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Determination of formaldehyde, acetaldehyde and glutaraldehyde in cosmetics by high-performance liquid chromatography

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Abstract- In this article, we determined the aldehyde groups-formaldehyde, acetaldehyde and glutaldehyde-simultaneously by high performance liquid chromatography after simple ultrasound-assisted microextraction sample preparation. The method was validated by limit of detection, limit of quantification, linearity and recovery. The concentrations were: formaldehyde 1.977 mg/kg, acetaldehyde 6.840 mg/kg and glutaraldehyde 3.898 mg/kg in wet tissues and perfumes.
Key words: cosmetics, formaldehyde, acetaldehyde, glutaraldehyde, HPLC

I. INTRODUCTION

Formaldehyde is used in cosmetics as a common preservative and but this compound can cause allergy to skin as an irritant agent [1] and inwater-based formulations such as hand-wash, shampoo, conditioner, shower gel [2].
The sufficient addition of formaldehyde is necessary to ensure the preservation of product in the whole lifetime and its level of free formaldehyde must be low. Its use is regulated by the Korean ministry of food and drug safety, allowing a maximum concentration of 0.2%.
These days, formaldehyde-releasing preservatives in cosmetics are more common.
These preservatives areimethylolodimethyl(DMDM) hydantoin,quaternium-15, Imidazolidinyl urea, diazolidinyl urea, sodium hydroxymethylglycinate and benzylhemiformaletc[3].
Formaldehyde can be determined by the Korean official method based on the DNPH-extraction in cosmetics and high performance liquid chromatography. In European official method, the classical liquid-liquid extraction (LLE) and spectrophotometric detection were applied.
Several different analytical approaches have also been applied in the cosmetics for this purpose, including chromatography [4]-[6]. The typical sample preparation procedure is tedious and needs lots of solvents.
The new analytical methods were focus on simplification of sample pre-treatment [7].
As a result, the microextraction techniques have developed [8], even though samples were scanty.
Solid phase microextraction (SPME) has been applied for determining cosmetic samples with gas chromatography (GC) [9]-[12].
SPME has difficulties for quantitative results to determine the fragrances of cosmetics[9]. Topiwala and Rivero have determined formaldehyde by solid phase microextraction-gas chromatography-mass spectrometry (SPME-GC-MS) [10]and solid phase microextraction-isotope dilution-mass spectrometry(SPME-ID-MS) [13].
In both of them, formaldehyde was derivatized in situ to form2,4-dinitrophenylhydrazone that was adsorbed on the fiber. Single – drop microextraction (SDME) has used for minimization of LLE [14] but SDME is difficult to adopt the cosmetic analysis because of the complexity of the matrix.Therefore, the sample pretreatments were needed for SDME and SDME is only limited to the analysis of clean cosmetics [15, 16].Saraji and Mirmahdieh have recently used SDME-GC-MS for the analysis of parabens from water-based cosmetics such as makeup remover, mouthwash solutions and hair gels [17]. In this case, samples were needed the dilution with water from 100 to 1200 times before the sample extracts.
Among microextraction approaches, dispersive liquid-liquid microextraction (DLLME) has been applied to the different inorganic and organic analytes in water-based samples. However, DLLME has the difficulties to apply to cosmetics. Recently, the aqueous extracts from plants [18], fruits [19]-[21], honey [22], saliva[23], urine [24, 25] and serum [26] have been tried by DLLME. Besides,DLLME method can avoid difficulties with sample foaming problem so that analytes cannot transfer onto the fiber in SDME and SPME, respectively. DLLME can also allow the close contact between organic and aqueous phases, especially if the ultrasonic vibration is used [27]. The ultrasonic agitation speeds up the reaction between two phases and provides the efficient extraction [27]. Therefore, the ultrasound-assisted emulsification-microextraction is considered the good method to analyze the aldehyde group [28, 29].

In this article, we determined the aldehyde groups-formaldehyde, acetaldehyde, glutaldehyde- simultaneously by high performance liquid chromatography after ultrasound-assisted microextraction sample preparation. Here, we also discussedaldehyde groups about formaldehyde-releasing preservatives. Theeasy sample extraction procedure presented this paper could be applied for trace-level analysis of cosmetic products.

II. MATERIALS AND METHODS

2.1 Instrumentation

The Waters Alliance HPLC system (Waters, Milford, MA, USA) equipped with Waters photodiode array (PDA) was used for determination of formaldehyde, acetylaldehyde and glutaraldehyde in cosmetics. The wavelength was 360 nm and the peak was calculated with the Empower software system and all chromatograms were recorded. A 250 × 4.6 mm Capcell Pak C18 column with a 5μmdiameter was used.

