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SAFEBITE: DESIGNING A MULTI-PURPOSE MACHINE BY COMBINING A DRYER AND ULTRAVIOLET (UV) STERILIZATION OPERATIONS

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ABSTRACT

The study aimed to promote sanitation and a hygienic community. This study was purely researchers-made, with some integration using the instructions provided in the user manual of each attached mechanism. First, the researchers crafted the machine by cutting the plyboard according to the dimensions of the box then attached five (*5) 254* mm Ultraviolet (UV) light and two (*2*) *220*V dryers. Next, the researchers tested its drying ability by exposing three different materials in the machine. These materials were fully dried in *17-25* minutes of exposure in the drying machine, making them effective for drying. Then, the researchers tested its antibacterial properties. With the use of *Staphylococcus aureus* and *Escherichia coli,* the machine showed no growth on samples exposed to the UV radiation of the machine, showing *0* colony-forming units (CFUs). Therefore, this study provides concrete evidence that it is efficient for sanitation and drying for households in the locality.

Keywords: *Safebite, Multi-Purpose Machine, Dryer, UV Sterilization, Drying Ability, Antibacterial Ability, Staphylococcus aureus, Escherichia coli, Colony-Forming Units, Sanitation, Drying*

Introduction

Foodborne illness, commonly referred to as food poisoning, can arise from consuming contaminated food. Any contamination signifies the presence of a potentially harmful organism, such as a bacteria, virus, fungus, or parasite. Sometimes the dangerous compounds produced by these microorganisms can cause food poisoning. (Scallan, Hoekstra, Angulo, Tauxe, Widdowson, Roy, Jones, & Griffin, 2011). Foodborne sickness is a constant danger that can be avoided by handling food products with care. The most frequent type of food poisoning is caused by bacteria, yet only a small percentage of the thousands of different types of bacteria cause it. (CDC, 2019). Poisoning is the harmful effect that occurs when a poisonous substance is consumed, inhaled, or meets the skin, eyes, or mucous membranes, such as those in the mouth or nose. Potential toxicants include prescription and over-the-counter drugs, illicit substances, gases, chemicals, vitamins, food, mushrooms, plants, and animal poisons. (Aljamali, 2021).

In addition to being a mutagen and non-specific damaging agent, UV radiation is classified as a "complete carcinogen" since it possesses the properties of both a tumor initiator and a tumor promoter. When it comes to abundance in the environment. For many other skin disorders, including skin cancer, UV exposure is the greatest modifiable risk factor. Although ultraviolet radiation has a variety of complex effects on human health, it also benefits people by promoting the skin's natural production of vitamin D and endorphins. (D'Orazio, Jarret, Amaro-Ortiz, & Scott, 2013). Whether pulsed UV radiation was more bactericidal than continuous UV was still up for discussion. The purpose of this study was to compare the disinfecting efficacy of UV light that was pulsed and continuous at different frequencies. (Luo, Chen, Chen, Dong, & Hou, 2014).

One of the most significant and ancient unit activities, drying is the process of removing a liquid from a substance. It has been employed for thousands of years on a wide range of materials, including wood, coal, paper, biomass, wastes, and foods. (Michailidis & Krokida, 2014). By forcing heated air through food to prevent the formation of bacteria and enzymes, food dehydration is the process of eliminating water from food. Dried foods are delicious, wholesome, portable, simple to make, and convenient to use and store (Ahmed, Singh, Chauhan, Anjum, & Kour, 2013). While solids are sulfated, soaked in solutions of various chemicals, dewatered by osmosis, blanched, frozen, or treated under high pressure, liquids are vacuum concentrated, treated with enzymes, or foamed. The pre-treated material can be dried at normal pressure or in a vacuum. Drying material may be heated either volumetrically or surface-wise, and it may be stationary or in motion. The degree of drying process completion determines the storage stability of a dried substance. All these processes' effects on the finished product's quality are examined. It is demonstrated that a complete grasp of all the processes affecting quality is required to design a hot air-drying process. (Lewicki, 2006).

Objectives of the Study

This project combined a dryer and sterilization machine that could create a new space for food and health safety. As this project progresses, this lessens the risk of food poisoning caused by multiple microbes and viruses that could be lethal if not taken seriously. Specifically, it performed the following tasks:

1. Design a multipurpose dryer and sterilizing device for efficient moisture removal and elimination of bacteria and viruses in food items.
2. Test the drying ability of the designed drying and UV sanitation machine.
3. Test the antibacterial ability of the designed drying and UV sanitation machine.

