and vapo-sprays was not possible due to the overlapping by a GC-peak of dipropylene glycol, which was present in relatively high amounts in these samples. Similarly, a C₁₁-alkyne interfered with the analysis of Lilial®; high amounts of ethyl citrate

and/or a sesquiterpene alcohol (C₁₅H₂₆O) present in a sample interfered with the analysis of Hedione®; and relatively high amounts of Hedione® present in a sample interfered with the analysis of α -amylcinnamic aldehyde. These prob-

Table 4. Contents of target fragrance substances in the 28 roll-on products*

Fragrance substance	Products containing the substance		Concentration range (g/100 ml)	Mean (g/100 ml)	Median (g/100 ml)
	no.	%**			
α -amylcinnamic aldehyde	6	23	0.0001–0.0376	0.0153	0.0117
benzyl acetate	18	69	0.0001–0.4999	0.0451	0.0233
benzyl alcohol	8***		0.0001–0.0357		
benzyl benzoate	8	31	0.0001–0.0368	0.0201	0.0227
benzyl salicylate	11	39	0.0001–0.1259	0.0457	0.0383
cinnamic alcohol	4	15	0.0031–0.0390	0.0197	0.0183
cinnamic aldehyde	2	8	0.0001, 0.0077		
citronellol	15	58	0.0001–0.2300	0.0386	0.0265
coumarin	12	46	0.0001–0.1411	0.0432	0.0351
eugenol	8	31	0.0001–0.0173	0.0095	0.0133
geraniol	12	46	0.0001–0.0673	0.0168	0.0141
Hedion®	17	65	0.0001–0.1497	0.0383	0.0206
α -hexylcinnamic aldehyde	13	50	0.0027–0.0919	0.0210	0.0158
hydroxycitronellal	3	12	0.0087–0.0668	0.0319	0.0201
isoeugenol	2	8	0.0241, 0.0268		
Lilial®	9	35	0.0001–0.3193	0.1001	0.0387
linalool	24	92	0.0047–0.0760	0.0332	0.0318
linalyl acetate	15	58	0.0001–0.0583	0.0237	0.0252
Lyrall®	7	27	0.0001–0.1822	0.0664	0.0582
α -iso-methylionone	13	50	0.0001–0.2765	0.0745	0.0380
piperonal	4	15	0.0153–0.0390	0.0267	0.0263

*Includes 1 deo-stick. **2 fragrance free roll-ons did not contain any of the target fragrances. The % of products containing the fragrance is, therefore, calculated on the basis of 26 perfumed products. ***Due to interference by dipropylene glycol, identification of benzyl alcohol was not possible in 10 products, and hence the % of products containing benzyl alcohol, mean and median values is not calculated.

lems, though, were solved by analysing diluted samples.

Contents of target fragrance materials

Contents and the concentration range of the target fragrance substances in the vapo-spray, aerosol spray and roll-on products investigated are described in Tables 2, 3 and 4, respectively. None of the target fragrance substances were detected in the 3 products (1 vapo-spray and 2 roll-on) labelled “not perfumed”. The trend was that target fragrances were more often found in vapo-spray $\geq$ aerosol spray $>$ roll-on products, but with a very small difference between vapo-sprays and aerosol sprays. In most cases, vapo-sprays contained the maximum number of the target fragrance substances and the highest maximum concentrations (Tables 2–4), while roll-on products on average had a median concentration $2\times$ the concentration in either vapo-sprays or aerosol sprays.

The vapo-spray for “babies” was found to contain 1 ppm (0.0001%) to 1640 ppm of 14 of the 21 target fragrance substances. Among the fragrance mix substances, geraniol (23 ppm), hydroxycitronellal (1 ppm), cinnamic alcohol (26 ppm) and α -amylcinnamic aldehyde (113 ppm) were all found in this sample. The content and concentration range of the target fragrance substances in all of

the 70 “perfumed” products are described in Table 5.

The frequency of the presence of the fragrance mix substances in all perfumed deodorants was geraniol $>$ eugenol $>$ hydroxycitronellal $>$ cinnamic alcohol $>$ α -amylcinnamic aldehyde $>$ isoeugenol $>$ cinnamic aldehyde. The highest concentration was found for eugenol (2300 ppm) in a vapo-spray, followed by geraniol, cinnamic alcohol and hydroxycitronellal (1100, 1100 and 1000 ppm, respectively). Last came isoeugenol and cinnamic aldehyde (both 400 ppm) (Table 5). As for the target fragrance materials in general, the roll-on products had a lower frequency of fragrance mix constituents than the vapo- and aerosol sprays. The tendency was for the vapo-sprays to have the highest maximum concentrations and the roll-on products the highest median concentrations of fragrance mix constituents.

