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Identification of Key Odorants in Used Disposable Absorbent Incontinence Products

Gunnar Hall ◆ Susanne Alenljung ◆ Ulla Forsgren-Brusk

ABSTRACT

PURPOSE: The purpose of this study was to identify key odorants in used disposable absorbent incontinence products.

DESIGN: Descriptive in vitro study

SUBJECTS AND SETTING: Samples of used incontinence products were collected from 8 residents with urinary incontinence living in geriatric nursing homes in the Gothenburg area of Sweden. Products were chosen from a larger set of products that had previously been characterized by descriptive odor analysis.

METHODS: Pieces of the used incontinence products were cut from the wet area, placed in glass bottles, and kept frozen until dynamic headspace sampling of volatile compounds was completed. Gas chromatography–olfactometry was used to identify which compounds contributed most to the odors in the samples. Compounds were identified by gas chromatography–mass spectrometry.

RESULTS: Twenty-eight volatiles were found to be key odorants in the used incontinence products. Twenty-six were successfully identified. They belonged to the following classes of chemical compounds: aldehydes (6); amines (1); aromatics (3); isothiocyanates (1); heterocyclics (2); ketones (6); sulfur compounds (6); and terpenes (1).

CONCLUSION: Nine of the 28 key odorants were considered to be of particular importance to the odor of the used incontinence products: 3-methylbutanal, trimethylamine, cresol, guaiacol, 4,5-dimethylthiazole-S-oxide, diacetyl, dimethyl trisulfide, 5-methylthio-4-penten-2-ol, and an unidentified compound.

KEYWORDS: Dynamic headspace sampling, GC–MS, GC–olfactometry, Incontinence pad, Incontinence product, Key odorant, Odor.

INTRODUCTION

Urinary incontinence (UI) is defined by the International Continence Society as any complaint of involuntary urine loss.¹ It is estimated that about 400 million persons worldwide are affected by UI²; incontinence is strongly related to aging.^{3,4} Although UI can be managed in various ways, the use of disposable absorbent incontinence products is common. Desirable characteristics of absorptive products are the ability to absorb urine without leaking (loss of containment) and the ability to reduce or eliminate odors.^{5,6} Fear that such odors can

be perceived by others exerts negative psychosocial effect on persons with incontinence.⁷

Most natural odors are caused by a mixture of volatile compounds.^{8,9} These compounds have a wide range of chemical structures present in variable concentrations, resulting in different odor characteristics. There are 3 main approaches in odor research: (1) sensory methods for studying how odors of various objects are perceived by humans; (2) instrumental methods to analyze the contents of volatile compounds; and (3) a combination of sensory and instrumental methods to find out which volatile compounds cause the odor of a particular object. The study presented in this article uses the combined approach.

Humans perceive odor when odorous compounds are emitted into the air and reach the nose. The composition of volatile compounds in the air (usually called the headspace) determines the character of the odors. One particular challenge in odor studies is to find an object's "key odorants," the compounds that are the main contributors to the odor. The most common technique for identifying key odorants is gas chromatography–olfactometry (GC–O), which was originally developed to study fragrances and food aromas. In GC–O, human assessors sniff at the effluent from the GC column.¹⁰ Volatile compounds that in the GC–O-analysis give rise to strong and characteristic odors make stronger contributions to an object's odor than compounds with weak and noncharacteristic odors. This is especially true if the volatile compounds are sampled by a headspace technique in which the sample

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This work was financially supported by SCA Hygiene Products AB, where Susanne Alenljung and Ulla Forsgren-Brusk are employed. SP Technical Research Institute of Sweden, where Gunnar Hall is employed, regularly carries out consultancy and analysis assignments for SCA Hygiene Products AB.

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DOI: 10.1097/WON.0000000000000325

reflects the composition of the air that humans inhale when the odor of the object is perceived.

Development of these analytical techniques provides a basis for analysis of urinary volatiles present within an organism, cell, or tissue¹¹ and for diagnostic purposes.¹² Although the volatile compounds emitted from urine have been investigated in several studies,¹³ research focusing on the odor potential of various urinary volatiles via the GC–O technique is sparse. The initial studies in this field have used various extraction and distillation techniques to collect and enrich urinary volatiles.^{14,15} Unfortunately this approach creates a somewhat-biased picture of what volatile compounds cause odor in urine.

