The application of UV-C light for a DIY fabricated device to reduce bad smell in boxing gloves

Meechai Thepnurat1,2, Paritchaya Sangto1,2, Nutnicha Jaisuk1,2, Parinya Saphet1,2, Kanitta Supawan1,2, Anusorn Tong-on1,2 and Kan Klaewklar3

1 Program of Physics Education, Faculty of Education, Chiang Rai Rajabhat University, 57100
2 Physics Innovation Laboratory, Faculty of Education, Chiang Rai Rajabhat University, 57100
3 Program of Physical Education, Faculty of Education, Chiang Rai Rajabhat University, 57100

*E-mail: TMeechai14@gmail.com

Abstract. Currently, boxing and Muay Thai are popular sports and exercises around the world. Foul-smell in boxing gloves becomes a problem that needs to be eliminated before the next training session. The musty smell in boxing gloves is caused by accumulation of sweat and bacteria from the boxer's hands. The process of eliminating odor using UV-C light can be the solution. In this research, the application of UV-C light was used to fabricate a DIY (Do it yourself) device to reduce bad smell in boxing gloves. Use of a UV-C light at a wavelength of 253.7 nm could remove musty smells within 30 minutes. The odor level in the boxing glove was measured by the electronic nose system, which was made up from 3 gas sensors. The results showed that UV-C light was able to reduce bad smell in boxing gloves up to 90%.

1. Introduction
Nowadays, boxing and Muay Thai are sports that are popular among many people from around the world [1]. Boxing glove is an important device for practice and competition that helps to reduce the force of the punch [2,3]. The musty smell in boxing gloves is unwanted and needs to be cleaned. There are many deodorization methods, such as washing, sun drying, baking, etc. However, these methods are not able to get rid of the smell inside the gloves and take long time to do so.

The UV-C light can be applied to remove odor because it can eliminate bacteria coming from hand sweat which are the cause of musty smell [4]. Application using UV-C light is an alternative method that does not require any water in cleaning process. Therefore, the UV-C light was applied in this research to fabricate a DIY (Do it yourself) [5] device to reduce bad smell in boxing gloves. The effectiveness of odor removal was determined from an electronic nose identification system by gas sensors in conjunction with the Arduino system and the LabView program.

2. Experimental setup and procedures
The application of UV-C light was used to fabricate a DIY cleaning device to reduce bad smell in boxing gloves (here after UVC-Box). It was fabricated from the components of a 6-Watt UV-C lamp producing a 253 nm wavelength which connected to the power supply control circuit board. The lamp was covered

*Content from this work may be used under the terms of the CreativeCommons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd*
by a rigid straight cylinder plastic mesh to protect the UV-C lamp and boxing gloves. They were installed together with the base ventilation pipe, which was a square plastic box as shown in figure 1 (a). Inside the box, it consisted of an electrical distribution control board for UV-C lamps, fans and on-off switches. The switch was designed in a way that works when the boxing glove was covered with UV-C lamps to prevent users from being exposed to UV radiation. Next, 6 boxing gloves were tested for musty odors detection by using an electronic nose consisting of three gas sensors including an MQ2, an MQ4 and an MQ135. The MQ gas sensors¹, the SnO₂ semiconductor sensors which are gas sensitive and combustible, were moduled to arduino. The MQ2 gas sensor is highly sensitive to alcohol, methane, propane, hydrogen, isobutane, smoke and liquefied petroleum gas (LPG). The MQ4 gas sensor detects methane (CH₄) and natural gas therefore it can be used in preventing any by-products produced from alcohol, smoke from cigarette and cooking fumes. The MQ135, usually used as an air quality control apparatus in buildings, can reasonably detect not only specific gases including carbon dioxide (CO₂), ammonia (NH₃), gas NOₓ, benzene, alcohol and also smoke[6].

The 3 sensors were connected to the arduino board and the LabView program as shown in figure 1 (c). After that, boxing gloves were put on the UVC-Box for 5, 10, 15, 20, 25 and 30 minutes respectively as described in figure 1 (b). After cleaning with UVC-Box, the boxing gloves were checked for odor by the electronic nose once more as shown in figure 1 (d). The results of the odor measurement from the electronic nose were taken to determine the efficacy of UVC-Box for proper odor removal.