2.2 Chemicals and reagents

Formaldehyde, acetaldehyde, glutaraldehyde, formaldehyde-DNPH, acetaldehyde-DNPH, glutaraldehyde-DNPH, 2,4-dinitrophenylhydrazine and acetonitrile were purchased from Sigma Aldrich.Ammonium acetate was obtained from Yakuri Pure Chemicals(Japan) and acetic acid was from Junsei Chemicals(Japan). Ultrapure water (18.2 MΩ) was used for the preparation of reagent and acquired from ElgaLabwater(UK).

2.3 Chromatographic conditions

The solvent system was a gradient of water (A) and Acetonitrile (B). The gradient condition was as follows:0 min: 50% A, 50% B; 10 min 50% A, 50% B; 12 min 10% A, 90% B; 18min 10% A, 90% B;25 min 50% A, 50% B. The flow rate was 1.0 mL/min. The injection volume was 10 µL. The column temperature was 40℃ and the analytes were detected by PDA detector. The identity of the 3 aldehydes was identified based on comparison of their spectrum with an authentic standard.

2.4 Sample preparation

Exactly 5 mLof cosmetic sample was weighted into a 20 mL headspace vial, after then 6 mL of 0.3% dinitrophenylhydrazine and 5 mL of acetate buffer were added. The vial then immersed in an ultrasonic bath at 40 ℃ for 60 min. The supernatants were subsequently filtered through a 0.2μmmembrane filter, and then the aliquots of the samples were injected into the column.

2.5 Validation procedure

Several experimental parameters such as LOD (limit of detection), LOQ (limit of quantification), linearity, recovery, stability and repeatability were evaluated for validation of this method. The calibration curves were applied with five different solutionsby the mean peak area according to concentration. For the recovery and precision of the method, a perfume and wet tissue not containing aldehydes were prepared.

III. RESULTS

3.1 Method validation

We presented a validated UPLC method for analysis of aldehyde group in cosmetics.

The linearity of three aldehydes was examined in the range of 0.702-15.625 mg/L. The correlation coefficients of the least-squares regression of the standard curves wereconsistently greater than 0.9999.As listed in Table 1, this method showed a good linearity to 3 aldehydes.

To determine the precision and recovery of this method, a perfume and wet tissue not containing aldehydes and 3 aldehyde stock solutions were prepared. Three different levels of aldehyde standards were added and then were tested five times. The recovery values ranged from 84.0% to 127.6% and RSD(relative standard deviation) values for the peak area and retention time were less than 10.1 %(Table 1). The limit of detection(LOD) is said as the smallest peak with a signal height which is three times that of the baseline. The LODs of 3 aldehydes were presented 0.04 for acetaldehyde, 0.02 for glutaraldehyde and 0.01 for formaldehyde. The LOQs were found 0.13 mg/kg for acetaldehyde, 0.05 for glutaraldehyde and 0.04 for formaldehyde.

The precision, accuracy, regression equation, correlation coefficients, LODsand LOQsof the determination of the aldehydes are summarized in Table 1.

3.2 Survey of aldehydes in wet tissues and perfumes

Table 2 shows the concentration of aldehydes: formaldehyde, acetaldehyde, glutaraldehyde. In 50 wet tissues, formaldehyde was detected average 2.299 mg/kg at 33 samples, acetaldehyde 5.051 mg/kg at 17 samples and glutaraldehyde 1.397 mg/kg at 13 samples.

In 20 perfumes, formaldehyde was average 1.447 mg/kg at 11 samples, acetaldehyde 8.360 mg/kg at all 20 samples andglutaraldehyde5.523 mg/kg at 18 samples.

Formaldehyde is prohibited in cosmetics in Korea but still found in commercial cosmetics. Somecountries still use formaldehyde as preservative. In Canada, there are different restrictions by product type and formaldehyde is not permitted in aerosol product. Health Canada permits the use of formaldehyde in non-aerosol cosmetics at concentrations of 0.2% or less, except in nail hardeners where the concentrations can be up to 5% and in oral products where concentrations limited to 0.1% or less.

In European Union, formaldehyde may be used at maximum concentration of 0.2% as free formaldehyde and is not permitted for use in aerosol products. USA, Twaiwan and Australia have no regulation about formaldehyde in cosmetics. The FDA in USA has indicated that formaldehyde can be used in nail hardener products.

