

Research Article

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Formaldehyde may be found in cosmetic products even when unlabelled

Abstract: Concomitant contact allergy to formaldehyde and formaldehyde-releasers remains common among patients with allergic contact dermatitis. Concentration of free formaldehyde in cosmetic products within allowed limits have been shown to induce dermatitis from short-term use on normal skin.

The aim of this study was to investigate the formaldehyde content of cosmetic products made in Lithuania. 42 samples were analysed with the chromotropic acid (CA) method for semi-quantitative formaldehyde determination. These included 24 leave-on (e.g., creams, lotions) and 18 rinse-off (e.g., shampoos, soaps) products. Formaldehyde releasers were declared on the labels of 10 products. No formaldehyde releaser was declared on the label of the only face cream investigated, but levels of free formaldehyde with the CA method was >40 mg/ml and when analysed with a high-performance liquid chromatographic method – 532 ppm. According to the EU Cosmetic directive, if the concentration of formaldehyde is above 0.05% a cosmetic product must be labelled “contains formaldehyde“. It could be difficult for patients allergic to formaldehyde to avoid contact with products containing it as its presence cannot be determined from the ingredient labelling with certainty. The CA method is a simple and

reliable method for detecting formaldehyde presence in cosmetic products.

Keywords: chromotropic acid; formaldehyde; formaldehyde-releaser; high-performance liquid chromatography

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1 Introduction

Formaldehyde is a well-documented contact allergen. Over recent decades, the prevalence of contact allergy to formaldehyde has been found to be 8-9% in the USA and 2-3% in European countries [1].

Formaldehyde as such is very seldomly used in cosmetic products anymore, but preservatives releasing formaldehyde in the presence of water are widely used in many cosmetic products (e.g., shampoos, creams, etc.), topical medications and household products (e.g., dishwashing liquids). These preservatives are called formaldehyde-donors or formaldehyde-releasers (Table 1). For consumers allergic to formaldehyde and suffering from any kind of dermatitis, it is very important to know the potential for formaldehyde exposure in order to avoid allergic contact dermatitis (ACD).

One of the simplest methods to detect formaldehyde release from various products is a semi-quantitative method based on the reaction of formaldehyde with chromotropic acid (CA) [2]. In some European dermatological clinics, this method is used routinely for checking the presence of formaldehyde in products labelled not to contain formaldehyde or formaldehyde-releasers and used by formaldehyde-allergic patients [3].

A more accurate quantitative method is a high-performance liquid chromatography analysis, with 2,4-dinitrophenylhydrazine (2,4-DNPH) as a derivatizing agent, but this method requires sophisticated equipment and trained personnel [3].

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Table 1. List of formaldehyde releasers allowed to be used in cosmetics in the EU

INN name	INCI name	Highest allowed concentration in the final product
Formaldehyde and Paraformaldehyde	Formaldehyde and Paraformaldehyde	Oral products 0.1% (free formaldehyde), other products – 0.2% (free formaldehyde); Not to be used in aerosol sprays.
Methanol, (phenylmethoxy-)	Benzylhemiformal	Rinse-off products 0.15%
Bronopol	2-Bromo-2-nitropropane-1,3-diol	0.1%
5-brom-5-nitro-1,3-dioxane	5-Bromo-5-nitro-1,3-dioxane	Rinse-off products 0.1%
N-(Hydroxymethyl)-N-(dihydroxymethyl-1,3-dioxo-2,5-imidazolidinyl-4)-N'-(hydroxymethyl) urea	Diazolidinyl urea	0.5%
N,N"-methylenebis[N'-(3-(hydroxymethyl)-2,5-dioxoimidazolidin-4-yl]urea]	Imidazolidinyl urea	0.6%
Methenamine 3-chloroallylochloride	Quaternium-15	0.2%
1,3-Bis (hydroxymethyl)-5,5-dimethylimidazolidine-2,4-dione	DMDM Hydantoin	0.6%
Sodium hydroxymethylamino acetate	Sodium hydroxymethyl glycinate	0.5%
Methenamine	Methenamine	0.15%

Abbreviations: INN name—International Nonproprietary Names; INCI name -International Nomenclature of Cosmetic Ingredients name; DMDM Hydantoin -1,3-Dimethylol-5,5-dimethylhydantoin.

