



Influence of Cosmetic Type and Distribution Channel on the Presence of Regulated Fragrance Allergens: Study of 2044 Commercial Products

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Abstract

Contact dermatitis linked to cosmetic products is a very common reason for visits to the dermatologist, and in more than half the cases, it is due to an allergic reaction. Fragrances are most often the culprit. The aim of the study was to describe the common fragrance allergens in different categories of cosmetic products available on the European market. We wanted to assess the influence of cosmetic type and distribution channel on the presence of fragrance allergens. There are the allergens whose concentration exceeds 0.001% in leave-on products and 0.01% in rinse-off products. A total of 2044 commercial hygiene, care, and makeup cosmetic products were analyzed to specifically study regulated fragrance allergens. The influence that the product category and its distribution channel (retail stores and specialized stores such as beauty institutes or hairdressers and pharmacy) have on the prevalence of these allergens was evaluated. The Kruskal-Wallis test has been used for statistical data analysis. There is a wide range of fragrance allergens, the most common being limonene (found in about 30% of products tested), linalool (just over a quarter of the products tested), and benzyl alcohol (approximately 16% of the products tested). The average number of allergens found and their nature varies depending on the type of product in question (maximum number for shampoos and oral care with about 70 allergens and minimum number for nail polish and makeup for eyes with fewer than 10 allergens). In the area of hygiene, deodorants and oral hygiene products are particularly noteworthy, the former for their significantly high number of allergens and the latter for their low number. There is also a significant difference between the number of allergens found in eye makeup and foundations. Our results indicate that the number of regulated fragrance allergens is particularly influenced by the type of products.

Keywords Allergens · Fragrance · Skin care · Personal care · Makeup

Introduction

Contact dermatitis linked to cosmetic products is a very common reason for visits to the dermatologist and has a very negative effect on patients' quality of life. In about 60% of the cases, it is due to an allergic reaction [1, 2]. Since fragrances are the most frequently questioned substances [3], we decided to assess 2044 cosmetic products and determine the presence (or absence) of a number of allergens. Since 2006, these must be mentioned on the label of the products in question pursuant

to Directive 2003/15/EC [4]. The products concerned are personal hygiene products (face, body and oral hygiene products, shampoo, soap and related products, deodorants and antiperspirants, hair removal products, and depilatories), care products (face care and moisturizers, body care, sunscreens, hair care), and makeup (foundation, eye makeup, lipstick, nail varnish), as well as baby care products and others specifically designed for men. For each of the products, we determined the number and nature of the regulated allergens they contained; we then tried to evaluate the possible influence that the distribution channel had on the number of allergens by comparing the products distributed in pharmacies and drugstores with those available in retail stores and beauty parlors.

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Materials and Methods

The formula of a diverse range of 2044 commercial cosmetic products available through different distribution channels (as

well as 48%, 29%, and 23%, respectively, in retail stores, pharmacy, and specialized stores) was analyzed to specifically study regulated fragrance allergens. These allergens correspond to the molecules for which the concentration is higher than 0.001% in leave-on products and 0.01% in rinse-off products. The products studied were concentrated into 5 categories and 16 subcategories. We determined the number and nature of the allergens found in the products studied for each product category. As data was not distributed in a normal fashion, we chose a nonparametric test for statistical processing purposes: the Kruskal-Wallis test was adopted [5].

Results and Discussion

Overall Results

It is important to note that 54% of the products in the sample did not contain any of the fragrance allergens listed in Directive 2003/15/EC and that all subsequent calculations were made only on the basis of the products that did contain them. Therefore, products free of fragrance allergens sold in pharmacies were excluded, leaving only the so-called pleasure ranges in this distribution channel. We found that fragrance allergens were present in all categories and subcategories of products (Fig. 1), but their prevalence varied (Table 1). All fragrance allergens were detected at least once, with the exception of tree moss. The average number of fragrance allergens found in the products sampled, broken down by category, is found in Table 2. The maximum number of allergens found in a product, broken down by category, is presented in Figs. 2, 3, and 4. It was quite common to find more than a dozen allergens, except in the category of products intended

