CHEMICAL ENGINEERING TRANSACTIONS

VOL. 112, 2024

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Selena Sironi, Laura Capelli

**ISBN** 979-12-81206-13-7; **ISSN** 2283-9216

DOI: 10.3303/CET24112036

# Assessment of Quality, Safety and Health Aspects in Deodorant Product

Rafeqah Raslan[a*], Normadyzah Ahmad[a], Irene Nindita Pradnya[b]

[a]School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia
[b]Department of Chemical Engineering, Faculty Engineering, Universitas Negeri Semarang 50229, Kota Semarang, Indonesia
rafeqah@uitm.edu.my

Consumers apply deodorant daily to prevent malodour, as the smell of body odour can be embarrassing. However, some consumers experience dripping and wetting when applying the liquid deodorant, resulting in an unpleasant sensation. Due to that, modification to the liquid deodorant formulation and determination of optimum process parameters are necessary. The liquid deodorant formulation was modified by adding salt, followed by the measurement of surface tension through the pendant drop method and wettability through the contact angle method. There was an increase in the surface tension of the formulation with salt, attributed to the increase in polarity and cohesive forces. A higher contact angle was observed in the formulation with salt, indicating enhanced hydrophobicity, thereby offering improved skin adherence and comfort. Furthermore, to determine the optimum process parameters, conductivity measurements were demonstrated, showcasing the ionic nature of the deodorant formulations that contribute to electrical conductivity. Stirring rate optimisation indicated that a range of 400 to 500 rpm for 10 min achieved the desired dissolution efficiency while minimizing energy consumption. Meanwhile, safety and health assessments were conducted to ensure that the liquid deodorant does not pose any risks. Results indicate that potassium alum induces mild skin irritation, while sodium chloride and preservatives exhibit potential for serious eye irritation and internal harm if swallowed. Since eye exposure and ingestion are not the major exposure route, the liquid deodorant is considered relatively safe.

## 1. Introduction

A deodorant is applied to the body to prevent malodour. Human sweat only has a noticeable smell when it is decomposed by bacteria. The use of deodorant helps to prevent skin bacteria breakdown while allowing sweating to occur. The demand for deodorant is expanding in most parts of the world, especially in Europe and the United States of America, and it has become the third most popular product. The contemporary deodorant product has evolved beyond merely combating malodour; it now offers enhanced features such as moisturizing properties, anti-irritant formulations, refreshing scents, and appealing aesthetics (Medical and In, 2020). Therefore, a lot of works have been conducted to enhance the features in deodorant. Kaul et al. (2022) evaluated the efficacy of deodorant products attributes including the product feel, texture, malodour, skin acceptance, and multi-functional. The deodorants were found to be satisfying in terms of feel and malodour and showed low skin irritation potential. Various researchers have expressed concerns on the use of hazardous ingredients in deodorant products. There were reported cases on dermatitis effect due to prolonged application of aerosol deodorant by Shah et al. (2022). There has been a controversial issue surrounding the usage of aluminium chlorohydrate, aluminium sesquichlorohydrate, and aluminium zirconium complex in deodorant products, with concerns raised about potential links to genotoxicity, breast cancer, and even Alzheimer's disease (Medical and In, 2020). However, the use of aluminium in deodorants specifically consumed by breast cancer patients during radiation therapy does not appear to have any adverse effects on axillary skin reaction (Lewis et al., 2014). Kim et al. (2018) has assessed the health risk from dermal and inhalation exposure to deodorants products for Korean consumers. The evaluated ingredients of deodorants were found to present no health risks at their maximum concentrations in the products.