The odor produced when an incontinence product is used is caused by more than the odorous compounds in urine alone. During use, an incontinence product comes into close contact with the urogenital area that contains varying levels of perspiration, cutaneous microflora, vaginal or urethral discharge, and possible fecal materials. Over time, volatile compounds can be generated via bacterial metabolism and/or a variety of chemical and enzymatic reactions. In a recent study of odorants released from used incontinence products, various volatile compounds were found.¹⁶ Five (acetaldehyde, butanal, 3-methylbutanal, methanethiol, and hydrogen sulfide) exceeded odor detection thresholds found in the literature and were therefore considered to contribute most to the odor. The aim of this study was to identify, using GC–O, the key odorants in used disposable, absorbent incontinence products. The study was part of a larger project in which the odors of used incontinence products were characterized by descriptive odor analysis.¹⁷

MATERIALS AND METHODS

Used incontinence products were collected from residents at geriatric nursing homes in the Gothenburg area of Sweden. The personnel were asked to collect products with noticeable odor from residents who frequently had odorous products. Thus, products with no odor or very faint odor were not sampled. No data on medications and medical diagnoses were collected.

Sample collection procedures were completed by the Swedish market research institute (ScandInfo, Goteborg, Sweden) in accordance with Swedish data privacy legislation (the Swedish Personal Data Act 1998) and the ICC/ESOMAR (International Code on Market and Social Research) in order to ensure the residents' privacy. This type of study, under Swedish Legislation, does not require review or approval by a Regional Ethical Review Board. The study did not involve any humans, only collection of used products. There was no direct contact between ScandInfo's personnel and the residents. The nursing homes' Local Authority Senior Medicine Advisor and the nursing home managers have reviewed and approved the study.

Used incontinence products, one from each resident, were collected either at night or in the morning (wearing time 5–13 h). Each resident used her or his ordinary incontinence product (5 TENA [Stockholm Sweden], 2 Abri-San, 1 Abri-Wing [Aabenraa Denmark]). The products had no added odor control function, according to the package. Products containing fecal materials were excluded. Collected products were wrapped in plastic bags by the personnel, placed in insulated bags with ice packs, and transported to SCA's Gothenburg

laboratory. No specific instructions were given to the personnel regarding sample handling.

Rectangular pieces (1 cm × 10 cm) were cut from the wet part of the incontinence products and placed in 500-mL glass bottles (Sovirel, France) with Teflon-lined lids; 2 pieces in each bottle and a set with 10 to 12 bottles for each product. A bottle containing incontinence product pieces is hereafter referred to as a sample. A used incontinence product is hereafter referred to as a product.

The samples were immediately placed in insulated bags with ice packs and transported to SP Food and Bioscience's Gothenburg laboratory. They were rapidly frozen with carbon dioxide ice and kept frozen (−40°C) for 3 to 4 months before analysis. The storage at this extra-low temperature was based on the outcomes of a prestudy in which no or only minor (from an odor point of view) noticeable changes were seen in the patterns of volatile, and potentially odorous, compounds in used incontinence products stored at −40°C for 4 months.

Unused incontinence products, from the packages that the used products had come from, were also collected for use as reference (control) samples. They were soaked with a 0.9% NaCl solution (400–600 mL, depending on absorption capacity of the product). After 30 minutes, they were cut and treated in the same way as the used products.

This study included products from 8 residents (7 females, 1 male; aged 64–90 years) selected from 14 products (designated S1–S14) that had previously been characterized by descriptive odor analysis.¹⁷ The 8 products in this study were selected to cover as wide a variation in odor characteristics as possible, based on the results from the sensory characterization.¹⁷ The same product designations (Sx) as used in the sensory study were used. The references to the used products were designated R-Sx. No used products were examined for microbial content.

Study Procedures

The headspace sampling of volatile compounds was done using a modification of an established method.¹⁸ The glass bottles used for frozen storage of the samples were also used as headspace sampling vessels. The frozen samples were thawed overnight in a refrigerator and then kept at room temperature for approximately 1 hour. The lids were then replaced by special headspace sampling adapters and the bottles were temperature-equilibrated in a water bath (+35°C) for 30 minutes. The inlet of the sampling vessel was connected to a gas supply system that delivered helium at a fixed flow rate. The outlet was connected to a sampling cartridge filled with the adsorbent Tenax TA 60/80 (Grace Discovery Science, Deerfield, Illinois). Figure 1 shows a headspace sampling flask fitted with a headspace sampling adapter. The volume of sampled gas was 1000 mL (gas flow rate: 20 mL/min; sampling time: 50 minutes).

