Performance Verification of Air Freshener Products and Other Odour Control Devices for Indoor Air Quality Malodours

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Abstract
In the realm of indoor air quality, odours possibly play the greatest role in determining whether occupants accept or reject their environment. Odours are an indicator and symptom of indoor air problems. Because of this, odour control methods are often utilized in commercial and residential buildings. While commercially, the odour control methods most often utilized include devices such as filters and ionizers, residential methods also include products like air fresheners and candles. These products are often used with little known about their effectiveness.

Sensory evaluation is practiced daily in the food, beverage and fragrance industries for decision making that affects billion dollar markets. Standards practiced in these industries can be applied to testing the efficacy of these odour control products.

This paper will discuss methods for testing the efficacy of odour control products. Discussion will include a review of testing procedures currently utilized in North America, including ASTM International E1593, *Assessing the Efficacy of Air Care Products in Reducing Sensorily Perceived Indoor Air Malodor Intensity*, and other related ASTM standards. Current practices and challenges will be discussed through presentation of several case studies.

1.0 Introduction

Concerns of comfort and health issues related to indoor air quality have continually increased in the past decade. Occupants of indoor spaces are demanding higher quality air that keeps them feeling healthy and relaxed. The air care industry has steadily produced more products to meet these desires of occupants in residential and commercial settings. These products include devices, such as air purifiers, and air fresheners with various modalities, such as aerosols, candles, etc.

The consumer, whether an individual or organization, is not currently provided with sufficient information to understand the expected performance of these types of products. For example, a residential consumer does not know how successfully a product will fill a room with fragrance and impact the intensity of malodours in the home. A sensitive individual buying an air purifier often does not understand what the vague performance claim statements made by the manufacturer mean with respect to the actual use of the product. Consumers are now beginning to demand documentation of claims made by these product manufacturers.

Standardization organizations such as ASTM International, the Comité Européen de Normalisation (CEN), and, cooperatively, ISO must take the lead in developing standard methods for testing performance of air care products.

ASTM International currently has standard method E1593-94(99), *Standard Practice for Assessing the Efficacy of Air Freshener Products in Reducing Sensorily Perceived Indoor Air Malodor Intensity*, which was published through ASTM E18 Sensory Evaluation Committee in 1994. This standard utilizes trained human assessors to document a product’s efficacy to remove malodours in indoor air.

While this standard has seen limited use by manufacturers conducting in-house testing, third-party testing is becoming more common in recent years. In 2006, this standard will be reapproved by ASTM International as E1593-06, with a slightly modified title of *Standard Guide for Assessing the Efficacy of Air Care Products in Reducing Sensorily Perceived Indoor air Malodor Intensity*. The change from “Air Freshener” to “Air Care” products highlights the fact that the standard can be used to test various odour control products, e.g. air filtration systems.

2.0 Malodours and Air Care Malodour Control Methods

A malodour is defined as "an olfactory stimulant that, when detected, is considered unpleasant or undesirable by the target population" (ASTM 1994). In other words, a malodour is an unpleasant odour. Common malodour categories include:

1. bathroom odours
2. refuse odours
3. cigarette smoke
4. cooking odours (e.g. fish, onions, etc.)
5. body odours
6. pet odours

The malodour (odour) is the perception experienced when one or more chemical substances in the air come in contact with the various human sensory systems (odour is a human response), see Figure 1. Some malodours may be composed of one key chemical compound (one odorant); however, most often, malodours are a complex mixture of various chemicals (many odorants).

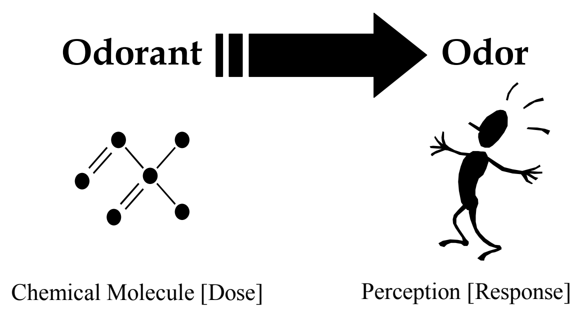

Figure 1. Chemical molecule odorants lead to the perception of odour/malodour.