Table 1 Prevalence of allergens subject to mandatory reporting in the 2044 products studied

Allergen	Prevalence (%)
Limonene	29.55
Linalool	26.30
Benzyl alcohol	15.90
Citronellol	14.25
Geraniol	12.90
Hexyl cinnamal	9.65
Benzyl salicylate	7.95
Citral	7.85
Coumarin	7.50
Alpha-isomethyl ionone	7.40
Butylphenyl methylpropional	5.55
Eugenol	4.55
Benzyl benzoate	4.30
Hydroxycitronellal	2.75
Hydroxyisohexyl 3-cyclohexene carboxaldehyde	1.60
Farnesol	1.45
Amyl cinnamal	1.20
Cinnamyl alcohol	0.75
Isoeugenol	0.75
Cinnamal	0.50
Benzyl cinnamate	0.20
Methyl 2-octynoate	0.20
Anise alcohol	0.05
<i>Evernia prunastri</i> (oakmoss) extract	0.05
Amyl cinnamal alcohol	0.05
<i>Evernia furfuracea</i>	0.00

Fig. 1 Maximum number of fragrance allergens found in cosmetic products studied

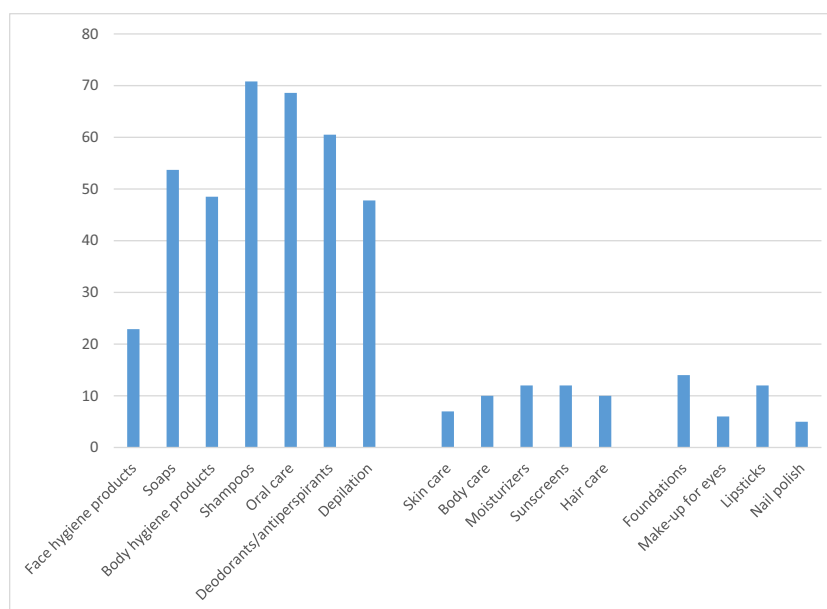


Table 2 Number of allergens found according categories and subcategories of cosmetics studied

Product category	Subcategory	Number of products concerned	Number of allergens found
Hygiene	Face	218	3.44 ± 2.30
	Soap and related	41	3.41 ± 2.36
	Body	231	3.35 ± 2.20
	Hair	130	3.41 ± 2.10
	Oral	188	1.26 ± 0.62
	Deodorant/antiperspirant	147	5.41 ± 3.38
	Hair removal/depilation	23	3.10 ± 1.51
Personal care	Face	119	4.04 ± 2.22
	Body	55	5.88 ± 2.64
	Moisturizers	281	4.66 ± 2.87
	Sunscreens	156	5.07 ± 2.91
	Hair	88	4.68 ± 2.52
Makeup	Foundations	100	4.29 ± 3.65
	Eyes	53	1.67 ± 1.50
	Lips	83	3.82 ± 2.45
	Nails	60	5.00 ± 0.00
Baby care		57	2.00 ± 1.91
Men's products		14	3.40 ± 2.51

for babies and that targeting men, for which the maximum number of allergens was 6 and 7, respectively. The 3 most common allergens we encountered were limonene, linalool, and benzyl alcohol, their prevalence being 29.6%, 26.3%, and 15.9%, respectively (Table 1). Previous studies also identified limonene and linalool as the most common allergens [1, 3, 6].