Discussion

For 20 years, the fragrance mix has been used as an efficient screening agent for perfume contact allergy (10). Previous studies showed that popular prestige perfumes (5), perfumes used in the formulation of other cosmetic products (6) and perfumes in natural ingredient-based cosmetics (7) all contained several of the fragrance mix substances in

Table 5. Contents of target fragrance substances in 73 deodorants

Fragrance substance	Products containing the substance		Concentration range (ppm)
	no.	%*	
α -amylcinnamic aldehyde	22	31	1–617
benzyl acetate	59	84	1–26960
benzyl alcohol	20**		1–629
benzyl benzoate	50	71	1–1075
benzyl salicylate	34	49	1–18758
cinnamic alcohol	27	39	6–1169
cinnamic aldehyde	12	17	1–424
citronellol	57	81	1–5585
coumarin	40	57	1–1411
eugenol	40	57	1–2355
geraniol	53	76	1–1178
Hedione®	55	79	1–17587
α -hexylcinnamic aldehyde	50	71	2–1684
hydroxycitronellal	35	50	1–1023
isoeugenol	20	29	1–458
Lilial®	36	51	1–3732
linalool	68	97	9–1927
linalyl acetate	51	73	1–1810
Lyrall®	37	53	1–1874
α -iso-methylionone	43	61	1–2765
piperonal	28	40	1–612

*% calculated on the basis of 70 products, because the 3 “fragrance-free” products did not contain any of the target fragrances.

**Due to interference by dipropylene glycol, identification of benzyl alcohol was not possible in 36 products. Therefore, the % of products containing benzyl alcohol is not reported.

various concentrations. Furthermore, it was demonstrated that exposure to low levels of fragrance mix constituents was associated with allergic contact dermatitis in sensitized patients (8). The deodorants in this study also contained the fragrance mix constituents in an almost identical pattern for all 3 groups of products: cinnamic aldehyde and isoeugenol were used less frequently, eugenol and geraniol most frequently (Tables 2–4). Cinnamic aldehyde, found in 17% of the products, is a strong allergen (11, 12). It is included as a single allergen in the North American standard patch test series (13). In 1992–1994, cinnamic aldehyde 1% pet. was found positive in 2.7% of 3528 consecutive eczema patients tested by the North American Contact Dermatitis Group (13). No restrictions are imposed on the concentration of cinnamic aldehyde in a product. According to IFRA information, as much as 8000 ppm (0.8%) may be used in perfumes (14). Cinnamic-aldehyde-sensitive individuals react down to 200 ppm in an occluded patch test and 1000 ppm (0.1%) in a repeated open application test (15). Deodorants are used repeatedly in an occluded environment. A maximum concentration of 424 ppm cinnamic aldehyde was found in 1 aerosol spray in this study, a concentration that would be expected to elicit dermatitis in sensitive individuals. The median concentrations of cinnamic aldehyde were more than 10 $\times$ lower and whether these concentrations are safe needs to be shown. Isoeug-

enol is also a strong sensitizer (12) and its use restricted by IFRA, so that no more than 2000 ppm (0.2%) is allowed in a product (16). Isoeugenol was found in 29% of the products at a maximum concentration of 458 ppm (Table 5). In a previous study, 20% of isoeugenol-sensitized individuals were found to react to the lowest concentration (100 ppm isoeugenol) patch tested (17). The median concentrations in the spray deodorants were 24 ppm and 98 ppm, and in 2 roll-on products, 241 and 268 ppm were found (Tables 2–4), concentrations that might elicit contact dermatitis in sensitized individuals.

The no-effect levels of other fragrance mix constituents have not been studied so far in eczema patients. Hydroxycitronellal is widely used, and was found in 50% of the deodorants examined at a maximum concentration of 1000 ppm (0.1%). Hydroxycitronellal has been tested in several human sensitization tests (18). 20% of subjects were sensitized to 25,000 ppm (2.5%) hydroxycitronellal in a 2-phase human repeated insult patch test. Similar testing with 10,000 ppm (1%) hydroxycitronellal gave questionable results (18). Some of the experimentally sensitized individuals continued with a long-term use test with different products. No reactions were found from daily use of a soap-bar containing 500 ppm (0.05%) hydroxycitronellal, 1/31 subjects reacted to a cologne containing 500 ppm hydroxycitronellal and 3/31 to a cologne

containing 10,000 ppm hydroxycitronellal (18). Persons sensitized under normal use conditions may show a different reactivity than experimentally-sensitized individuals and data documenting the safety of hydroxycitronellal in sensitized eczema patients is needed.

The vapo-spray for "babies" was found to contain 14 of the 21 target fragrance-substances. Among the fragrance mix substances, geraniol (23 ppm), hydroxycitronellal (1 ppm), cinnamic alcohol (26 ppm) and α -amylcinnamic aldehyde (113 ppm) were found. Neonates and small infants can be sensitized, but often children are kept from exposure to potent allergens, and sensitization is very rarely seen in the first 2–3 years of life (19). The start of exposure to perfumes containing well-established contact allergens early in life may lead to a clinical problem at an early age.

The remaining target fragrance substances were present in 40–97% of the deodorants. Linalool was found most often (Table 5). Cases of contact allergy to linalool have been published (1), as also to the 2nd most commonly found fragrance, citronellol (1, 20, 21). α -hexylcinnamic aldehyde was found in 71% of the products (Table 5) and is special, as it is a strong sensitizer in animal assays and therefore made a positive control substance in the OECD-test-guideline for predicting skin sensitization (22), while few cases of contact allergy in humans have been documented (23). Lyrall[®], Lilial[®] and coumarin are also contact allergens (10), while no reports have been found on Hedione[®], linalyl acetate and α -iso-methylionone. However, very few systematic investigations into the frequency of contact allergy to fragrance substances, other than constituents of the fragrance mix, have been performed (20, 23–26). For most of the above-mentioned substances, this means that the frequency of problems with sensitization to single fragrance materials is largely unknown. In this study, it is documented that all these substances are used frequently in deodorants and some at more than 1% concentration (Table 5).

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