The perception of a malodour can only be eliminated either by removing some critical portion of the odorants to bring the chemical concentration below the threshold of perception or by altering how the odorants are perceived.

Air purification removes odorant molecules from the air through various technologies such as filtration and adsorption. Examples of filtration include processes like high efficiency filters or electro-static precipitators. A common example of adsorption is granulated carbon filters.

The malodour chemical odorants can be altered through neutralizing or masking. Neutralizing is the action of changing the odorant chemical structure, which in turn alters the way the olfactory system perceives the odorants. An example of neutralizing is ozone treatment of the air. Masking is "the phenomenon where one quality within a mixture obscures one or several other qualities present" (ASTM, 2005). The most common example is an aerosol air freshener that adds a pleasant odour to cover-up the malodour.

Another term often used in malodour control is counteracting. Counteracting includes some combination of masking and neutralizing, which claims that the control product is neutralizing the chemical odorants of the malodour in some way, and there is also a fragrance component to provide masking. Another definition of counteracting is the claim that the pleasant fragrance is some opposing match to the malodour, and, due to its higher affinity to the olfactory receptors, blocks any perception of the malodour.

Through this discussion, it is shown that the absence of the malodour perception does not prove the malodorous chemicals have been removed. There may only be masking taking place.

3.0 Overview of ASTM E1593 Test Method

In 1994, ASTM International published standard E1593, *Standard Practice for Assessing the Efficacy of Air Freshener Products in Reducing Sensorily Perceived Indoor Air Malodor Intensity,* which outlines the necessary elements to test the efficacy of an air care product at controlling malodours. The E1593 test method allows for in-house (within a manufacturer's facility) or third-party testing, following detailed procedures in order to control the variables related to a test of this type as opposed to the limited control in a home use test with consumers. The control of these variables include utilization of trained assessors, performing the test under controlled laboratory conditions, utilization of a standard malodour, standard procedure of malodour application, standard procedure for air care control product operation or application, and following a standard method of sensory evaluation.

3.1 Assessors

Testing is conducted with assessors who are trained and experienced at the specific sensory evaluation methods chosen. Odour assessors are initially recruited from the community at large and selected and trained following ASTM Special Technical Publication 758, *Guidelines for Selection and Training of Sensory Panel Members* (ASTM, 1981). For example, each odour assessor is tested to determine their individual olfactory sensitivity using standard odorants, e.g. n-butanol and hydrogen sulfide. The assessors receive training that consists of olfactory awareness, sniffing techniques, standardized descriptors, and olfactory responses.

With proper training of odour assessors, the communication between the assessors and the test administrator is clear, concise, and efficient. A well-organized efficiently conducted odour panel ensures quality odour evaluation work.

The number of assessors utilized for a test session varies depending on the project's statistical needs. Assessors are not provided information about the odour samples being presented, including the sample type or sample properties.

Standing odour test session rules are part of the assessor's agreement to participate in odour testing, e.g. free of colds and allergies, no eating 30-minutes before test session, being scent free, etc.

Attention to the assessors' comfort and working environment nurtures their commitment and dedication to quality performance. The waiting area of the assessors is separated from the testing area. The assessors are provided water for drinking during the waiting time between sample testing. The assessors are not permitted to eat, chew gum, or drink beverages during the test session. A comfortable and relaxing waiting area enhances a low stress environment for the assessors. Limiting test session length minimizes assessor fatigue.

3.2 Testing Environment

The odour testing laboratory is an odour-free, non-stimulating space. The laboratory is organized so that odours from sample preparation do not migrate to areas where the assessors are present. If assessors are sniffing directly from the chamber(s), the area around the chambers should be organized and clean to prevent any visual bias.

Testing chambers can be various sizes depending on the specifications of the testing project. Primary consideration must be made for the control device and the mode of action. For example, an air filtration device is usually designed for operation in a room and should thus be tested only in a room-size chamber. Some air freshener testing can be conducted in smaller chambers with proper scaling taken into account in order to determine the amount of malodour to test, as well as the activation time of the product.

While a larger chamber provides a more realistic testing scenario, a smaller chamber usually provides more precise control of the testing parameters, such as level of malodour. Figure 2 is a photo of a large (4m x 5m x 3m), room-size chamber. Figure 3 shows an assessor sniffing directly form a smaller (1.2m x 1.2m x 1.5m) stainless steel chamber.