The GC–O and GC–mass spectrometry (MS) analysis system consisted of a Trace 2000 GC and an Automass Solo MS (Thermo Quest, Milan, Italy) combined with an ATD 400 thermal desorption unit (Perkin Elmer, Beaconsfield, UK). The GC was supplied with a 30 m × 0.32 mm DB-5 column (J&W, Agilent Technologies Folsom, CA). A Y-shaped nozzle, placed after the column, split the carrier gas flow between the flame ionization detector (FID) and MS, and the FID and the sniffing port used in the GC–O analysis. To reduce the amount of injected water, the Tenax cartridges were dried by

Figure 1. Flask for headspace sampling equipped with an adapter to which a cartridge with adsorbent is connected.

passing 400 mL of dry helium through them at room temperature. Volatile compounds were desorbed at 250°C for 5 minutes. The carrier gas was helium (3 mL/min) and the temperature program was 30°C to 220°C at 4°C/min, with 2

minutes' initial and 10 minutes' final holding times. The system's Xcalibur program, supplied with the NIST library for MS identification, was used for storage and treatment of the data. In the GC–O configuration, make-up gas (air, 50 mL/min) was added to that part (about 80%) of the carrier gas that was passed through a heated (170°C) transfer line to the sniffing port where the carrier gas was mixed with humidified air (100 mL/min). An outline of the system for GC–O analysis is shown in Figure 2.

Two experienced assessors carried out the sniff analysis. As the chromatographic analysis proceeded, they recorded their odor observations on an FID chromatogram printed on an analog recorder. Odor intensities were assessed on a scale where 0 indicated “no perceived odor” to 5, which indicated “very strong odor.” The assessors were instructed to, as far as possible, characterize the odors they perceived in their own words. Each GC–O analysis was divided into three 20-minute sniffing sessions. For each product, as well as for its reference, duplicate GC–O analyses were carried out. In the first analysis, one assessor was sniffing during the first and third sessions and the other assessor was sniffing during the second session. In the second analysis, the sniffing order was shifted between the assessors.

RESULTS

Outcomes of the GC–O and the GC–MS analyses are summarized in Table 1. The odor intensity observations on each used product (Sx) are displayed in the column next to the observations for its corresponding reference product (R-Sx).

Based on the GC–O analysis, 28 volatile compounds in this study were defined as key odorants. Key odorant profiles varied between the studied products; the number of key odorants

Figure 2. Gas chromatography (GC)–olfactometry of effluent from the GC column.

TABLE 1. Chemical Identities of Key Odorants and Their Perceived Odor Intensities and Odor Characteristics in Used (S) and Unused (R) Incontinence Products

Retention Time, min	Compound (MS Identification)	Odor Intensity ^a													Odor Description (During 1 or More GC–O Analyses)			
		S2	R-S2	S3	R-S3	S6	R-S6	S7	R-S7	S8	R-S8	S9	R-S9	S11		R-S11	S13	R-S13
Aldehydes																		
5.9	3-Methylbutanal	ms		vw	w	vw	S	vw		ms		vw	vw	S	vw	w	w	Sweat, cheese, green, vomit, burnt
6.2	2-Methylbutanal			ms		ms			vw					ms				Sour, cheese, milky
7.2	Pentanal	w		vw	w	w		ms	vw	w	w	vw	vw	vw			w	Solvent, wood, butter
11.1	Hexanal	ms	ms	w	ms	w	ms	ms	w	w	ms	w	ms	w	ms	w	ms	Green, flower, apple, fruit
19.6	Octanal	ms	ms	ms	ms	ms	ms	ms	w	w	S	ms	ms	ms	ms	ms	ms	Fatty, washing, sloe bug, metal
23.6	Nonanal	ms	ms	ms	ms	S	ms	ms	ms	ms	ms	S		ms	ms	ms	ms	Fatty, washing, citrus
Amines																		
2.4	Trimethylamine					S												Stockfish, dry fish
Aromatic compounds																		
21.4	2-Phenylethanol					ms		ms	ms									Flower, ether, washing, leather
22.3	Cresol (isomers)			S		S												Urine, urinal, stable, tar
23.0	Guaiacol			S														Smoked, earth
Heterocyclic compounds																		
18.5	4,5-Dimethylthiazole-S-oxide						S								S			Pungent, onion
20.3	Benzoxazole			ms														Almond, washing, ether
Ketones																		
4.2	Diacetyl (2,3-butanedione)	ms	w	ms	vw	w	ms	S	w	ms	ms	w	ms	w	w	w	ms	Butter
10.4	2,4-Pentanedione	ms	ms			w	w	w	vw		vw			vw				Musty, plastic, sour, vomit, washing
14.1	2,3-Hexanedione	w		w		w	w	w		vw		vw	vw	vw		w		Sour, plastic, varnish, musty
6.8	2-Pentanone	w				vw	w	vw		vw	vw							Musty, cocoa powder
14.8	2-Heptanone					ms							vw			ms		Bread, roasted, good
18.8	6-Methyl-5-hepten-2-one	w	w	vw	vw	ms	ms	w	vw	ms	w	w	ms	w	w	w	w	Mushroom, onion
Sulfur compounds																		
2.3	Methanethiol	ms						ms								w		Cabbage, feces, rotten
3.0	Dimethyl sulfide					ms		w								ms		Egg, sweet, butter
8.9	Dimethyl disulfide	w		w		ms		vw		vw		w	w	w		ms		Garlic, feces, nasty, musty