This is because these molecules are commonly found in nature. Limonene or 1-methyl-4-(1-methylphenyl) cyclohexene is commonly found in plants in two enantiomer forms: D-limonene (or R-(+)-limonene) and L-limonene (or S-(-)-limonene), in varying volumes and proportions. Turpentine contains L-limonene. D-limonene is a characteristic of the *Citrus*

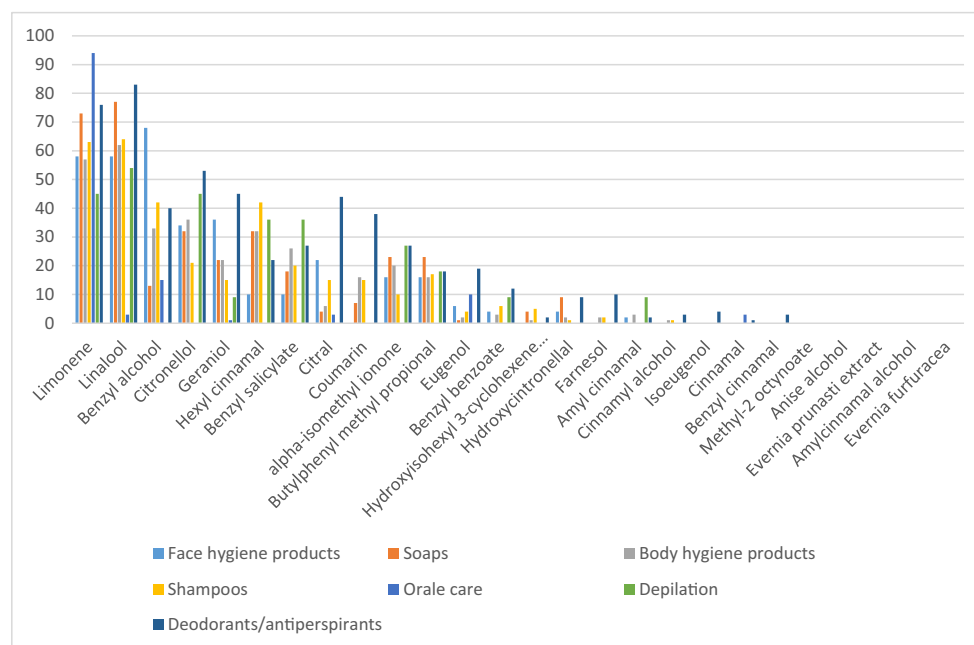
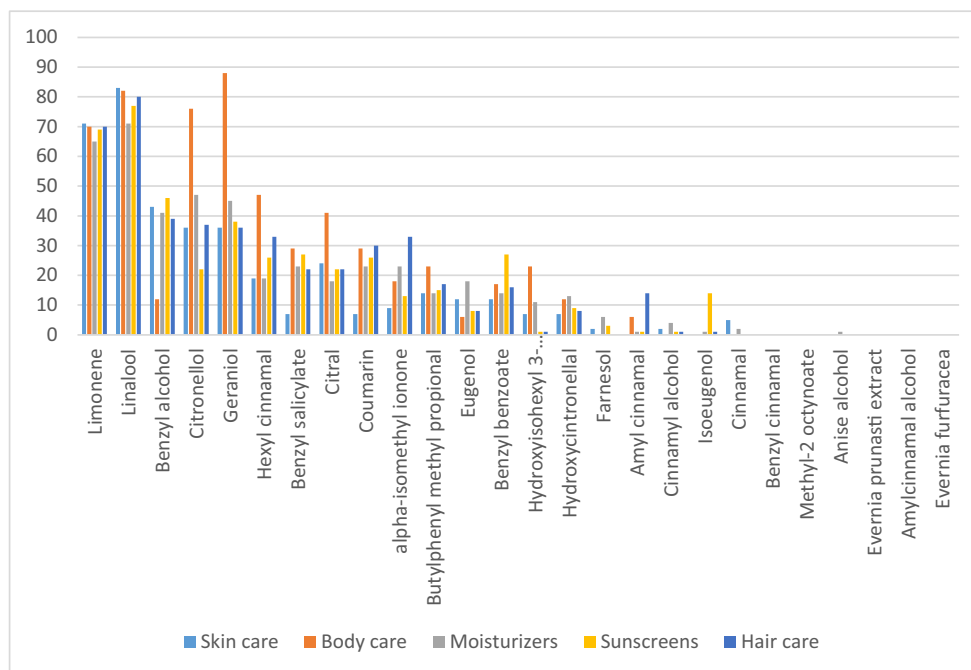
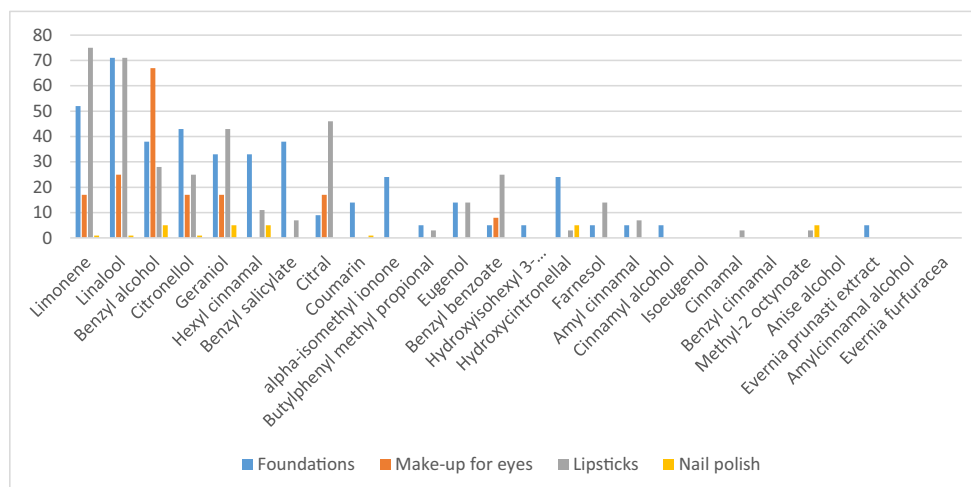
Fig. 2 Fragrance allergens present in the hygiene products studied