Research Questions

Guided by the objectives of the study, the researchers sought answers to these scientific questions:

1. How is a multipurpose dryer and sterilizing device for efficient moisture removal and elimination of bacteria and viruses in food items designed?
2. What is the drying ability of the designed drying and UV sanitation machine?
3. What is the antibacterial ability of the designed drying and UV sanitation machine?

Research Gap

There is a need for an innovative UV sanitation and dryer machine that can effectively kill bacteria and viruses while also serving as a dryer for various food items. This machine would help to prevent the spread of antibiotic-resistant bacteria and other pathogens in the population and the discharge of toxic components into the environment (Wetsus, 2023). Additionally, it would help to achieve sustainability objectives such as water reuse, recovery of resources, and energy savings within SSS.

Currently, there are various methods for water treatment and disinfection, such as chemical-free UV-based advanced oxidation technologies and instruments and methods for fast and simple process validation on log removal and log inactivation values (Wetsus, 2023). However, there is a lack of sensitivity of operational monitoring which may reduce the log credits that can be claimed.

In terms of drying technology, there is a need for a machine that can effectively dry various food items while also serving as a sanitizer. This machine would help to prevent the spread of bacteria and viruses in food products, thereby improving food safety and reducing the risk of foodborne illnesses.

In conclusion, there is a need for an innovative UV sanitation and dryer machine that can effectively kill bacteria and viruses while also serving as a dryer for various food items. This machine would help to prevent the spread of antibiotic-resistant bacteria and other pathogens in the population and the discharge of toxic components into the environment, while also achieving sustainability objectives such as water reuse, recovery of resources, and energy savings. Additionally, it would help to improve food safety and reduce the risk of foodborne illnesses.

Scope and Delimitation of the Study

To bridge the research gap stated, the current researchers were encouraged to innovate their study by combining the importance of UV Sanitation and Dryer in one machine. This is to limit the risk of food poisoning that has been prevalent in these modern times, especially in food handling and safety.

Additionally, this study began with the preparation and gathering of materials needed which were collected in Maasim, Sarangani Province. Next, the researchers cut the plyboard they used as the body of their machine. After that, they assembled the whole body of the machine, along with adding a glass pane to observe what was happening inside and adding a small water-catching drawer to limit the spread of water inside the machine.

Furthermore, the installation of the UV Lights and Dryer was done along with the wiring to obtain its functionality and efficiency. Additionally, the whole internal part of the machine was covered with an insulation foam to isolate the sanitation and drying process inside the machine. Finally, the researchers tested the drying and antibacterial abilities of the machine.

The final output of the innovation was endorsed to the school administrators for approval of its use in the school among the students and teachers. Finally, the study was conducted in the academic year *2023-2024*.

Significance of the Study

To Environmental Science, this study holds significant implications for environmental science by potentially reducing the need for chemical preservatives in food processing, thereby minimizing environmental pollution and ecological impact.

To Policy Implication, the findings of this study could inform the development of policies and regulations aimed at promoting the adoption of innovative technologies in food processing, ultimately enhancing food safety standards and public health.

To STEM students, this research offers valuable insights into the interdisciplinary field of food science and technology, providing STEM students with opportunities to explore cutting-edge methods and technologies for improving food safety and efficiency.

To the Community (including school), by fostering the adoption of combination dryer and sterilization machines, this study contributes to safeguarding community health by ensuring the production of safer and more wholesome food products, thereby enhancing overall food security and well-being.

Conceptual Framework of the Study

UV sanitation is a non-thermal processing technique that uses UV light to inactivate microorganisms on the surface of food. The UV light damages the DNA of microorganisms, preventing them from reproducing and causing foodborne illnesses. The effectiveness of UV sanitation depends on the intensity and duration of UV exposure, as well as the type of microorganism and the food matrix. Drying is a preservation technique that reduces the water activity of food, inhibiting the growth of microorganisms and extending the shelf life of food. Drying can be achieved through various methods, including thermal drying, solar drying, and mechanical drying. The choice of drying method depends on the type of food, the desired quality attributes, and the available resources.

The integration of UV sanitation and drying machines can provide a synergistic effect on the microbial safety and quality of food. UV sanitation can be applied before or after drying to inactivate microorganisms on the surface of food. The drying machine can reduce the water activity of food, inhibiting the growth of microorganisms and enhancing the stability of the UV sanitation effect. The optimization of UV sanitation and drying machines involves the optimization of the UV intensity, duration, and wavelength, as well as the drying temperature, time, and method. The optimization can be achieved through experimental design, mathematical modeling, and simulation.

The evaluation of the UV sanitation and drying machine involved the drying and antibacterial abilities. Figure 1 depicts the framework used by the researchers for this study.