(continues)

TABLE 1. Chemical Identities of Key Odorants and Their Perceived Odor Intensities and Odor Characteristics in Used (S) and Unused (R) Incontinence Products (*Continued*)

Retention Time, min	Compound (MS Identification)	Odor Intensity ^a															Odor Description (During 1 or More GC–O Analyses)	
		S2	R-S2	S3	R-S3	S6	R-S6	S7	R-S7	S8	R-S8	S9	R-S9	S11	R-S11	S13		R-S13
18.3	Dimethyl trisulfide	S	vw	S	ms	VS		S		S		S	ms	S		S	ms	Rubber, stinky, feces, garlic, nasty
16.6	Methyl propyl disulfide					ms			vw					w	vw			Nuts
20.0	5-Methylthio-4-penten-2-ol							S								ms		Rubber, garlic
Various compounds																		
14.4	Allyl isothiocyanate	w		ms		w				w								Garlic, rubber, musty
16.7	Pinene (most likely β-isomer)	w	w		vw	w	w	w	w	w	w	w	vw	w	ms		w	Wood, solvent, washing
16.3	Unidentified 1	w		w		S	S	S	S	S	w	w	w	w		S	vw	Roasted, popcorn, nuts, burnt, milk
18.6	Unidentified 2	ms	ms	ms	w	S	w		w	ms	vw	ms	w	ms	ms			Mushroom, garlic

Abbreviations: empty box, no odor; GC–O, gas chromatography–olfactometry; MS, mass spectrometry; vw, very weak; w, weak; ms, medium strong; S, strong; VS, very strong.
^aThe highest intensity of each of the odor observations is reported.

varied between 15 and 23 in each used product and between 7 and 11 in the reference products. Most key odorants could be identified by MS and belonged to the following classes of compounds, in alphabetical order and giving the number of compounds in parentheses: aldehydes (6); amines (1); aromatics (3); isothiocyanates (1); heterocyclics (2); ketones (6); sulfur compounds (6); and terpenes (1). Two compounds could not be identified, as they were present at very low concentrations; nevertheless, the odors omitted from these were perceptible. This is a common finding in odor research and illustrates the sensitivity and usefulness of the nose as detector in the GC–O technique.

Of the 28 compounds defined as key odorants, 11 were judged to be strong or very strong in at least 1 used product. These compounds were (from top to bottom in Table 1) 3-methylbutanal, nonanal, trimethylamine (TMA), cresol, guaiacol, 4,5-dimethylthiazole-*S*-oxide, diacetyl, dimethyl trisulfide (DMTS), 5-methylthio-4-penten-2-ol, and 2 unidentified compounds.

DISCUSSION

It has previously been shown that the odors of used incontinence products vary both in character and in intensity,¹⁷ indicating a complex odor chemistry. As expected, the present study confirms that used incontinence products emit large numbers of volatile compounds of different classes. This is exemplified in Figure 3, which presents gas chromatograms obtained when analyzing headspace samples of volatile compounds emitted from 2 used incontinence products. Each peak was caused by at least one compound; this finding indicates that the products contained, and emitted, several hundred volatile compounds. In this study, only compounds of importance, according to the GC–O analysis, were identified. Some compounds of potential importance may remain undetected in the analysis, as either they were not adsorbed by Tenax TA or do not chromatograph well on a DB-5 column. Examples of such compounds are ammonia and carboxylic acids.

Some of the key odorants were perceived with similar GC–O intensities in the used and reference incontinence products. This was the case for straight chain aldehydes and β -pinene, for example. Straight chain aldehydes are usually described as secondary lipid oxidation products and are commonly found in various wood-based materials. Also, terpenes are common contributors to the odors of wood-based materials. It is likely that these compounds primarily originated from the incontinence product itself, and not from the use of the product. All disposable absorbent incontinence products have an intrinsic odor from their constituent materials, which is more easily released when the product is wetted. The incontinence product materials contribute with a background odor that is nonspecific for different patient groups. By carefully selecting the materials, the background odor may be reduced.