Fig. 3 Fragrance allergens found in the personal care products

family. Lemon essential oil, extracted by steam distillation from orange peel of the species *Citrus sinensis*, contains mainly D-limonene, up to 95%. In the case of bitter orange (*Citrus aurantium*), limonene content ranges from 70 to 90%. It ranges from 40 to 70% and from 50 to 70%, respectively, for lemon (*Citrus lemon*) and mandarin (*Citrus reticulata*) [7]. We would note that limonene content and yield increases with ripening [8]. Linalool or 3,7-dimethyl octa-1,6-diene-3-ol, accounting for 70% of floral fragrances, is commonly found in nature. It plays an important role in pollination by attracting pollinating insects. It is especially found in plants of the Lamiaceae (mints), Lauraceae (laurels), and Apiaceae (umbellifers) families. Essential oils contain variable proportions. Coriander seed and mericarp essential oils, for example, contain high levels of linalool (66% and 79%, respectively).

The essential oils obtained by steam distillation from the aerial parts of oregano, thyme, basil, and hyssop (content of 8, 12, 18, and 51%, respectively); from camphor, bitter orange, and verbena leaves (12, 17, and 53%, respectively); and myrtle fruit (19%) are all sources of linalool. Lavender is also an important source of linalool [9]. Lastly, benzyl alcohol is a molecule found in a number of essential oils. It is found in plants of the *Allium* genus [10]. Ylang ylang (*Cananga odorata*) essential oil contains about 10% [11], while cinnamon tree bark essential oil contains 12% benzyl alcohol, the second major ingredient after trans-cinnamaldehyde (73%) [12]. *Piper sarmentosum* leaves are also rich in benzyl alcohol, the essential oil extracted from them containing 18% [13]. It is also found, along with many other sensitizing molecules, in Peru balsam [14]. The prevalence of benzyl alcohol is most

Fig. 4 The different fragrance allergens found in makeup products

likely related to its microbial properties and its use as a preservative [15], as concentrations of up to 1% are allowed in Europe [16].

Hydroxycitronellal, cinnamyl alcohol, cinnamyl, amyl cinnamyl, eugenol, isoeugenol, 2-methylbutanoate, and tree moss are among the strong sensitizers. Most of these allergens are either rare or not found in the products studied. Only eugenol was found in 93 products.

Lastly, we would draw attention to the particular case of hydroxyisohexyl 3-cyclohexene carboxaldehyde better known by its trade name Lyrall®. It is a strong sensitizer, and its use in cosmetics was therefore banned by European authorities [17, 18]. We found it in about 30 of the products included in the sample as the regulation prohibits new placing on the market as from 23 August 2019, a total ban coming into force on 23 August 2021.

Results by Product Category and Distribution Channel

Results for Personal Hygiene Products

The use of hygiene products such as shampoos is likely to cause allergic reactions, especially lateral dermatitis of the face and/or neck [2]. Allergens are found in this type of cosmetic product as it is formulated with fragrances. This aspect is taken into consideration when a consumer chooses a product. The fragrance allergens we identified in the hygiene products studied are presented in Fig. 2. Two products, one shower product and a shampoo, were each found to contain 11 fragrance allergens. With a *p* value under 0.05, the null hypothesis H_0 according to which the different data to be compared are from the same distribution or distributions of the same median is rejected. While there is no significant difference between soaps and hygiene products for the face, body, and hair, it seems that deodorants and oral hygiene products differ significantly. Oral hygiene products stand out for having fewer allergens than other hygiene products. Conversely, deodorants contain significantly more allergens. This is directly related to their mode of action. Deodorants, unlike antiperspirants, have no effect on sweating. They are used to mask body odor generated by the transformation of some sweat compounds by commensal bacteria. Their formulation is therefore essentially based on fragrances and antimicrobial agents [19].

The prevalence of fragrance allergens in hygiene products as a function of the distribution channel is presented in Table 3. The average number of fragrance allergens found in personal hygiene products according to the distribution channel is found in Table 4. The number of allergens appears to be lower in hygiene products available in pharmacies compared with those found in other distribution channels. We reached a similar conclusion in a previous study of about a hundred shampoos [20].

Table 3 Prevalence expressed as a percentage of fragrance allergens in cosmetic products tested according to the distribution channel

	Specialized stores	Retail stores	Pharmacy
Hygiene			
Face	48.3	28.8	9.8
Soap	40.0	72.0	16.7
Body	58.6	54.1	26.6
Hair	76.5	89.2	31.8
Oral care	42.9	77.3	78.3
Deodorant/antiperspirant	88.9	77.6	85.0
Care cosmetics			
Face	55.0	48.6	6.8
Body	57.0	16.7	24.1
Moisturizers	70.6	47.5	18.1
Sunscreens	55.1	52.2	11.5
Hair	88.9	75.4	22.2
Makeup			
Foundations	23.9	21.7	16.1
Makeup for eyes	22.6	20.0	28.6
Lipsticks	32.1	40.9	30.3
Nail polish	3.0	16.7	0.0