In this study we aimed to investigate the formaldehyde release from a selection of cosmetic products made exclusively and obtained in Lithuania in 2013.

2 Materials

Forty two cosmetic products were bought in various supermarkets in Vilnius (Table 2). The main criteria selecting products were the following: they had to be made in Lithuania and be easily purchased in ordinary shops. These cosmetic products included 18 rinse-off products (6 shampoos, 2 shower gels, 2 liquid soaps, 3 face cleaners and peelings, 5 hair conditioners and masks) and 24 leave-on products (3 make-up removers and tonics, 1 leave-on hair conditioner and 20 creams).

All these unopened samples were transported to the department in Malmö, then opened and the content analysed for formaldehyde release using the CA method [2]. High-performance liquid chromatography (HPLC) was performed on samples for which formaldehyde presence had been demonstrated by the CA method and the presence of formaldehyde/formaldehyde-releaser was not labelled [3]. All analyses of samples, standards and blanks were performed in duplicate.

3 Methods

3.1 Chromotropic acid method for semi-quantitative formaldehyde determination

To 25 ml glass jars with ground-in stoppers, we added 1.0 ml of standard solutions of formaldehyde (40.0 mg/ml, 20.0 mg/ml, 10.0 mg/ml and 2.5 mg/ml). A jar with 1.0 ml of purified water was used as a blank. For the analysis of the samples, 1.0 g of each sample was weighed and placed in a jar. In each of these jars (standard, blank and sample) a 1.0 ml glass tube containing 0.5 ml of the reagent, freshly prepared CA (98.5% chromotropic acid disodium salt dihydrate, E.Merck, Darmstadt, Germany) in concentrated sulphuric acid (4 mg/ml) (98% sulphuric acid, Sigma Aldrich, St.Louis, MO, USA) was placed. The jars were kept in the dark and the colour observed after 2 days. A violet colour of the reagent appears if formaldehyde is present in a sample, and this would be compared with the violet colour of the reagents in the jars with standard solutions to get a semi-quantitative estimation of formaldehyde content.

High-performance liquid chromatography quantitative determination of formaldehyde

Table 2. Preservatives most commonly present in investigated Lithuanian cosmetics according to labelling**, in numbers and percentage

	Number of products	Diazolidinyl urea (%)	MI/MCI or MI(%)	Parabens (%)	5-Bromo-5-Nitro-1,3-Dioxane (%)
Hair cosmetics*	12	0	6 (50)	0	3 (25)
Soaps	10	2 (20)	3 (30)	1 (10)	1 (10)
Face creams	12	4 (33)	6 (50)	3 (25)	0
Body creams	8	0	5 (63)	0	1 (13)
total	42	6 (14)	20 (48)	4 (9)	5 (12)

*Product could be preserved with other preservatives or combined several preservatives, including benzyl alcohol, dehydroacetic acid phenoxyethanol, benzalkonium chloride, sodium benzoate, cetrimonium chloride, triclosane, climbazole, potassium sorbate.

**Including shampoos, hair conditioners and masks. MCI/MI – methylchloroisothiazolinone/methylisothiazolinone;

MI – methylisothiazolinone.

1.0 g of sample was dissolved in 9.0 ml of tetrahydrofuran (THF): water (9:1).

Standard solutions of formaldehyde, 4 mg/ml, 6 mg/ml and 10 mg/ml, were prepared. 1.0 ml of each of these standard solutions was added to 9.0 ml of THF:water (9:1). A blank solution consisting of 1.0 ml of purified water and 9.0 ml of THF:water (9:1) was also prepared. 1.0 ml of each of these standard, blank or sample solutions was added to 0.4 ml of 0.1% 2,4-DNPH, stirred for 60s in a vortex mixer and allowed to stand for 2 min at room temperature. This solution was then stabilized by adding 0.4 ml of 0.1M phosphate buffer (pH 6.8), 0.7 ml of 1M sodium hydroxide solution and 2.5 ml of acetonitrile. Aliquots of 20 µl were injected into the HPLC system.