The odor intensity of 3-methylbutanal was medium strong to strong in most used incontinence products. Its odor was described as sweat, cheese, vomit, as well as green, and burnt. 3-Methylbutanal was perceived also in reference products, but only at low intensity. Its isomer, 2-methylbutanal, was also perceived, although generally at lower intensities compared to 3-methylbutanal. One possible source of 2- and 3-methylbutanal in used incontinence products is urine, as these compounds can sometimes be found in headspace samples of urine.^{13,16} Another possible source is microbial metabolism.^{19,21}

Figure 3. Examples of chromatograms of headspace sampled volatile compounds in 2 used products.

During use, the products will come in close contact with the urogenital area containing microflora. The urine itself may also contain bacteria since the prevalence of bacteriuria is very high in institutionalized populations.²² In this study, no urine samples from residents were collected; thus, no data on bacteriuria are available.

As previously mentioned, straight chain aldehydes seemed to originate mainly from the materials in the reference product. Still, nonanal was perceived as strong in 2 of the used products, but not in their corresponding reference. A consultation of the GC chromatograms (unpublished data), however, showed that nonanal was probably derived from the product itself, rather than from the use of the product.

A strong TMA odor, with a typically fishy character, was perceived in one of the used incontinence products. Trimethylamine in the body generally has dietary origin and is mainly removed from the body, via the urine, as nonodorous trimethylamine-*N*-oxide. Studies have demonstrated that trimethylamine-*N*-oxide can be reduced to TMA by *Escherichia coli*^{23,24} and that several uropathogens can produce TMA.^{19,25} An underlying cause of TMA in urine can also be

the rare metabolic condition trimethylaminuria, which leads to an excess of TMA in the body.²⁶

In some of the used incontinence products, the phenolic compounds cresol (unidentified isomer) and guaiacol were perceived at medium strong to strong intensities. Normally, urine contains very little free cresol.^{27,28} The para isomer of cresol is actually produced in the body, by bacterial degradation of tyrosine in the intestines,^{29,30} but is mainly excreted in the urine in conjugated, nonodorous forms.^{27,28} *p*-Cresol is known to have a horse stable-like, fecal odor,³¹ and is considered to be one of the main contributors to the odor of pig farms.³² Cresol in this study was associated with urine, urinal, stable, and tar. Guaiacol was described as having a smoked, earthy odor character. Guaiacol is likewise believed to be excreted in the urine, mainly in a conjugated form.³³ The conjugates can be hydrolyzed by enzymes found in bacteria and feces.^{28,33-35} When these enzymes are present and active in used incontinence products, free odorous *p*-cresol and guaiacol may be released. It is also possible that *p*-cresol and guaiacol are generated by bacteria during the use of an incontinence product, as bacteria can produce both compounds in urine.¹⁴

Diacetyl was detected in all incontinence products, both used and unused, although the perceived odor intensities were generally higher in the used products. This compound has a characteristic buttery odor and is a common constituent of various natural systems, as well as food and beverages. Diacetyl can also sometimes be found in urine.¹³ In addition, diacetyl is produced by several *Lactobacillus* species found in the female urogenital area³⁶ and also by some pathogens.^{21,37}

Dimethyl trisulfide is considered to be of very high importance for the odor of used incontinence products, as its odor was perceived as strong or very strong in all tested, used products. No other compound was perceived with such high intensities, and as frequently, as DMTS. The GC–O assessors described DMTS as stinky, rubbery, fecal, garlicky, and nasty. This compound has been associated with livestock, and with flavors and off-flavors in food and beverages.^{38,39} Apart from DMTS, various mono- and disulfides were also perceived in the used incontinence products, although at lower intensities. Many of these sulfur compounds can be found in urine samples,^{16,40} although mostly at low concentrations.^{16,41} Sulfur compounds are also generated by a number of common uropathogens.^{19,20,42}

5-Methylthio-4-penten-2-ol and 4,5-dimethylthiazole-S-oxide were assessed as strong and medium strong in 2 of the used products. According to the GC–O assessors, the odor of 5-methylthio-4-penten-2-ol had a rubbery, garlicky character, and the odor of 4,5-dimethylthiazole-S-oxide was pungent, with an onion character. Little information is available about these compounds, but origins from food and medicines might be considered.^{43,44}

The odor character of one of the unidentified compounds (unidentified 1) was described as roasted, popcorn, nuts, burnt, milk. This compound was perceived as strong in 3 of the used products, with almost no odor contribution from the product itself.

The other unidentified compound (unidentified 2), with an odor character of mushroom and garlic, was likely derived largely from the product itself. Although the odor intensity of this compound was strong in one of the used products, the overall GC–O results indicate that the product itself emitted this compound, and that there was little or no contribution from the use of the product.