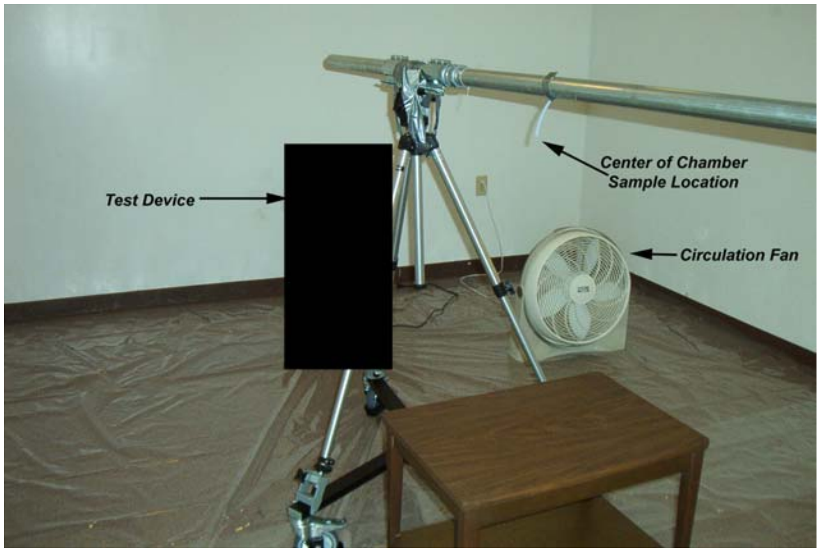

Figure 2. Example large, room-size chamber with test device (intentionally blocked out for confidentiality) and sampling locations identified. Photo courtest St. Croix Sensory, Inc.

Figure 3. Example small chamber with assessor sniffing directly through the sniffing port. Photo courtesy St. Croix Sensory, Inc.

3.3 Malodours

The selection of specific malodour and level of malodour is a critical element of the testing protocol. Malodours can be generated using real-life sources or through synthetic models. While real-life sources will provide the correct odorants in the room, this addition of malodour into the chamber can be variable. For example, in the process of using real animals or animal paraphernalia to create a pet malodour, the specific odour left in the room may be quite variable depending on the specific animals used and the activities of these animals.

Synthetic malodours can be easier to reproduce consistently, however, while they may smell similar to a malodour, they may be difficult to match perfectly and all the chemical odorants responsible for the real malodour may not be represented. For example, low concentration odorants in a malodour mixture, not present in a synthetic mixture, may become important as other malodour components are removed during product operation.

The magnitude of malodour produced in the room will depend on the testing goals and the discrimination level of the assessors. The odour must be strong enough that the assessors can discriminate its presence from an odour-free reference. Methods should be designed to create a consistent odour level when running multiple trials of one product or of several competing products.

3.4 Test Methods

ASTM E1593 is a document that outlines issues that need to be considered and addressed during protocol design. This standard does not specify the exact methods of odour testing to utilize. Instead, the specific goals of the testing will dictate the type of odour evaluation to perform.

The intent of testing may be to document the performance of one product under one or more conditions and operating parameters, or to compare the product to competing brands. It is common to present the assessors with several of the following control samples for QA/QC purposes: 1) malodour control sample – a sample with only malodour, 2) a product control sample – a sample of only the product used with no malodour, and 3) an odour-free blank control sample.

4.0 Odour Evaluation Test Methods

The general practice outlined in ASTM E1593 allows for customizing procedures depending on the specific product being tested. Odour threshold and whole odour intensity are used for documenting performance of products that remove the malodour without the addition of fragrance. Magnitude estimation and odour character profiling are ideal for testing products which add fragrance to the presence of the malodour, even if the concentration of malodour is reduced.

4.1 Odour Thresholds

Detection and recognition thresholds are determined according to ASTM International E679-04, *Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits*, and EN13725:2003, *Air Quality – Determination of odour concentration by dynamic olfactometry* (ASTM, 2004; CEN, 2003).