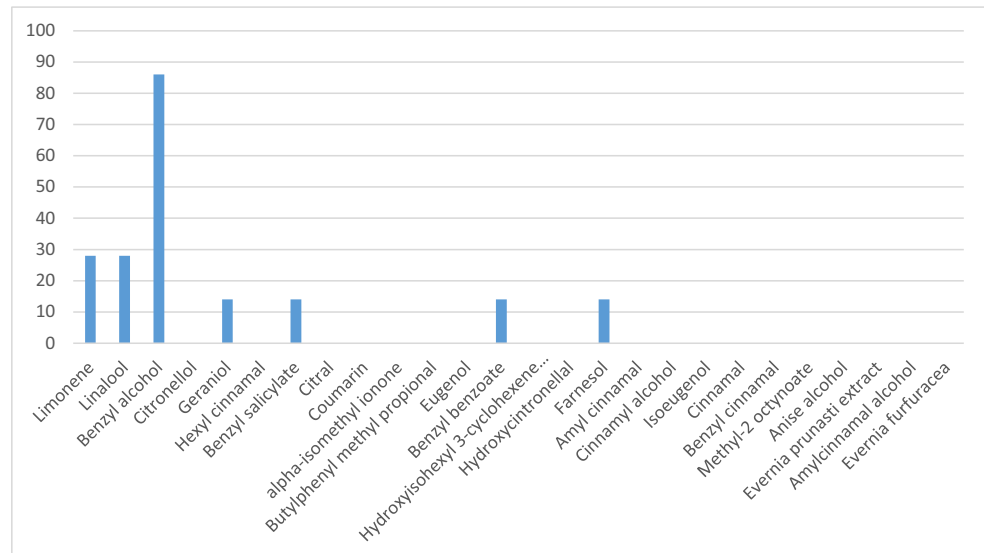
Results for Personal Care Products

Fragrance allergens are also found in care products such as moisturizers. Care products are among the cosmetics

Table 4 Number of allergens in cosmetic products tested according to the distribution channel

Hygiene products	Distribution channels		
	Specialized stores	Retail stores	Pharmacy
Face	3.3 ± 1.6	3.4 ± 2.0	2.4 ± 1.6
Soap and related	4.0 ± 1.1	3.4 ± 2.4	4.0 ± 0.0
Body	2.5 ± 1.6	3.4 ± 2.0	4.1 ± 2.5
Hair	2.7 ± 1.3	3.6 ± 2.3	3.0 ± 1.6
Oral	1.7 ± 0.5	1.2 ± 0.5	1.3 ± 0.8
Deodorant/antiperspirant	5.0 ± 2.8	5.0 ± 2.8	6.6 ± 3.6
Personal care products			
Face	4.8 ± 2.2	3.0 ± 1.7	4.7 ± 3.5
Body	5.9 ± 2.9	6.5 ± 3.5	5.7 ± 2.6
Moisturizers	4.9 ± 2.5	4.5 ± 3.2	4.2 ± 3.3
Sunscreens	5.1 ± 2.7	5.0 ± 3.2	4.4 ± 3.3
Hair	3.9 ± 1.9	5.1 ± 2.6	3.0 ± 2.8
Makeup products			
Foundations	4.0 ± 3.1	4.6 ± 5.5	4.6 ± 3.5
Makeup for yes	2.1 ± 1.9	1.0 ± 0.0	1.0 ± 0.0
Lipsticks	4.1 ± 3.6	3.4 ± 2.2	3.9 ± 1.4