Of the odorants discussed earlier, 9 can be considered to be of particular importance. These odorants were perceived as strong in 1 or more of the used incontinence products, and they originated fully or partially from the use of the product. They were 3-methylbutanal, TMA, cresol, guaiaicol, 4,5-dimethylthiazole-S-oxide, diacetyl, DMTS, 5-methylthio-4-penten-2-ol, and one of the unidentified odorants (unidentified 1).

For most of these key odorants of particular importance, there is clearly more than one possible origin of the odor. Many of these odorants can normally be found in the human body, as metabolites of human tissue or as metabolites of bacteria in the intestines. The odorants formed in the body can often also be detected in urine, although some of them are conjugated into nonodorous forms before excretion. Another possible cause of odor is bacteria present in the urine and the urogenital area, such as uropathogens and the normal urogenital microflora. The presence of bacteria in urine, that is, bacteriuria, is associated with UI,^{45,46} and the prevalence of bacteriuria is particularly high among elderly people at nursing homes.^{47,48} Many bacteria species often present in urine can potentially generate a number of odorants,^{14,19,42} including most of the odorants identified in this study to be of partic-

ular importance in the odor of used incontinence products. Besides being of urinary and bacterial origin, some odorants may also be the result of chemical and enzymatic reactions in the products during use. Odorants may also derive from body liquids other than urine, such as perspiration and vaginal or urethral discharges. Gender-specific differences in odorant content have not been investigated in this study as only 1 male resident was included, and further studies are needed for possible differences to be revealed.

Implications for Practice

Depending on the origin of the odorants, different measures can be taken to reduce the odor in incontinence products. One is to target the microbial, enzymatic, or chemical processes that generate odorants in the product, for example, by including a bacterial or enzyme inhibitor. Another way is to remove already-existing odorants, such as those present in the voided urine, by using substances that, for example, adsorb or absorb them. Considering the high number of odorants identified in the used incontinence products in this study, and the different origins that they might have, a combination of odor inhibitors—targeting a variety of odorants with a variety of different origins—will have the highest probability of succeeding in removing odor.

Many people worldwide are suffering from incontinence and have a constant fear of odor. In developing incontinence products, there is a need for better knowledge of the odorants of used incontinence products to minimize the discomfort of odor. The result of this article is a contribution to the effort of developing effective odor inhibition, as well as to the development of standardized laboratory methods for evaluation of the odor-inhibiting effect of incontinence products.

Limitations

A limited number of products were analyzed. Additional tests need to be performed to further identify key odorants of importance for the odor of used incontinence products. Complementary testing is also needed to identify compounds undetected in this study. Nevertheless, the knowledge of key odorants will contribute to development of disposable absorbent incontinence products with improved odor control.

CONCLUSIONS

The analyzed products contained large numbers of volatile compounds, 28 of which were defined as key odorants. Nine of the key odorants were considered to be of particular importance to the odor of the used incontinence products: 3-methylbutanal, TMA, cresol, guaiaicol, 4,5-dimethylthiazole-S-oxide, diacetyl, DMTS, 5-methylthio-4-penten-2-ol, and 1 unidentified compound.

ACKNOWLEDGMENT

We thank Karin Hägerström and Anders Leufvén for skillful assistance with the instrumental and olfactory analyses.

REFERENCES

- Haylen BT, de Ridder D, Freeman RM, et al. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female pelvic floor dysfunction. *Neurourological Urodyn*. 2010;29(1):4-20.