The testing procedure is based on a presentation method called 3-alternative forced-choice (3-AFC) or triangular forced-choice (TFC). Each assessor performs the odour evaluation task by sniffing the diluted odour from an olfactometer. The assessor sniffs three sample presentations; one contains the diluted odour while the other two are blanks (odour-free air). Figure 4 shows one assessor (left) sniffing from the olfactometer nasal mask while the test administrator (right) operates the olfactometer. The assessor is required, or forced, to choose one of the three presentations. The assessor acknowledges their choice as a guess, a detection, or recognition. As defined by E679, a response of detection is determining the selection is different from the other two, and a recognition response is that the sample smells like something (ASTM, 2004).

Figure 4. Assessor (left) sniffing from dynamic dilution olfactometer. Photo courtesy St. Croix Sensory, Inc.

The assessor is then presented with the next dilution level. The assessor is again presented with three sample choices, one of which is the diluted odour sample. However, this next dilution level presents the odour at a higher concentration (e.g. two times higher). This is one-half the dilution ratio of the previous level. This first dilution level presented to the assessor is below the odour threshold (sub-threshold). The assessor proceeds to higher levels of sample presentation following these methods. The statistical approach of increasing the concentration is called “ascending concentration series.”

The detection threshold is defined as the number of dilutions needed to make the odour just detectable (a detectable difference from a blank air presentation). The recognition threshold is defined as the number of dilutions needed to make the odour just recognizable (some specific odour character is recognizable).

The detection and recognition thresholds are directly related to the concentration of odour present. When the same odorants are involved, a higher threshold value means a higher concentration of the odorants are present.

4.3 Whole Odour Intensity

Whole odour intensity evaluations (suprathreshold intensity) utilizes n-butanol as a reference odorant following ASTM International E544-99, *Standard Practice for Referencing Suprathreshold Odor Intensity* (ASTM, 1999). An eight (8) level intensity scale is commonly utilized with a presentation concentration range starting at 12-ppm for level 1 and doubling each additional level to 1550-ppm at level 8.

During this test procedure, the odour samples are presented to assessors by filling a 50-cc glass syringe (without a needle) with the odour sample and expelling it just under the nose of the assessor. The assessor then compares the whole odour, both malodour and fragrance, of this presentation to the 8-point n-butanol scale. The odour intensity is reported as the n-butanol concentration equivalent in parts per million (ASTM, 1999).

Whole odour intensity would identify if a treatment reduces the perceived intensity of all odour in a room. For example, if a very light fragrance reduces the malodour and did not add significant odour, then the whole odour intensity may decrease over time with treatment. Conversely, a strong fragrance may reduce malodour, but add a significant amount of fragrance odour, thus the whole odour intensity may increase with time even though the malodour level decreases.

4.3 Malodour Intensity

Malodour intensity can also be evaluated following a procedure called “Magnitude Estimation.” This method is detailed in ASTM International E1697-95, *Standard Test Method for Unipolar Magnitude Estimation of Sensory Attributes* (ASTM, 1995).

Magnitude estimation is a procedure where the intensity of one odour sample is compared to another sample. For example, the assessor would be presented odour sample A. The assessor would give the intensity of this odour an arbitrary value such as “100.” The assessor would then be presented with sample B, and they would provide a rating based on sample A. Therefore, if sample B were perceived as half as intense as sample A, the assessor would give sample B an intensity of “50.” This method is difficult to compare across many odours. It is best suited for comparing similar odours.

Magnitude estimation can be extended to compare one specific attribute to the same attribute in a reference sample. For example, the level of malodour present even with other odours (i.e. fragrance) present. The chamber air before any application or operation of the control product is identified as the reference. Assessors are instructed that this reference sample has a malodour intensity of “100.” The assessors then evaluate all other samples based on this reference. Assessors are trained to ignore other odours present, such as the fragrance, and only evaluate the intensity of the malodour present. If an assessor judges a specific odour sample has a malodour intensity that is half as intense as the reference, then the assessor gives the sample a value of “50,” regardless of the intensity of the fragrance.

Referring to a previous example, while the application of a fragrance may actually increase the whole odour intensity, based on the butanol intensity scale, the level of malodour may be significantly reduced compared to the reference sample, and thus have a low magnitude estimation value.

4.4 Odour Characterization

Descriptive analysis is a sensory science term meaning the action of a panel of assessors describing attributes about a product sample (qualitative) and scaling the intensity of these attributes (quantitative).