Fig. 5 Fragrance allergens found in the baby care products studied



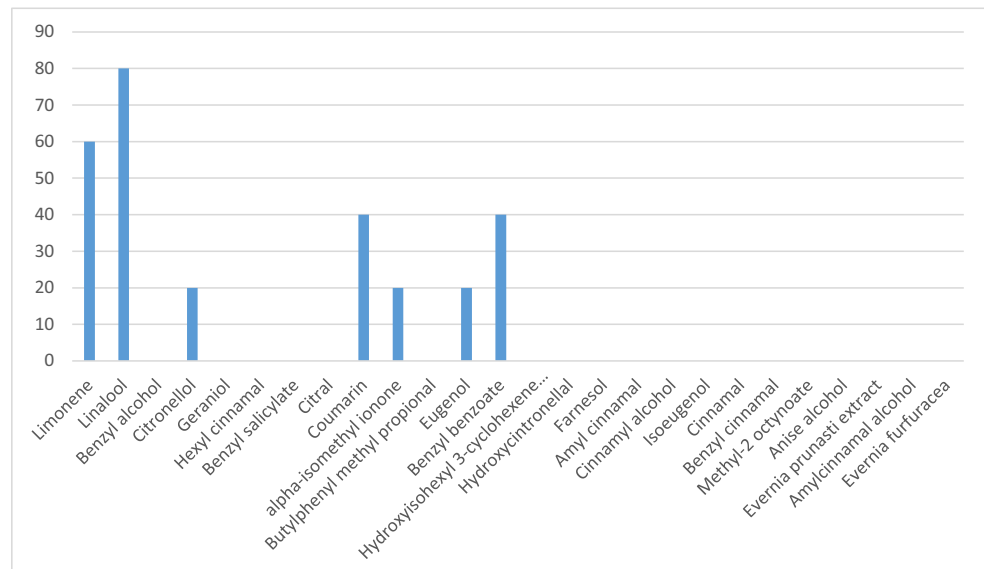
frequently involved in face and neck allergic reactions [21]. The allergens identified in the products studied are shown in Fig. 3. No significant differences were found between averages. These findings confirm the fact that care products, whatever they may be, are the main contributors to cosmetic-related allergic contact dermatitis [22].

The prevalence of fragrance allergens in care products according to the distribution channel is found in Table 3. The highest number of fragrance allergens was found in hair care products sold in specialty shops (Table 4). Facial products, moisturizers, and sunscreens with the fewest fragrance allergens were found in pharmacies. However, the difference was not statistically significant. This is because we only considered the “pleasure” ranges that are less distinguishable from the ranges sold through channels other than the so-called dermocosmetic ranges.

Results for Makeup Products

We found fewer of the allergens referred to in Directive 2003/15/EC [4] in foundations and eye, lip, and nail products (Fig. 4) than in the other types of products in the sample. These products are mainly chosen based on their color as opposed to fragrance. Although less common than in hygiene products, fragrance allergens were found in foundations, lipstick, eye makeup, and nail varnish. Lipsticks are specifically known to cause cheilitis due to contact hypersensitivity [23]. While fragrance allergens are not the only substances responsible, they do significantly contribute to these types of ailments [24]. A comparison of the means shows that there is a difference between the number of allergens in eye makeup products and the number in foundations. Special precautions are therefore taken in the formulation of mascara, eyeliner, and

Fig. 6 Allergens found in the men's products studied



similar products. There are, of course, publications reporting on cases of allergies, but these relate to ingredients other than fragrances such as shellac, for example [25].

The average number of fragrance allergens found in make-up products is found in Table 3. Lipstick sold in supermarkets contains the most (Table 4). With regard to foundations and eye and lip makeup, differences between the different distribution channels were not statistically significant.

Results for Baby Care Products

Various different allergens can be found in baby products; some are in the fragrance, while others are found in preservatives such as iodopropynyl butylcarbamate [26]. There were far fewer allergens found in these products in comparison with the other product categories. Only 7 different fragrance allergens were identified (Fig. 5): benzyl alcohol (the most common), limonene, linalool, geraniol, benzyl salicylate, benzyl benzoate, and farnesol.

Results for Men's Products

As in baby products, only a few allergens were found in these products. We identified limonene, linalool, citronellol, and coumarin (Fig. 6), characteristic of the rather specific “fern” fragrances for men [27], as well as alpha-isomethyl ionone, eugenol, and benzyl benzoate.

Conclusion

In terms of regulated fragrance allergens, there is a significant disparity between different categories of cosmetics. Furthermore, other categories of additives such as preservatives and coloring agents, as well as active substances such as protein hydrolysates which are also sensitizing, have yet to be studied.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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