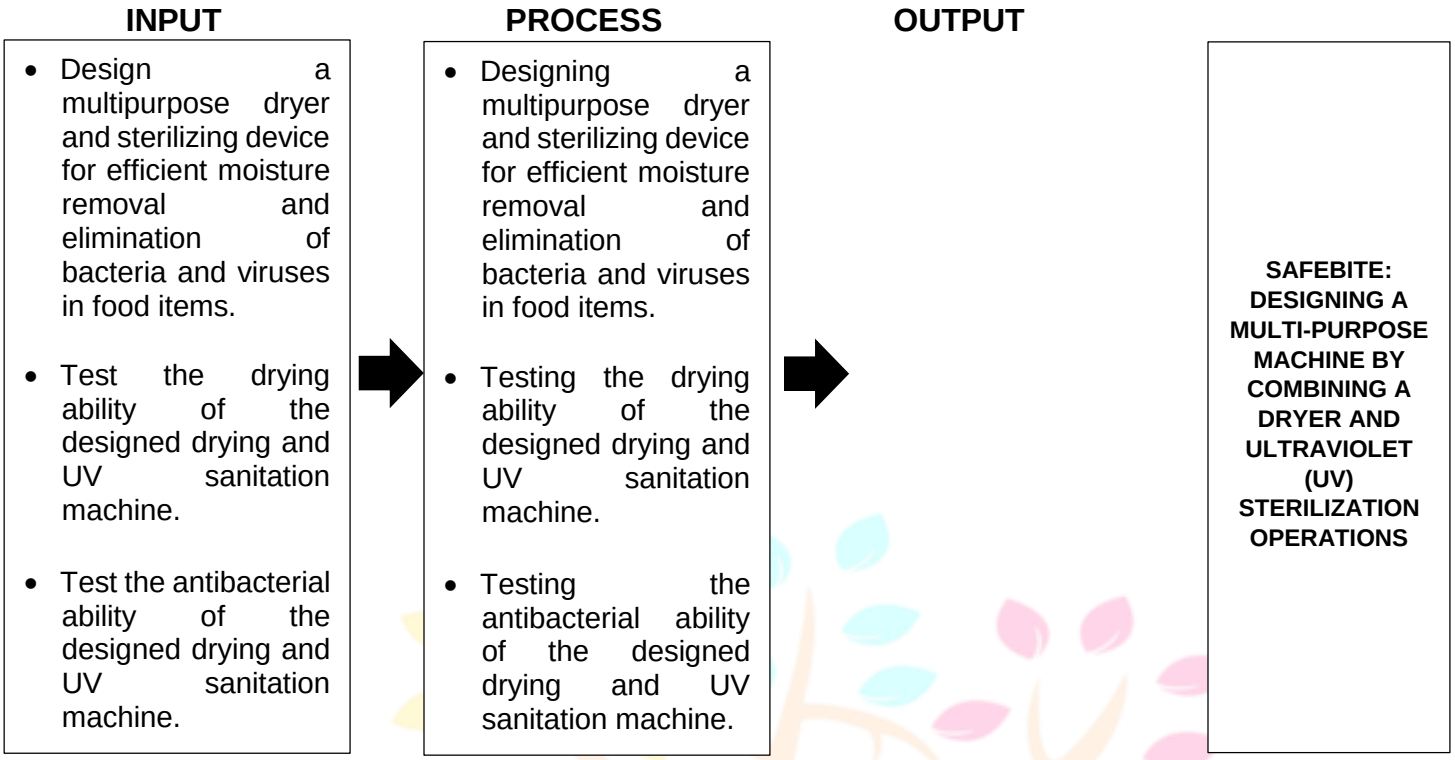

Figure 1. The Conceptual Framework

Research Design

This study employed the quantitative method, particularly the true experimental design. Utilizing this design helped the researchers in designing a combined dryer and Ultraviolet (UV) sterilization machine. According to Pubrica-Academy (2022), a sort of scientific inquiry known as experimental research involves changing one or more independent variables before applying them to one or more dependent variables to see how they influence the former. To help researchers understand the link between these two types of variables, the influence of independent factors on dependent variables is routinely observed and tracked through time. Furthermore, Experimental research designs, which are frequently related to laboratory test processes, involve gathering quantitative data and analyzing it as the study is being conducted.

Procedures

A. Gathering of Materials

The researchers gathered the needed materials for the making of the drying and UV sanitation machine through online and physical means. This means that materials such as UV lights, timers, and dryers were bought online due to their scarcity in the locality. However, plyboards, insulation foam, racks, and other materials were bought at the hardware.

B. Construction of Machine

The gathered materials were constructed by cutting the plyboard according to its needed dimensions, then adding the dryer fan, UV light, and switch in the machine then followed by installing the rack and adding a catch to capture excess water under the machine.