In this study, formaldehyde did not exceed the established limits,20mg/kg wet tissue and 2000 mg/kg perfumes. Although present at levels not normally considered harmful, they are known to cause allergic contact dermatitis in certain sensitized individuals[30].

As known formaldehyde releasers-quaternium-15, imethylolodimethyl(DMDM) hydantoin, imidazolidinyl urea, diazolidinyl urea, 2-bromo-2-nitropropane-1,3-diol(bronopol) etc.[3], we investigated all labels of 70 samples. All samples didn't have the formaldehyde releasing preservatives, but 44 samples were detected the formaldehyde. We can consume that formaldehyde might generate by the carbon or methan from the ingredients of cosmetics[31].

Acetylaldehyde occurs widely in nature and being produced on a large scale in industry. It is found naturally in coffee, bread and ripe fruit [32] and is produced by plants.

In Korea, there is no regulation for acetaldehyde in cosmetics. However, acetaldehyde was found at 37 samples.Acetaldehyde can be produced by the partial oxidation of ethanol [33] and is known to the byproduct of ethanol. Wet tissues usually use the ethanol as a gradient and ethanol was the main ingredient in perfumes. Therefore, acetaldehyde was detected in all perfumes and 17 wet tissues. One of perfumes showed high concentration up to 44.819 mg/kg.

Glutaraldehyde, also called glutaral, occurs as a colorless liquid in its pure form and known as a disinfectant, preservative and medication and used to sterilize surgical instruments and hospitals [34]. In cosmetics, as a preservative,glutaraldehyde is used in the formulation of bath products, cleansing products, hair conditioners and other hair products but prohibited in aerosol and spray products.Glutaraldehyde prevents or retards bacterial growth, and thus protects cosmetics and personal care products from spoilage[34].

In Korea, glutaraldehyde is limited as the maximum concentration of 0.1% and banned in sprays and aerosols in cosmetics. Most of countries have the same restriction of our country.Glutaraldehyde wasdetected in 31 samplesand up to 15.087 mg/kg. All samples were found under the limits of 0.1%.

IV. CONCLUSIONS

The determination of aldehyde group in wet tissues and perfumes was carried out by HPLC. Formaldehyde, acetaldehyde and glutaraldehyde were analyzed after simple ultrasonic-assisted microextration and the methods were validated. The sample preparation in this study is targeted for simple, easy, reliable and efficient method for aldehyde group in cosmetics. Formaldehyde was all under the limit of korea-20mg/kg in wet tissues and 2000 mg/kg in perfumes. Acetaldehyde has no regulations in Korea, but still existed in cosmetics. The results from this study could help the formaldehyde determination method in Korea, and offer the method of acetaldehyde and glutaraldehyde.

V. REFERENCES

[1] Aalto-Korte K, Kuuliala O, Suuronen K,Alanko K. "Occupational contact allergy to formaldehyde and formaldehyde releasers". Contact Dermatitis.Vol.59, no. 5, pp. 280-289, 2008.

[2] Salvador A, Chisvert A. "Analysis of cosmetic products, 1st edition". Elsevier Science.2007.

[3] SCCNFP/586/02, final. The Scientific committee on cosmetic products and non-food products intended for consumers. Opinion concerning the determination of certain formaldehyde releases in cosmetic products.

[4] Heyden Y.V, Nguyet A.N.M, Detaevernier M.R, Massart D.L, and Plaizier-Vercammen J. "Simultaneous determination of ketoconazole and formaldehyde in a shampoo: liquid chromatography method development and validation". J.Chromatogr.Avol. 958, no. 2, pp. 191-201,2002.

[5] Wu P.W, Chang C.C, and Chou S.S. Determination of formaldehyde in cosmetics by HPLC method and acetylacetone method.J.Food Drug Anal.vol.11, no. 1, pp. 8-15, 2003.