Paper Received: 30 March 2024; Revised: 2 May 2024; Accepted: 8 June 2024
Please cite this article as: Raslan R., Ahmad N., Pradnya I.N., 2024, Assessment of Quality, Safety and Health Aspects in Deodorant Product, Chemical Engineering Transactions, 112, 211-216 DOI:10.3303/CET24112036

To the best of our knowledge, there is no work concerning the product quality of deodorant and limited works have been conducted to determine the safety and health effects due to the exposure to deodorant. With the increasing demand for deodorant products in the market, it is worth exploring the significant product quality properties to meet consumer satisfaction. Therefore, in this work, the product quality properties and the safety and health effects of deodorant were explored. The desired properties of a deodorant include pleasant feeling, non-sticky, non-dripping, less wetting and low safety, and health effects. To ensure that deodorant formulation will result in non-dripping and less wetting, the surface tension and wettability properties were investigated. Salt (sodium chloride) was added in the deodorant formulation to increase the surface tension. The selection of ingredients in the deodorant formulation should contribute to safer products and minimize health effects. Thus, the safety and health assessment of the ingredients used in deodorant formulation were presented.
In the preparation of liquid deodorant, it is crucial to determine the optimum process parameter to reduce the operating cost due to the energy consumption from the stirring. The movement of the particles by stirring will increase the speed of the solute particles dispersed into a greater volume of the solution. Meanwhile, the indicator that all the solute particles had fully dissolved can be determined by conductivity measurements. The process parameter for the preparation of deodorant includes stirring rate and blending time. Methodology

## 2. Methodology

### 2.1 Preparation of Deodorant

In the preparation of liquid deodorant, two main solid ingredients used were potassium alum and salt (sodium chloride). Two samples of deodorant liquid were prepared, namely Formulation 1 (without salt) and Formulation 2 (with salt). The preparation of the deodorant liquid began with rinsing the overhead stirrer of the mixer (Eurostar 40 digital Overhead Stirrer, 10000762, IKA) with reverse osmosis (RO) water. All the ingredients were weighed using the balance (A&D EK-610i). The RO water was filled in a large bowl that was attached to the mixer. The ingredients were added sequentially into the RO water, starting with potassium alum. The mixer was turned on, and the speed of the stirrer increased slowly as the ingredients were added. It was ensured that all the ingredients had dissolved completely and uniformly mixed.

### 2.2 Surface Tension of the Liquid Deodorant

The surface tension of the two samples was measured using a pendant drop test. During the test, the pendant drop formed was analysed in terms of its shape, and the surface tension was measured. The VCA 3000s Wafer Surface Analysis Systems with a precision camera was utilized to capture an image that is of sufficient quality for precise determination of surface tension. The drop image, as acquired at the digital camera sensor, must be undistorted by lensing effects to obtain a good analysis of a homogeneous image background. In particular, the drop size needs to be of adequate size to ensure that gravitational effects are non-negligible. The gravitational is set to be 980.35 cm/$S^2$ and the volume of the droplet is 30 µl (Mat-shayuti et al., 2020).

### 2.3 Contact Angle of the Liquid Deodorant

The contact angles of the two samples of liquid deodorant were measured using an automatic micrometre syringe through the sessile drop methodology in VCA 3000S Wafer Surface Analysis Systems. The static images of the droplet were captured and the tangent lines were determined for the basis of contact angle measurement. The contact angle measurement was based on the numerical curve fitting using the Laplace equation of capillarity generated by the embedded software. The reference plane was settled in the three-phase line, so the mathematical methodology calculated the contact angle (θ) using the contact point with the drop for each one of the images taken. The surfaces employed in this test were cleaned, before and after the assay. Finally, the contact angle values were obtained from the mean of at least three measurements.

### 2.4 Determination of Optimum Process Parameter

The liquid deodorants (Formulation 2) were prepared. The ingredients (potassium alum and salt) were added to the beaker that was attached to the mixer (Eurostar 40 digital Overhead Stirrer, 10000762, IKA). The stirring speed was set to be 300 rpm. The mixing was allowed to continue to ensure the conductivity was consistent. The conductivity probes were then carefully lowered into the middle of the beaker, avoiding interference with the blade but submerged enough to ensure a reliable conductivity reading. The conductivity value was increased when the mixing started and eventually reached the optimum value. When the conductivity reached the optimum value, it indicated that all the ingredients had dissolved completely, and the mixing was stopped. The conductivity data was collected for every 2 min until the value reached the desired consistent level. The data collection process was repeated for stirring rates of 400 rpm, 500 rpm, 600 rpm and 700 rpm. The stirring rate with the minimum blending time is considered the optimum stirring rate. The schematic diagram of the conductivity test is shown in Figure 1.