The HPLC system used was from ThermoFinnigan (San Jose, CA, USA). This system was equipped with a P4000 gradient pump, a Spectra System UV6000 detector, AS3000 injector with a 20 ml loop and Chromeleon Chromatography Dionex 7.1.2 software with Spectral Analysis for ChromoQuest. The column (internal diameter 4.6×250 mm) was packed with Nucleosil C18 (100 Å, 5 µm; Eka Nobel, Bohus, Sweden). The mobile phase was acetonitrile:water (60:40). The flow rate was 1 ml/min.

The identity of the substance detected by the UV absorption peak was confirmed by the same retention time and UV absorption spectra as those from the control formaldehyde solution. The limit of detection was 0.0001 µg/ml.

4 Results

The presence of formaldehyde-releasers diazolidinyl urea and 5-bromo-nitro-1,6-dioxane was declared in 10 (5 rinse-off and 5 leave on) of 42 products. The products with the highest content of free formaldehyde were 1 rinse-off and 5 leave-on products with a content of >40 mg/ml by the

semi-quantitative CA method. On the labels of these products the presence of the formaldehyde-releaser diazolidinylurea was declared with the exception of one cream (cream for the skin with dilated capillaries, JSC Ineco) in which another preservative, phenoxyethanol, was declared. The free formaldehyde content of this dilated capillary cream was 532 ppm (532 µg/ml) by the HPLC method.

Very low amounts of formaldehyde (less than 2.5 mg/ml by the CA method) were found in 3 rinse-off products preserved with 5-bromo-5-nitro-1,3-dioxane. Seven samples released less than 2.5 mg/ml. They showed a slight tinge of yellow-violet discoloration. These samples were not labelled to contain formaldehyde-releasers and were obtained from plastic packages. Three samples were labelled to contain Bronidox.

The results of the CA method are summarized in Table 3.

5 Discussion

Formaldehyde, or methanal, is a gas with a distinctive sharp odour. This aldehyde is widely used as disinfectant and biocide, embalming agent, and tissue fixative. Moreover, formaldehyde is found in aminoplastics and phenolic resins, various glues, and textiles.

The CA method for qualitative formaldehyde determination was first described in 1959 by Blohm [5]. This method is now an internationally recognized reference method to detect formaldehyde, and it is widely used due to its simplicity and high sensitivity. The method was modified by researchers in the department of Occupational Dermatology in Lund, Sweden to make it a semi-quantitative analysis by comparing the intensity of the violet colour of the reagents with that of 4 standard solutions

Table 3. Results of chromotropic acid method in the investigated Lithuanian cosmetics (in mg/ml)

Product Name	Number of Products	Chromotropic acid method					
		Neg	Yellow discoloration	<2.5	2.5-20	20-40	>40
Hair cosmetics	12	5	1	6	0	0	0
Soaps	10	4	2	1	0	0	3
Face creams	12	8	1	0	0	0	3
Body creams	8	5	3	0	0	0	0
Total	42	22	7	7	0	0	6

of varying concentrations[4]. It allows detection of small concentrations of free formaldehyde in the range 2.5 – 40 mg/ml [3]. However, the method may give false-negative results due to discoloration of the reagent solution [7]. Other substances present in the sample (e.g., isopropanol) may react with CA and give discoloration, and it can also mask the violet colour.

Formaldehyde was found in polyethylene glycols (carbowaxes and macrogol) and their derivatives contained in creams due to auto-oxidation and degradation of these substances producing formaldehyde [7,8]. Surfactants used as emulsifiers in oil-in-water products can also generate formaldehyde due to oxidation during storage and long-term handling of these products [9].

As mentioned, isopropanol can be the cause of discoloration in the CA assay[6]. Other substances, such as isopropyl palmitate or myristate, hydrolyze to isopropanol in the presence of water. However, in our study, only in 1 out of 7 products that gave discoloration of the CA, had isopropyl palmitate labelled. Studies on products that showed yellow discoloration in the CA assay have shown that no formaldehyde can be detected using more sensitive methods such as HPLC. Another source of formaldehyde contamination may be the plastic packaging. Water-based products (e.g., lotions, creams) in plastic tubes coated with melamine- or carbamide-formaldehyde resin can take up formaldehyde [11,12]. In our study, 40 products were in plastic packages and only 2 in glass jars.