[6] Nguyet A.N.M, Tallieu L, Plaizier-Vercammen J, Massart D.L, and Heyden Y.V. "Validation of an HPLC method on short columns to assay ketoconazole and formaldehyde in shampoo". J.Pharm.Biomed.Anal. vol.32,pp. 1-19, 2003.
[7] Rios A, Escarpa A, Gonzalez M.C,Crevillen A.G. "Challenges of analytical microsystems". TrAC-Trends Anal.Chem.vol.25, no. 5,pp. 467-479. 2006.
[8] Pena-Pereira F, Lavilla I, Bendicho C,"Miniaturized preconcentration methods based on liquid-liquid extraction and their application in inorganic ultratrace analysis and speciation: A review". Spectroc.Acta B: Atom.Spectr. vol.64, no. 1, pp. 1-15. 2009.
[9] Offant J, Arzouyan C, Ollivier B,Lesgards G,Annales des Falsifications de l'ExpertiseChimique et Toxicologique 95, (2002). 41.
[10] RiveroR.T, and Topiwala. V,"Quantitive determination of formaldehyde in cosmetics using combined headspace-solid-phase micreextraction-gas chromatography".J.Cosmet.Sci. vol. 55, no. 4,pp. 343-350, 2004.
[11] Fuh C.B, Lai M, Tsai H.Y, Chang C.M,"Impurity analysis of 1,4-dioxane in nonionic surfactants and cosmetics using headspace solid-phase microextraction coupled with gas chromatography and gas chromatography-mass spectrometry". J.Chromatogr.Avol.1071,pp. 141-145, 2005.
[12] Tsai T.F and Lee.M.R,"Determination of antioxidants and preservatives in cosmetics by SPME combined with GC-MS". Chromatographiavol.67, no. 5-6, pp. 425-431. 2008.
[13] Rivero R.T and Topiwala V,"Quantitative determination of formaldehyde in cosmetics using a combined solid-phase microextraction-isotope dilution mass spectrometry method".J.Chromatogr.Avol.1029, no. 1-2, pp. 217-222. 2004.
[14] Pena-Pereira F, Lavilla I,Bendicho C,"Liquid-phase microextraction approaches combined with atomic detection". Anal.Chim.Actavol.669,no.1-2, pp. 1-16, 2010.
[15] Ma J.J, Du X, Zhang J.W, Li J.C, Wang L.Z,"Ultrasound-assisted emulsification-microextraction combined with flame atomic absorption spectrometry for determination of trace cadmium in water samples".Talantavol.80, no. 2,pp.980-984. 2009.
[16] Pena-Pereira F, Senra-Ferreiro S, Lavilla I,Bendicho C,"Determination of iodate in waters by cuvetteless UV-vismicrospectrophotometry after liquid-phase microextracion". Talantavol.81,no.1-2, pp. 625-629. 2010.
[17] Saraji M and Mirmahdieh S,"Single-drop microextraction followed by in-syringe derivatization and GC-MS detection for the determination of parabens in water and cosmetic products". J.Sep.Sci. vol. 32, no.7, pp. 988-995. 2009.
[18] Lu Q, Chen L, Lu M, Chen G, Zhang L, "Extraction and analysis of auxins in plants using dispersive liquid-liquid microextraction followed by high-performance liquid chromatography with fluorescence detection". J.Agric.Food Chem. Vol.58, no.5, pp.2763-2770, 2010.
[19] Zhao E, Zhao W, Han L, Jiang S, Zhou Z, "Application of dispersive liquid-liquid microextraction for the analysis of organophosphorus pesticides in watermelon and cucumber. J.Chromatogr.Avol.1175, no.1, pp.137-140. 2007.
[20] Ravelo-Perez L.M, Hernarndez-Borges J, Asensio-Ramos M, Rodriguez-Delgado M.A,"Ionic liquid based dispersive liquid-liquid microextraction for the extraction of pesticides from bananas". J.Chromatogr.Avol.1216, no.43, pp.7366-7345. 2009.
[21] Zhang S., Li C., Song S., Feng T., Wang C. and Wang Z. Application of dispersive liquid-liquid microextraction combined with sweeping micellarelectrokinetic chromatography for trace analysis of six carbamate pesticides in apples. Anal.Methodsvol.2, no.1, pp. 54-62. 2010.
[22] Chen H, Chen H, Ying J, Huang J,Liao L,"Dispersive liquid-liquid microextraction followed by high-performance liquid chromatography as an efficient and sensitive technique for simultaneous determination of chloramphenicol and thiamphenicol in honey". Anal.Chim.Actavol.632, no.1,pp. 80-85.2009.
[23] Beron P, Martinis E.M,Wuilloud R.G,"Development of an on-line temperature-assisted ionic liquid dispersive microextraction system for sensitive determination of vanadium in environmental and biological samples". J.Hazard.Mater. vol.176, no. 1, pp721-728. 2010.
[24] Melwanki M.B, Chen W.S,Bai H.Y, Lin T.Y, Fuh M.R,"Determination of 7-aminoflunitrazepam in urine by dispersive liquid-liquid microextraction with liquid chromatography-electrospray-tandem mass spectrometry". Talantavol.78, no. 2, pp. 618-622. 2009.
[25] Xiong C, Ruan J, Cai Y, Tang Y,"Extration and determination of some psychotropic drugs in urine samples using dispersive liquid-liquid microextraction followed by high-performance liquid chromatography". J.Pharm.Biomed.Anal. vol.49, no.2,pp. 572-578. 2009.
[26] Lili L, Xu H, Song D, Cui Y, Hu S, Zhang G,"Analysis of volatile aldehyde biomarkers in human blood by derivatization and dispersive liquid-liquid microextraction based on solidification of floating organic droplet method by high performance liquid chromatography". J.Chromtogr.Avol. 1217, no.16, pp. 2365-2370, 2010.
[27] Rezaee M, Yamini Y,Faraji M,"Evolution of dispersive liquid-liquid microextraction method". J.Chromatogr.Avol.1217, no.16,pp. 2342-2357, 2010.
[28] Regueiro J, LlomartM, Garcia-Jares C, Garcia-Monteagudo J.C, Cela R,"Ultrasound-assisted emulsification-microextraction of emergent contaminants and pesticides in environmental waters". J.Chromatogr.Avol.1190, no.1,pp. 27-38, 2008.
[29] Fontana A.R, Wuilloud R.G, Martinez L.D,Altamirano J.C,"Simple approach based on ultrasound-assisted emulsification-microextration for determination of polibrominated flame retardants in water samples by gas chromatography-mass spectrometry". J.Chromatogr.Avol. 1216, no.1, pp. 147-153, 2009.
[30] Anton C. de Groot, White I.R, Mari-Ann F, Gerda L, Pieter-Jan C,"Formaldehyde-releasers in cosmetics: relationship to formaldehyde contact allergy". Contact Dermatitis.vol.62, no. 1,pp. 2-17, 2010.
[31] European Food Safety Authority (EFSA),"Endogenous formaldehyde turnover in humans compared with exogenous contribution from food sources". EFSA J. vol. 12, pp. 3550. 2014.
[32] Miyake T, Shibamoto T,"Quantitative analysis of acetaldehyde in foods and beverages". J.Agric. Food Chem. vol.41, pp.1968-1970, 1993.
[33] Liu S.Q,Pilone G.J,"An overview of formation and roles of acetaldehyde in winemaking with emphasis on microbiological implication".Int. J. Food Sci. Technol. vol.35, no.1, 49-61, 2000.
[34] Speer D.P, Chvapil M, Eskelson C.D, Ulreich J,"Biological effects of residual glutaraldehyde in glutaraldehyde-tanned collagen biomaterials". J. Biomed Mater Res A. vol.14, no.6, pp.753-764, 1980.