Odours can be characterized using a reference vocabulary. Standard practice is to provide assessors with a standard list of descriptor terms, which are organized with like terms in groups. Similarly, terms with negative connotation (unpleasant) would be grouped with other negative terms and positive (pleasant) terms with other positive terms. One example of such lists is the ASTM International publication D-61, *Atlas of Odor Character Profiles* (Dravnieks, 1985).

Figure 5 is an odour descriptor wheel developed by St. Croix Sensory, Inc. for use with odour sample character profiling. The eight character families of odour descriptors include: floral, fruity, vegetable, earthy, offensive, fishy, chemical, and medicinal. Assessors observe the odorous air sample and report which general and specific odour descriptors form this list they notice. Assessors can also rate the relative strength of odour character groupings on a scale, e.g. five or ten point scale of not present, faint…very strong.

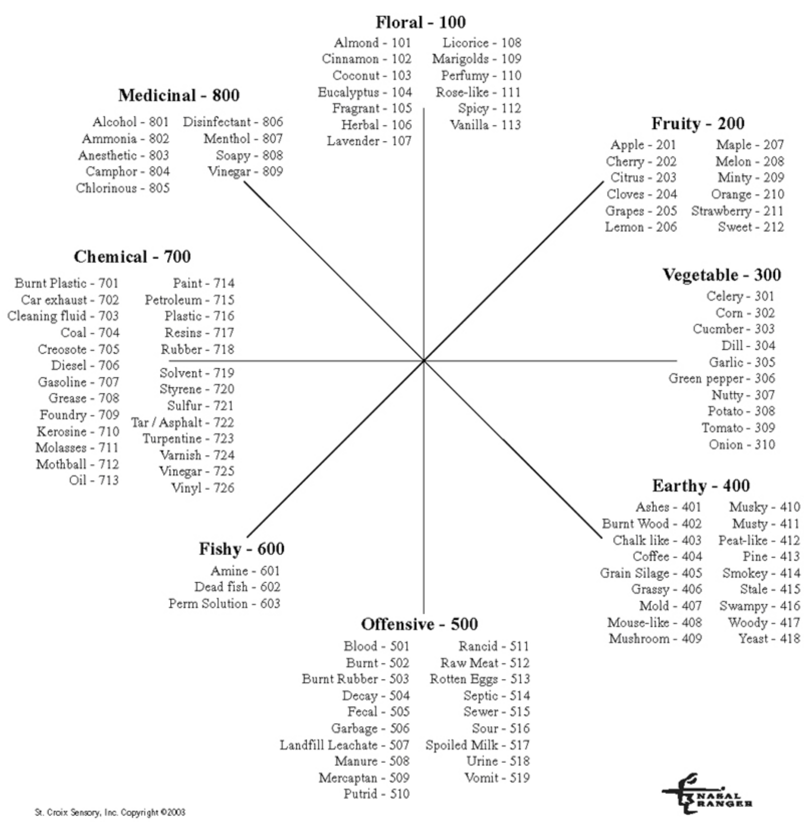

Figure 5. Example odour character descriptor wheel.

5.0 Example Testing Results

A hypothetical case study will assist in understanding the testing procedures and interpretation of results from testing the efficacy of malodour reduction. The testing results of four different products will be reviewed. Product A, B, and C are sold as air purifying devices that reduce odours. Product D is a product that produces a fragrance.

All four products were tested against the same malodour, generated with the same preparation procedure. Once the malodour was prepared, the test product was operated for two hours. Air samples were collected from the chamber at time zero, 0.25, 0.5, 1, 1.5, and 2 hours and presented to the assessors for sensory evaluation.

Figure 6 displays the detection threshold value (number of dilutions to threshold) results for these products. These results show that, with 95% reduction in the detection threshold value at two hours, product A provided the most significant reduction in this parameter. Product B had some initial reduction, however, after one-hour, the odour level began to increase. This is characteristic of the product adding some non-fragrance odour to the room (e.g. ozone generating device). Product C showed minimal reduction in the detection threshold value. Product D, which adds a fragrance, had an increase in the odour threshold value. This is common with the introduction of fragrances, which often have low odorant threshold concentration, i.e. requiring more dilution to threshold.