Our study has shown that formaldehyde-releasers are not frequently used in cosmetic products made in Lithuania. It is found that around 20% of cosmetics in the USA and up to 30% in Denmark and Sweden contain formaldehyde-releasers [13-15]. One study in Sweden showed that 70% of rinse-off and 48% of leave-on products in which free formaldehyde was found were not labelled to contain any formaldehyde-releasers [16]. Most of these products released more than 40 ppm formaldehyde, which is a significant level for formaldehyde-allergic individuals.

According to legislation in the USA and the European Union, free formaldehyde content up to 0.2% (2000 ppm) is allowed to be present in cosmetics and household

products [17]. However, this concentration is sufficient to provoke ACD in those allergic to formaldehyde and using these products on healthy skin [18]. It was also shown that these allergic individuals cannot safely use products with low amounts (10-40 ppm) of formaldehyde if they have irritant contact dermatitis, as their dermatitis deteriorates [18].

According to the European Cosmetic Directive, all products containing formaldehyde or its releasers must be labelled “contains formaldehyde” when the concentration of formaldehyde in the finished product exceeds 0.05% (500 ppm) [17].

The threshold concentration for a positive patch test reaction in occluded patch testing to formaldehyde on healthy skin in formaldehyde-sensitive patients has been reported to be 250 ppm [19]. Auto-oxidation of surfactants possibly can generate higher than 500 ppm concentration of formaldehyde [20]. In our study, formaldehyde was detected in the product which was not labelled to contain formaldehyde or its releaser. It could be intentionally added but may also appear in the final product due to contaminated raw material, due to degradation of surfactants in the final product or due to migration of formaldehyde from the plastic package.

It is impossible to detect contact allergy to formaldehyde based solely on clinical findings. Usually contact allergy to formaldehyde manifests as chronic ACD, because contact with this substance is very frequent. Surfactants present in rinse-off products have irritating properties, which may help promote sensitisation to contact allergens. Low concentrations of formaldehyde (10-20 ppm) probably have no effect on sensitisation or elicitation of ACD when used on healthy skin, but when used on already compromised skin may provoke or maintain ACD [19]. This is in line with a study on 2500 patients with atopic dermatitis, which was shown to be a risk factor for becoming allergic to formaldehyde [22]. It is possible to recommend that cosmetics containing formaldehyde or formaldehyde releaser should not be used on damaged skin because of compromised barrier function and persons suffering from formaldehyde allergy should use cosmetics packaged in

glass but not plastic jars. At present, there are no available spot tests for the consumers to detect formaldehyde in the cosmetics.

The most prevalent preservative in our study was methylisothiazolinone or its mixture with methylchloroisothiazolinone (MCI/MI). MCI/MI or MI was declared in 20 (48%) products, and MI alone in 7 products, of which 6 of these were creams. This poses a high risk for sensitization to MI. In the past few years, the prevalence of contact allergy to MI and MCI/MI has increased worldwide [23,24]. According to a study in Denmark, the prevalence of MI and MCI/MI contact allergy increased significantly from 2010 to 2012, from 2.0% to 3.7% for MI (n=2766), and from 1.0% to 2.4% for MCI/MI (n=2802) [23]. In 5,881 consecutively tested dermatitis patients in Malmö, the contact allergy rate for MI varied between 0.5 and 6.5%, with a marked increase in recent years [25]. One of the main reasons for this is probably more frequent use of MI only and that legislation allows the use of much higher concentrations of MI than previously [26].

6 Conclusions

It could be difficult for patients allergic to formaldehyde to avoid contact with products containing it as its presence cannot be determined from the ingredient labelling with certainty. Our results are good concerning the labelling of formaldehyde or formaldehyde-releaser presence, as only in 1 product the labelling did not match the ingredient which also was too high according to law in EU. We found some products that were not clearly labelled as containing formaldehyde-releasers or formaldehyde that released very small amounts of formaldehyde. For an individual with a very strong contact allergy, this could pose a risk for aggravated dermatitis on already compromised skin. The CA method is a simple and reliable method for detecting formaldehyde in cosmetic products.

Conflict of interest statement: Authors state no conflict of interest

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