2. Irwin DE, Kopp ZS, Agatep B, Milsom I, Abrams P. Worldwide prevalence estimates of lower urinary tract symptoms, overactive bladder, urinary incontinence and bladder outlet obstruction. *BJU Int*. 2011;108:1132-1138.
3. Wennberg AL, Molander U, Fall M, Edlund C, Peeker R, Milsom I. A longitudinal population-based survey of urinary incontinence, overactive bladder, and other lower urinary tract symptoms in women. *Eur Urol*. 2009;55:783-791.
4. Malmsten UG, Molander U, Peeker R, Irwin DE, Milsom I. Urinary incontinence, overactive bladder, and other lower urinary tract symptoms: a longitudinal population-based survey in men aged 45-103 years. *Eur Urol*. 2010;58:149-156.
5. ISO 15621:2011. *Urine-Absorbing Aids—General Guidelines on Evaluation*. Geneva, Switzerland: International Organization for Standardization; 2011.
6. Getliffe K, Fader M, Cottenden A, Jamieson K, Green N. Absorbent products for incontinence: "treatment effects" and impact on quality of life. *J Clin Nurs*. 2007;16:1936-1945.
7. Emmons KR, Robinson JP. Urinary incontinence severity and quality-of-life instruments. *J Wound Ostomy Continence Nurs*. 2013;40:350-354.
8. Agus A, Zhang L, Sedlak DL. A framework for identifying characteristic odor compounds in municipal wastewater effluent. *Water Res*. 2012;46:5970-5980.
9. Muñoz R, Sivret EC, Parsci G, et al. Monitoring techniques for odour abatement assessment. *Water Res*. 2010;44:5129-5149.
10. Brattoli M, Cisternio E, Dambruoso PR, et al. Gas chromatography analysis with olfactometric detection (GC-O) as a useful methodology for chemical characterization of odorous compounds. *Sensors (Basel)*. 2013;13:16759-16800. doi: 10.3390/s131216759.
11. Rocha SM, Caldeira M, Carrola J, Santos M, Cruz N, Duarte IF. Exploring the human urine metabolomics potentialities by comprehensive two-dimensional gas chromatography couple to time of flight mass spectrometry. *J Chromatogr A*. 2012;1252:155-163.
12. de Lacy Costello B, Ratcliffe NM. Volatile organic compounds (VOCs) found in urine and stool. In: Amann A, Smith D, eds. *Volatile Biomarkers: Non-invasive Diagnosis in Physiology and Medicine*. Oxford, UK: Elsevier; 2013: Chapter 22.
13. Smith S, Burden H, Persad R, et al. A comparative study of the analysis of human urine headspace using gas chromatography-mass spectrometry. *J Breath Res*. 2008;2:037022.
14. Troccaz M, Niclass Y, Anziani P, Starkenmann C. The influence of thermal reaction and microbial transformation on the odour of human urine. *Flavour Frag J*. 2013;28:200-211.
15. Wagenstaller M, Buettner A. Characterization of odorants in human urine using a combined chemo-analytical and human-sensory approach: a potential diagnostic strategy. *Metabolomics*. 2013;9:9-20.
16. Pandey SK, Kim KH, Choi SO, Sa IY, Oh SY. Major odorants released as urinary volatiles by urinary incontinent patients. *Sensors (Basel)*. 2013;13:8523-8533. doi:10.3390/s130708523.
17. Widén H, Alenljung S, Forsgren-Brusk U, Hall G. Sensory characterization of odors in used disposable absorbing incontinence products. *J Wound Ostomy Continence Nurs*. In press.
18. Hall G, Andersson J, Lingnert H, Olofsson B. Flavour changes in whole milk powder. II. The kinetics of the formation of volatile fat oxidation products and other volatile compounds. *J Food Qual*. 1985;7:153-190.
19. Storer MK, Hibbard-Melles K, Davis B, Scotter J. Detection of volatile compounds produced by microbial growth in urine by selected ion flow tube mass spectrometry (SIFT-MS). *J Microbiol Methods*. 2011;87:111-113.
20. Jünger M, Vautz W, Kuhns M, et al. Ion mobility spectrometry for microbial volatile organic compounds: a new identification tool for human pathogenic bacteria. *Appl Microbiol Biotechnol*. 2012;93:2603-2614.
21. Filipiak W, Sponring A, Baur MM, et al. Molecular analysis of volatile metabolites released specifically by *Staphylococcus aureus* and *Pseudomonas aeruginosa*. *BMC Microbiol*. 2012;12:113.
22. Nicolle LE. Urinary tract infections in the older adult. *Clin Geriatr Med*. 2016;32:523-538.
23. Ansaldi M, Théraulaz L, Baraquet C, Panis G, Méjean V. Aerobic TMAO respiration in *Escherichia coli*. *Mol Microbiol*. 2007;66:484-494.
24. Barrett EL, Kwan HS. Bacterial reduction of trimethylamine oxide. *Annu Rev Microbiol*. 1985;39:131-149.
25. Thorn RM, Reynolds DM, Greenman J. Multivariate analysis of bacterial volatile compound profiles for discrimination between selected species and strains in vitro. *J Microbiol Methods*. 2011;84:258-264.