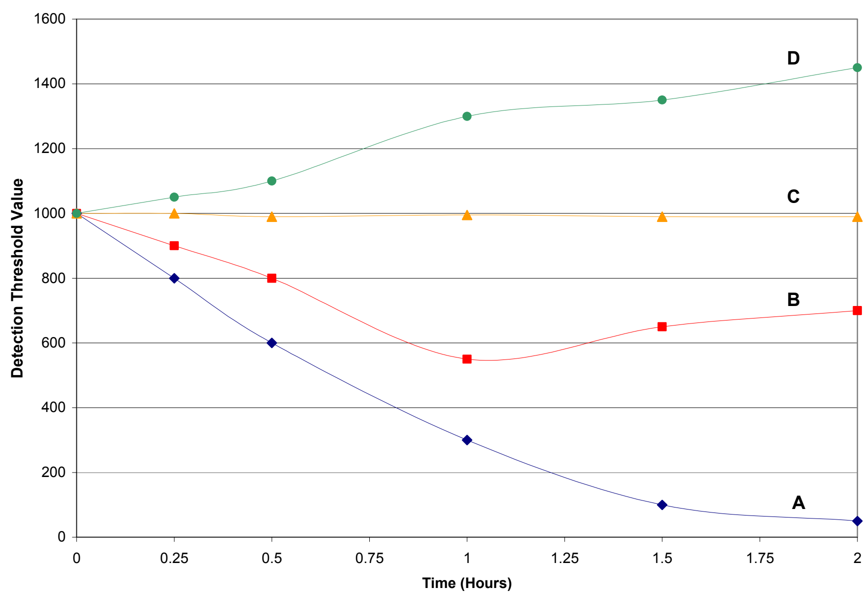

Figure 6. Example results of odour threshold data (ASTM E679 and EN13725) collected from testing with four different malodour reduction products.

Figure 7 are the results of the four products tested for perceived whole odour intensity. The trend in these results is very similar to the odour threshold results. Product A had the largest reduction in the whole odour intensity. As with the threshold testing, the odour intensity results for product B initially decreased, but then began to increase after one hour. Minimal odour intensity reduction was recorded for product C. For product D, the perceived odour intensity increased due to the presence of the fragrance.

Due to the presence of the fragrance in product D, the odour threshold and odour intensity tests were biased against this product. The presence of a fragrance would likely increase the odour threshold value and odour intensity, therefore, these methods did not provide evidence for or against reduction in malodour. Other testing methods, such as magnitude estimation and odour character profiling must be utilized to define the malodour reduction from products that produce a fragrance.

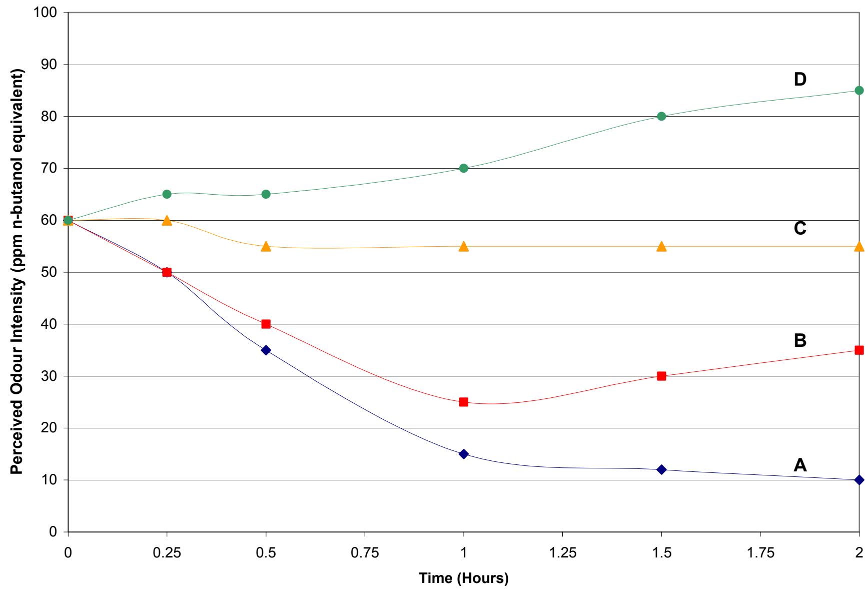

Figure 7. Example results of whole odour intensity data (ASTM E544) collected from testing with four different malodour reduction products.