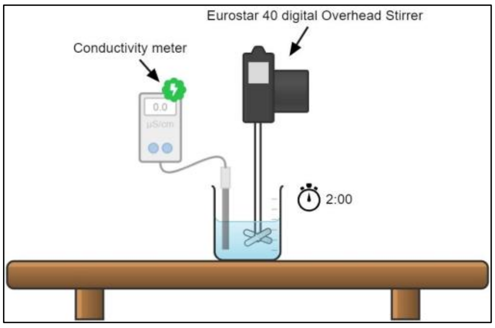


*Figure 1: Schematic diagram of the conductivity test*

### 2.5 Safety and Health Assessment

The safety assessment of the liquid deodorant was conducted based on the ingredients used and the exposure route. The safety of the ingredients due to the exposure routes via the eye, inhalation, ingestion, and dermal was assessed by referring to the hazard statements provided by the Globally Harmonised System of Classification and Labelling Chemicals (GHS) (Raslan et al., 2020). The hazard statements provided by the GHS were taken from the chemistry database known as PubChem provided by the National Institutes of Health (NIH).

## 3.Results

### 3.1 Surface Tension of the Liquid Deodorant

The surface tensions were observed for both Formulation 1 and Formulation 2 of liquid deodorant. Pendant drop tensiometry allows the measurement of the vapour-liquid or liquid-liquid interfacial tension by numerically solving the equilibrium between surface tension and gravitational force in the Laplace equation of capillary using advanced numerical integration schemes like Newton-Raphson and Levenberg-Marquardt (Mat-shayuti et al. 2020). Figure 2 shows the pendant drop images of Formulation 1 and Formulation 2. The average surface tensions for the Formulation 1 and Formulation 2 were 31.23 mN/m and 40.41 mN/m, respectively. For both results, the standard deviations were within an acceptable range of around 0.6 to 0.7 mN/m.

The surface tension of Formulation 2 is higher due to their higher polarity resulting in higher cohesive forces. The addition of the salts has increased the surface tension of the liquid deodorant. Surface tension could be increased by increasing the polarity of water. The addition of a more polar substance, such as inorganic, may increase the surface tension of water. At the molecular level, salt dissolves in water due to electrical charges and since both water and salt compounds are polar, with positive (cations) and negative (anions) charges on opposite sides of the molecule (Sedev, 2011).

The addition of sugars such as sucrose and glucose into water could also increase the surface tension (Docoslis et al., 2000). This is because the molecules of sugar are also polar. The water molecules will cluster around the sugar molecules as their negative charges are attracted to the positive charges of the sugar molecules. However, the extensive hydrogen bonding between sugar and water molecules increases the cohesion and adhesion of the solution making the solution become ‘sticky’. Therefore, sugar is not suitable to be used in the preparation of liquid deodorant to avoid the unpleasant sensation. Salt is more suitable to be added in the liquid deodorant to increase the surface tension of the water, thus, providing a better quality. The increase in the stability of the liquid makes it stay on the skin and not drip off once the deodorant is sprayed on the underarms. On the other hand, a thickening agent or a thickener, such as Xanthan gum, at a very low concentration, will thicken the water and increase the viscosity. With the thickening agent, the water will flow yet stay on surfaces and better penetration through the skin (Ganesan et al., 2022). In a way, the surface tension is also increased. However, it is time-dependent because the water molecules are still free to move.

### 3.2 Contact Angle of the Liquid Deodorant

A sessile drop test was conducted to determine the contact angle between the liquid deodorant and a flat surface. The average contact angle for the Formulation 1 and Formulation 2 were 98.54◦ and 105.53◦, respectively. The contact angle images of Formulation 1 and Formulation 2 are shown in Figure 3. The addition of salt affects the contact angle where the contact angle of Formulation 2 is higher than Formulation 1. The increase in the contact angle indicates that salt results in an increase in the hydrophobicity of the liquid deodorant. The liquid deodorant of Formulation 2 possessed less wettability and was able to prevent the liquid from spreading out on the skin, thus offering a better quality of deodorant. With the improved formulation, the consumer will feel more comfortable and confident.