26. Messenger J, Clark S, Massick S, Bechtel M. A review of trimethylaminuria: (fish odor syndrome). *J Clin Aesthet Dermatol*. 2013;6:45-48.
27. de Loor H, Bammens B, Evenepoel P, De Preter V, Verbeke K. Gas chromatographic-mass spectrometric analysis for measurement of p-cresol and its conjugated metabolites in uremic and normal serum. *Clin Chem*. 2005;51:1535-1538.
28. Martinez AW, Recht NS, Hostetter TH, Meyer TW. Removal of p-cresol sulfate by hemodialysis. *J Am Soc Nephrol*. 2005;16:3430-3436.
29. Curtius HC, Mettler M, Ettlinger L. Study of the intestinal tyrosine metabolism using stable isotopes and gas chromatography-mass spectrometry. *J Chromatogr*. 1976;126:569-580.
30. Hughes R, Magee EA, Bingham S. Protein degradation in the large intestine: relevance to colorectal cancer. *Curr Issues Intest Microbiol*. 2000;1:51-58.
31. Czerny M, Brueckner R, Kirchhoff E, Schmitt R, Buettner A. The influence of molecular structure on odor qualities and odor detection thresholds of volatile alkylated phenols. *Chem Senses*. 2011;36:539-553.
32. Cai L, Koziel JA, Lo YC, Hoff SJ. Characterization of volatile organic compounds and odorants associated with swine barn particulate matter using solid-phase microextraction and gas chromatography-mass spectrometry-olfactometry. *J Chromatogr A*. 2006;1102(1/2):60-72.
33. Wagenstaller M, Buettner A. Quantitative determination of common urinary odorants and their glucuronide conjugates in human urine. *Metabolites*. 2013;3(3):637-657. doi:10.3390/metabo3030637.
34. Spoelstra SF. Degradation of tyrosine in anaerobically stored pig-gery wastes and in pig feces. *Appl Environ Microbiol*. 1978;36:631-638.
35. Gostner A, Blaut M, Schäffer V, et al. Effect of isomalt consumption on faecal microflora and colonic metabolism in healthy volunteers. *Br J Nutr*. 2006;95:40-50.
36. Ogunshe AA, Omotoso MA, Bello VB. The in vitro antimicrobial activities of metabolites from lactobacillus strains on *Candida* species implicated in *Candida vaginitis*. *Malays J Med Sci*. 2011;18:13-25.
37. Bean HD, Dimandja JM, Hill JE. Bacterial volatile discovery using solid phase microextraction and comprehensive two-dimensional gas chromatography-time-of-flight mass spectrometry. *J Chromatogr B Analyt Technol Biomed Life Sci*. 2012;901:41-46.
38. McGorin RJ. The significance of volatile sulfur compounds in food flavors. An overview. In: Qian MC, Fan X, Mahattanatawee K, eds. *Volatile Sulfur Compounds in Food*. ACS Symposium Series, 1068. Washington, DC: American Chemical Society; 2011:chapter 1.
39. He J, Vazquez-Landaverde P, Qian MC, Eskin NAM. Off-flavors in milk. In: Eskin NA, Shahidi F, eds. *Biochemistry of Foods*. 3rd ed. London, UK: Academic Press; 2013: chapter 12.
40. Mochalski P, Krapf K, Ager C, et al. Temporal profiling of human urine VOCs and its potential role under the ruins of collapsed buildings. *Toxicol Mech Methods*. 2012;22:502-511.
41. Tangerman A. Measurement and biological significance of the volatile sulfur compounds hydrogen sulfide, methanethiol and dimethyl sulfide in various biological matrices. *J Chromatogr B Analyt Technol Biomed Life Sci*. 2009;877:3366-3377.
42. Bos LD, Sterk PJ, Schults MJ. Volatile metabolites of pathogens: a systematic review. *PLoS Pathog*. 2013;9(5):e1003311.
43. Offen CP, Frearson MJ, Wilson K, Burnett D. 4,5-Dimethylthiazole-N-oxide-S-oxide: a metabolite of chlormethiazole in man. *Xenobiotica*. 1985;15:503-511.
44. Calvo-Gómez O, Morales-López J, López MG. Solid-phase microextraction-gas chromatographic-mass spectrometric analysis of garlic oil obtained by hydrodistillation. *J Chromatogr A*. 2004;1036:91-93.
45. Eriksson I, Gustafson Y, Fagerström L, Olofsson B. Prevalence and factors associated with urinary tract infections (UTIs) in very old women. *Arch Gerontol Geriatr*. 2010;50:132-135.
46. Caljouw MA, den Elzen WP, Cools HJ, Gussekloo J. Predictive factors of urinary tract infections among the oldest old in the general population. A population-based prospective follow-up study. *BMC Med*. 2011;9:57.
47. Nicolle LE. Urinary tract infections in the elderly. *Clin Geriatr Med*. 2009;25:423-436.
48. Hedin K, Petersson C, Widebäck K, Kahlmeter G, Mölstad S. Asymptomatic bacteriuria in a population of elderly in municipal institutional care. *Scand J Prim Health Care*. 2002;20:166-168.