Figure 8 provides the magnitude estimation results for all four products. All four products begin with a 100 value for the intensity level of the malodour. As with the threshold and whole odour intensity results, product A shows a significant reduction in the magnitude estimation value. Product B shows a continual reduction in the malodour magnitude estimation value, even though the threshold and whole odour intensity testing showed increases after one hour. These results show that product B must have been adding some odour to the room that is different from the malodour. Product C shows minimal reduction in the malodour magnitude estimation value. The magnitude estimation results for product D are significantly different then the threshold and whole odour intensity results. For product D, the intensity of malodour was significantly reduced even though the overall odour threshold value and whole odour intensity had increased.

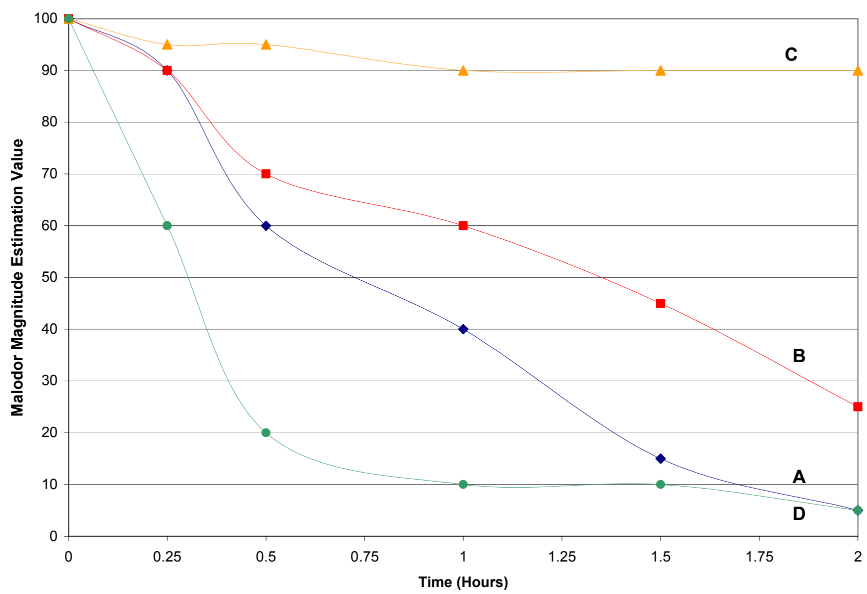

Figure 8. Example results of malodour intensity magnitude estimation data (ASTM E1697) collected from testing with four different malodour reduction products.

Figure 9 displays the magnitude estimation results as percent reduction in malodour. While product A had shown the most reduction in malodour through the threshold and whole odour intensity testing, the magnitude estimation testing shows product D had the greatest reduction in the malodour intensity through 1.5 hours. At the two-hour time, product A and product D had similar reduction of malodour intensity, however, the overall whole odour intensity with product A was significantly less due to the absence of any fragrance.

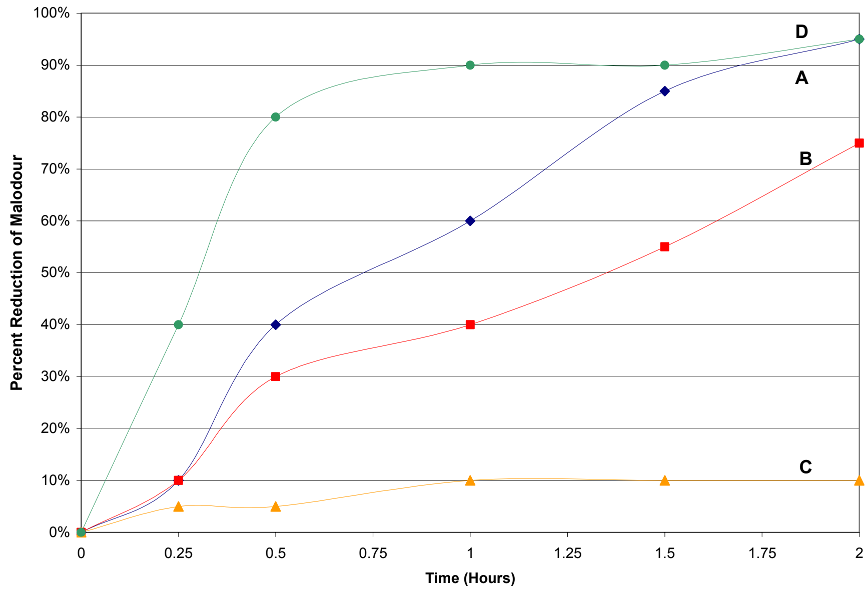

Figure 9. Example results of percent malodour reduction based on malodour intensity magnitude estimation (ASTM E1697) values collected from testing with four difference malodour reduction products.