Table l. Relavant regression result for the calibration graph, detection limit, repeatability and decision for determination of aldehydes

matrix	No.	Aldehyde	Added (mg/kg)	Recovery (%)	RSDa % (nd=5)	LODb (mg/kg)	LOQc (mg/kg)	Regression Equation	Correlation coefficient
Perfume	1	Acetaldehyde	1	95.6	10.1	0.04	0.13	D=69400*C + 12100	0.9999
			5	120.5	5.2				
			10	110.3	2.7				
	2	Glutaraldehyde	1	110.5	3.0	0.02	0.05	D=97800*C - 21100	0.9999
			5	110.8	4.3				
			10	112.5	2.6				
	3	Formaldehyde	1	110.8	3.4	0.01	0.04	D=172000*C -16100	0.9999
			5	118.1	2.6				
			10	115.3	5.9				
Wet tissues	1	Acetaldehyde	1	108.0	2.3	0.04	0.13	D=69400*C + 12100	0.9999
			5	105.6	2.5				
			10	104.3	1.3				
	2	Glutaraldehyde	1	109.3	2.1	0.02	0.05	D=97800*C - 21100	0.9999
			5	107.6	2.6				
			10	111	2.8				
	3	Formaldehyde	1	109.2	2.1	0.01	0.04	D=172000*C -16100	0.9999
			5	111.4	5.2				
			10	121.3	4.4				

aRelative Standard Deviation.

bLimit of detection ; cLimit of qualification

C, Concentration(mg/kg) ; D, Sample area ; nd, Repeatability

Table Ⅱ. Concentrations(mg/kg) of aldehydes

		Concentration(mg/kg)		
Type	Number	Formaldehyde	Acetaldehyde	Glutaraldehyde
Wet tissues	50	2.299(1.935~2.998)	5.051(3.095~7.816)	1.397(1.096~2.301)
Perfumes	20	1.447(0~4.044)	8.360(3.346~44.816)	5.523(0~15.087)
Total	70	1.977(0~4.044)	6.840(3.095~44.816)	3.898(0~15.087)