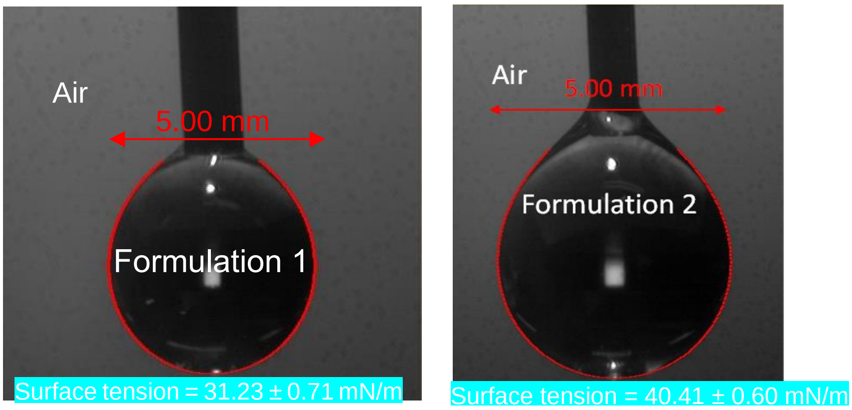


*Figure 2: Pendant drop images of liquid deodorant*

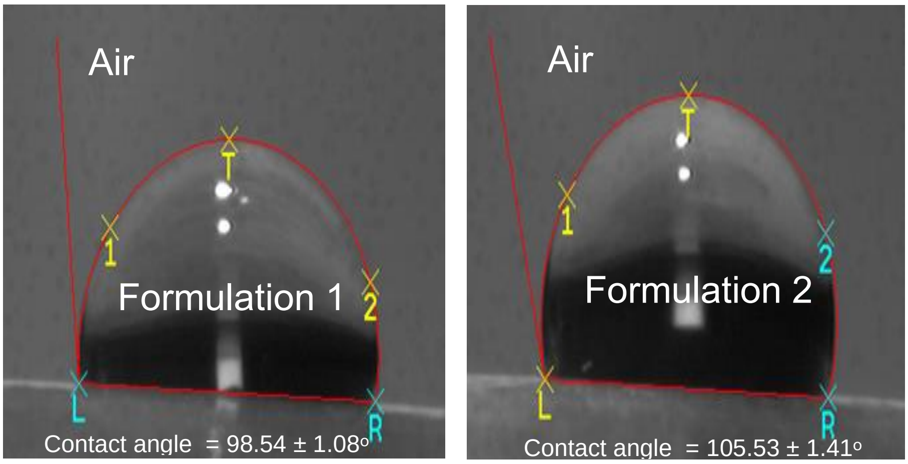


*Figure 3: Contact angle images of liquid deodorant*

### 3.3 Determination of Optimum Process Parameter

Sodium chloride or salts are ionic compounds that, when dissolved in an appropriate solvent, such as water, may split apart or dissociate due to the polarity of the water. In addition, the process of dissolving may also occur where the solute (salts) and solvent interact at the particulate level, with the solute occupying spaces between solvent molecules, and the solute would eventually be evenly distributed throughout the solvent through the movement of the particles (Budimaier and Hopf, 2023). As such, the ions are free to move through the liquid to conduct electrical current. To the best of our knowledge, the liquid deodorant may conduct an electrical current because it contains potassium alum and sodium chloride. The average conductivity data for each stirring rate of 300 rpm, 400 rpm, 500 rpm, 600 rpm and 700 rpm are shown in Figure 4. Initially, the conductivity value was increased sharply at the duration of 2 min. This is when the particles of the solute move into the larger volume of the solution. Then, there comes a saturation point where solute particles would eventually be evenly distributed throughout the solvent and no further dissolution process was observed. At this point, the conductivity value has reached a plateau and the final conductivity value was taken. At a low stirring rate of 300 rpm, a longer duration of time was taken for the process of dissolving to complete. As the stirring rate was increased from 400 rpm to 700 rpm, a lesser duration of time was taken to reach the optimum value. Stirring increases the movement of the particles, whereas the higher the stirring rate, the faster the movement of the particles. It is important to note at a low stirring rate of 300 rpm, the dissolution process took 20 min to complete, while at higher stirring rates of 400 rpm and 500 rpm, the dissolution process took around 10 min. A longer duration of time was observed at the stirring rates of 600 rpm and 700 rpm, which was approximately 16 min.