Figure 1. The DIY UV-C light cleaning device for boxing gloves (UVC-Box) has been fabricated (a). Boxing gloves are worn on the UVC-Box to reduce odor in the boxing gloves (b). Electronic nose systems are connected to the Arduino board and the LabView program (c). The electronic nose is imported into the boxing glove to smell inside the stuffy gloves (d) and the drawing describes the function of UV-C light for microorganism infection (e).

¹ manufactured by HANWEI ELECTRONICS CO., LTD
3. Theoretical background

Ultraviolet radiation is the electromagnetic wave with radiation wavelength shorter than visible light. The wavelength, range between 100 and 400 nm, is normally subdivided into three types: UV-C (100 - 280 nm), UV-B (280 - 315 nm) and UV-A (315 - 400 nm). The UV-C applied with the ultraviolet germicidal irradiation (UVGI) was used in killing or inactivating bacteria and microorganisms. UVGI is designed and generated by a UV-C lamps outstandingly kills and inactivates those microorganisms at a wavelength of 253.7 nm [7,8]. The UV-C light could penetrate microbial cell walls and destroy DNA. DNA of bacteria and microorganisms has been damaged by UV-C radiation occurs directly on DNA. UV-C irradiation directly exposes on DNA caused thymine bases to form dimers. Therefore, the enzymes responsible for unwinding, copying the DNA and obstructed cell division during replication are cannot function anymore and result in failure of cellular repair process. This renders the bacteria and the microorganism unable to multiply procreate and cause an infectiousness. Therefore, UV-C light has a bacteriostatic effect, UV-C light killed microbes, prevented cell regeneration and the spread of infection as described in figure 1 (e) [9]. The microorganism on the skin, hands and human body cause odors. Human body odor such as skin odor, foot odor and hand odor have complicated composition of volatile organic compounds (VOCs) belonging to several chemical classes, amine, acid, ketones, alcohol, including aldehyde, hydrocarbon, terpenoids, sterols, and sulfur compounds [10] as shown in figure 1 (e).

![Figure 2](image)

**Figure 2.** The odor measurement results of the gas sensors MQ2, MQ135 and MQ4 are shown in the form (a-c), respectively. The electronic nose system shows the results (voltage average from MQ gas sensors \(V_g\)) of the analysis of musty smell in boxing gloves and the time for cleaning inside boxing gloves by UVC-Box (d).

4. Experimental results

The MQ gas sensors revealed the default normal voltage values based on the type of MQ gas sensors including MQ2, MQ135 and MQ4. Their average initial voltages are found to be 215.09 ±0.05 mV,
263.87 ± 0.05 mV and 459.00 ± 0.02 mV, respectively. When MQ gas sensors are exposed to gas or are inside the boxing gloves, the resistance of the semiconductor decreases and causes their voltages to be increased. Their highest voltage presented when they are in the unclean boxing gloves (i.e. cleaning time of 0 minute by UVC-Box). The voltage dropped when the boxing gloves were cleaned by UVC-Box for 5, 10, 15, 20, 25 and 30 minutes, respectively. Findings were found to be the same for each MQ gas sensor as shown in figure 2 (a-c). The average voltages detected from each MQ gas sensor was shown in figure 2 (d) and Table 1.

| Boxing gloves No. | Time of boxing gloves cleaned by UVC-Box (min) | Average voltage detected from MQ2 gas sensor(mV) | Average voltage detected from MQ4 gas sensor(mV) | Average voltage detected from MQ135 gas sensor(mV) | Average voltage detected from MQ gas sensor(mV) |
|-------------------|-------------------------------------------------|-----------------------------------------------|-------------------------------------------------|-------------------------------------------------|-----------------------------------------------|
| 1-6               | 5m                                              | 215.09±0.05                                   | 215.09±0.05                                     | 215.09±0.05                                     | 215.09±0.05                                   |
|                   | 10m                                             | 215.09±0.05                                   | 215.09±0.05                                     | 215.09±0.05                                     | 215.09±0.05                                   |
|                   | 15m                                             | 215.09±0.05                                   | 215.09±0.05                                     | 215.09±0.05                                     | 215.09±0.05                                   |
|                   | 20m                                             | 215.09±0.05                                   | 215.09±0.05                                     | 215.09±0.05                                     | 215.09±0.05                                   |
|                   | 25m                                             | 215.09±0.05                                   | 215.09±0.05                                     | 215.09±0.05                                     | 215.09±0.05                                   |
|                   | 30m                                             | 215.09±0.05                                   | 215.09±0.05                                     | 215.09±0.05                                     | 215.09±0.05                                   |