Figure 10 presents the odour character profiling results for the original malodour at time zero and each product at two hours. Each axis refers to one of eight odour character categories with units referring to the average relative strength on a 0 to 5 scale (not present, faint, ... very strong). The results show that the malodour is mostly characterized as offensive, with significant levels of vegetable, earthy, and chemical odours. Product A had significantly lower relative strength of offensive odours, as well as reductions in vegetable and chemical odour. Product B had smaller reductions in the relative strength of offensive and vegetable characters compared to product A; however, as the other testing suggested, product B created increases in chemical and medicinal characters. The ineffectiveness of product C is proven further with only minimal odour reduction of offensive and earthy characters. Product D created a significant reduction in offensive character relative strength, as well as reductions in vegetable, earthy, and chemical characters. The fragrance of product D is shown in the high relative strength of floral and fruity characters at two hours.

This case study of different types of products shows how the different odour testing parameters can be used to understand the amount and type of malodour reduction. While one product may decrease the whole odour in the room and leave some minimal malodour remaining (product A), others may add some non-fragrance odours (product B), and still others may add fragrance, which covers the malodour, but adds to the overall odour in the room (product D). Product C is an example of a product that is ineffective at removing malodour.

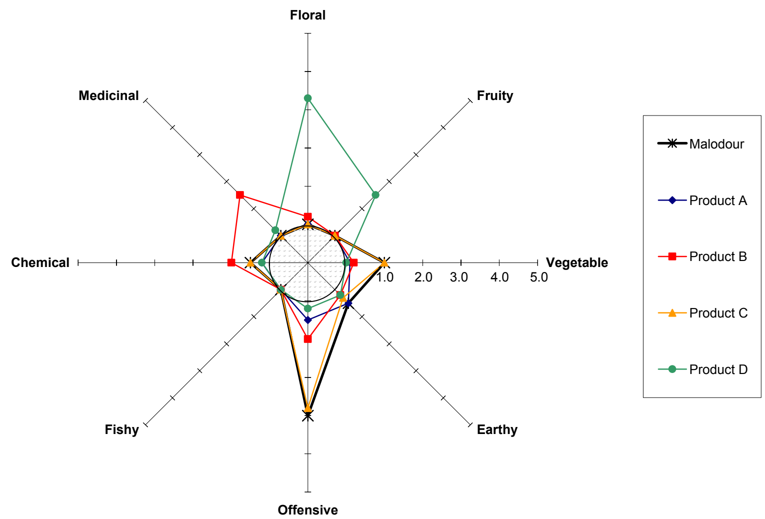

Figure 10. Example results of odour character profiling data collected from testing with four different malodour reduction products. Presented are the malodour at time zero and the four products after two hours of operation.

6.0 Conclusions

Methods exist for quantifying the malodour reduction performance of air care products. ASTM International E1593, *Standard Guide for Assessing the Efficacy of Air Care Products in Reducing Sensorily Perceived Indoor Air Malodour Intensity*, originally published in 1994 and due for republication with minor revisions in 2006, is one example testing guidance for collection of data on product performance.

Specific testing methods vary depending on the test product and the testing goals. The case study presented in this paper shows how different odour parameters can be used under different circumstances and how the results can be interpreted. Variables to consider are the operating time (for a device) or activation time (for application), specific device operating parameters, size of the test chamber, the test malodour, and the odour testing parameter data to collect.

Large organizations and consumers are demanding this performance data to make an informed purchase decision. Manufacturers are using this performance data for decision making related to product development and fragrance selection and for providing vendors and sales force with product claims. Cooperation between standardization organizations, industry organizations, and product manufacturers can lead the way to create detailed standardized test methods that will provide consistent information to both the manufacturers and consumers.

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