The determination of the optimum stirring rate is based on the minimum blending time of the dissolution process. When the conductivity value has reached a plateau, the final conductivity value is taken, and the duration of time is considered the minimum blending time. The range of final conductivity is between 8.94 mS/cm to 9.02 mS/cm. The conductivity of potassium alum at 35°C is 31540 μS/cm (Abdulwahab et al. 2019). Meanwhile, the conductivity of sodium chloride at 17°C is 67200 μS/cm and at 23°C is 14000 μS/cm (Valdez and Smith, 2020). Based on this data, the conductivity value is decreased when the temperature is increased. The experimental setup in this work was at room temperature, which was around 25°C. Thus, the process of dissolving to complete is targeted to achieve when the conductivity value estimated to be higher than 14000 μS/cm. Since the duration of time for the dissolution process with the stirring rate of 300 rpm is longer, the optimum stirring rate is considered in the range of 400 rpm to 500 rpm with a duration of 10 min. Hence, a longer duration of time that is more than 10 min and a higher stirring speed of more than 500 rpm will result in excess energy consumption from the stirring. The obtained optimum process parameters of stirring rate and blending time may reduce the operating cost.

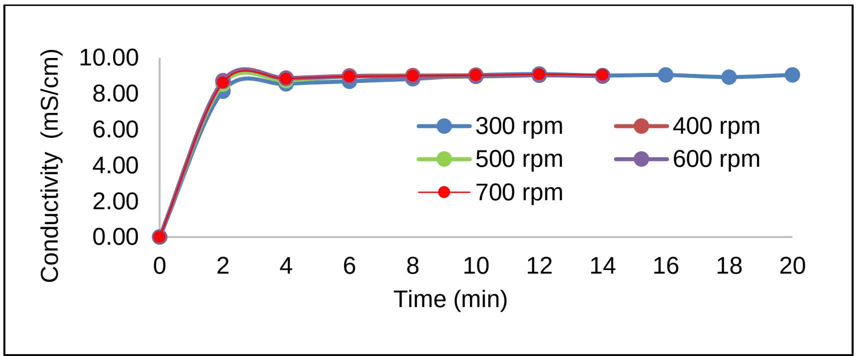


*Figure 4: The average conductivity data of different stirring rates*

### 3.4 Safety and Health Assessment

The potassium alum possessed mild skin irritation, while sodium chloride and preservative possessed serious eye irritation. In addition, preservatives are hazardous if swallowed, as they can cause internal harm. When contact with skin, it may irritate, leading to discomfort or inflammation. Furthermore, it has the potential to induce allergic reactions on the skin or provoke respiratory issues if inhaled, which could manifest as asthma symptoms or breathing difficulties. Since eye exposure is not the main exposure route of liquid deodorant, exposure to sodium chloride and preservative can be considered safe. Therefore, the deodorant product is safe for human health based on the assessment of its ingredients and the exposure route. The safety and health hazards of ingredients are shown in Table 1.

*Table 1: Safety hazards of ingredients*

| Ingredient | Hazard Statement |
|---|---|
| Potassium alum<br>National Center for Biotechnology Information (2024a). | Cause mild skin irritation |
| Sodium chloride<br>National Center for Biotechnology Information (2024b). | Serious eye irritation |
| Preservative<br>National Center for Biotechnology Information (2024c). | Harmful if swallowed ; skin irritation; allergic skin reaction; serious eye irritation; allergy or asthma symptoms or breathing difficulties if inhaled ; respiratory irritation |

## 4. Conclusions

Adding salt (sodium chloride) to liquid deodorant helps to increase the surface tension and wettability based on the findings from the pendant drop method and contact angle measurement. The improved formulation of deodorant can stop the liquid from dripping and avoid skin wetting. The optimum stirring rate was in the range of 400 rpm to 500 rpm, while the blending time was 10 min. Meanwhile, the safety and health assessment of the ingredients in deodorant formulation indicates that the deodorant can be considered as safe to human health.

**Acknowledgments**

This research was funded by College of Engineering, Universiti Teknologi MARA.

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