Bacteria in the boxing gloves produced musty odor, containing a component of methane gas. Therefore, the methane gas sensor was built and integrated into the electronic nose system. The gas sensors MQ2, MQ4, and MQ135 had various voltage values as shown in the figure 2 (d), respectively. The odor levels detected by the gas sensors were inversely proportional to the cleaning time of boxing gloves. Monitoring by gas sensors, the musty smell in boxing gloves decreased when time increased. The efficiency(%) of UVC – Box defines as the percentage of amount of odor that are cleaned and deodorized where the electronic nose (MQ gas sensors) can measure voltage average the same amount as the air outside the boxing glove. It can be calculated with this equation (1).

$$\text{The efficiency(\% of UVC – Box) = } 100 - \frac{(V_g(t)-V_g(0))\times100}{(V_g(t=0)-V_g(0))}$$

$$V_g(t)$$ is voltage average from MQ gas sensors at 0 (in air), 10, 15, 20, 25 and 30 minutes. $$V_g$$ is voltage average from MQ gas sensors in air outside the boxing glove in the table 1. The 30-minute duration was the proper time which best reduced musty smell as the smell level dropped to a minimum of 0.01%. Cleaning more than 30 minutes resulted in a burning smell, therefore, the optimum time for UVC-Box cleaning should not be more than 30 minutes. The results of the electronic nose performance showed that the efficiency(%) of UVC – Box cleaning and reducing musty odors was higher when more time was added as shown in figure 3. It was most efficiency(%) at a period of 25-30 minutes to reduce the smell up to 90%. This duration was a good time for cleaning and allowed boxers to take a break before practice in the next round.
Figure 3. Graph showing the foul odor compared to the time when using UVC-Box for reducing musty odor in boxing gloves and graph showing the efficiency (%) of UVC – Box for odor removal at various times.

5. Conclusions
The application of UV-C light was used to fabricate a DIY (Do it yourself) device to reduce bad smell in boxing gloves, named as DIY UV-C light cleaning device for boxing gloves (UVC-Box). It was tested for efficiency with an electronic nose system. UVC-Box was effective in cleaning and reducing odor and better when increasing the time but must not more 30 minutes. It provides most efficiency (%) (> 90% of smell reduction) at a period of 25-30 minutes at maximum. Therefore, it could be used for boxing and Muay Thai, and can be installed in a number of boxing gyms in the future.

Acknowledgement
Authors wish to acknowledge the Research and Development Institute Chiang Rai Rajabhat University and the Faculty of Education Chiang Rai Rajabhat University.

References
[1] Chaabene H, Tabben M, Mkaouer B, Franchini E, Negra Y, Hammami M, Amara S, Chaabene R B and Hachana Y 2014 *Sports Med.* **45** 337–52
[2] Perkins P, Jamieson A, Spratford W and Hahn A 2018 *WJET.* **6** 603–24
[3] Bledsoe G H, Li G and Levy F 2005 *South. Med. J.* **98** 994–8
[4] Guridi A, Sevillaño E, Fuente I D L, Mateo E, Eraso E and Quindós G 2019 *Int. J. Environ. Res. Public Health* **16** 4747
[5] Thepnurat M, Saphet P and Tong-on A 2017 *J. Phys.: Conf. Ser.* **901** 012120
[6] Wijaya D R, Sarno R and Zulaika E 2018 *Data Brief* **21** 2414–20
[7] Gross A, Stangl F, Hoenes K, Sifft M and Hessling M 2015 *Water* **7** 4605–21
[8] Comstock W S 2016 *ASHRAE Handbook-HVAC Systems and Equipment (SI)* (Georgia: ASHRAE) pp 17.1–10
[9] Timmermann L F, Ritter K, Hillebrandt D and Küpper T 2015 *Ravel. Med. Infect. Di.* **13** 466–74
[10] Jha S K 2017 *Rev. Anal. Chem.* **36** 1–16