C. Testing the Drying Ability

The researchers tested one (1) the drying ability of the developed machine. By this method, the researchers set a timer based on the recommended time for drying in the timer i.e. *20-60* minutes. Next, a piece of kitchen material/fruit/vegetable was placed inside the machine after being washed/rinsed. The researchers waited until there was no presence of water on the surface of the medium.

D. Media Preparation

The researchers prepared two types of growth media suitable for the growth of both *S. aureus* and *E. coli*. Common media for this purpose included nutrient agar or tryptic soy agar. Next, they sterilized the growth media by autoclaving according to standard protocols. Then, they poured the sterilized media into Petri dishes or test tubes and allowed them to solidify.

E. Bacterial Inoculation/Preparation for UV Sterilization Protocol

Using a sterile technique, the researchers inoculated one set of Petri dishes with a known amount of *S. aureus* bacterial culture. This involved streaking the bacteria onto the surface of the agar using a sterile loop. Similarly, they inoculated another set of Petri dishes with a known amount of *E. coli* bacterial culture using a separate sterile loop. Next, they ensured that the bacterial cultures were evenly spread across the surface of the agar plates to facilitate uniform exposure to UV light. Then, they inoculated each agar plate or test tube with a bacterial suspension containing approximately *100* microliters (µL) or *0.1* milliliters of the bacterial culture. For *S. aureus* and *E. coli*, a common approach is to inoculate the agar plates with a bacterial suspension containing approximately *10^5* colony-forming units (CFUs) per milliliter (CFU/mL). This concentration allows for enough bacteria to be present on the agar surface for effective UV exposure and subsequent assessment of UV sanitation effectiveness.

F. UV Exposure

The researchers placed the inoculated Petri dishes in a UV sterilization chamber or under a UV lamp emitting light at a wavelength of *254*nm, which is effective for microbial sterilization. Next, they exposed the plates to UV light for a specified duration. This duration can vary depending on the intensity of the UV light source and the desired level of sterilization. Common exposure times range from a few seconds to several minutes. Then, they ensured that the distance between the UV light source and the plates was consistent for all samples to maintain uniform exposure. For *S. aureus* and *E. coli,* it was recommended to expose plates with bacterial culture within a span of *15-30* minutes and *30-60* minutes, respectively.

G. Control Group Preparation

The researchers prepared the control plates for both *S. aureus* and *E. coli* by inoculating Petri dishes with the same amount of bacterial culture but without exposing them to UV light. These control plates served as a baseline for comparison to assess the effectiveness of UV sterilization.

H. Post-Exposure Incubation:

After UV exposure, the researchers incubated all the plates, including the control plates, at the appropriate temperature (usually around *37*°C) for the growth of *S. aureus* and *E. coli*. They incubate the plates for *24* to *48* hours to allow bacterial growth and colony formation.

I. Evaluation of the Antibacterial Activity

After the incubation period, the researchers observed the plates for bacterial growth. The effectiveness of UV sterilization was assessed by comparing the number and size of bacterial colonies on the exposed plates to those on the control plates. A significant reduction or absence of bacterial growth on the UV-exposed plates compared to the control plates indicated the effectiveness of UV sanitation in eliminating or reducing bacterial contamination.

To calculate the colony-forming units (CFUs) per unit volume of the original bacterial culture, these general steps were followed:

1. Count the colonies: Count the number of colonies on the agar plate. Ensure you count only well-isolated colonies, as overlapping colonies can skew the results.
2. Determine the dilution factor: If you plated a diluted bacterial sample (e.g., a *1*:*10* or *1*:*100* dilution), consider the dilution factor used during plating. For example, if you plated *0.1* mL of a *1:100* dilution onto the agar plate, the dilution factor would be *100*.
3. Apply the dilution factor: Multiply the number of colonies counted by the reciprocal of the dilution factor. This corrects for the fact that you plated only a fraction of the original sample.

$$CFUs/mL = \frac{\text{Number of Colonies Counted} \times \text{Dilution Factor}}{\text{Volume Plated (in mL)}}$$

Figure 2. The Formula in Finding the Colony-Forming Units per mL

Low CFU counts after UV sterilization suggest that the UV treatment was effective in reducing the number of viable bacteria. It indicates that the UV radiation successfully killed or inhibited the growth of a significant portion of the bacterial population. For *S. aureus* and *E. coli*, a low CFU count post-UV

sterilization indicates a successful reduction in the number of surviving bacteria, contributing to a safer environment or product.

However, High CFU counts after UV sterilization indicate that the treatment may not have been as effective in reducing the number of viable bacteria. It suggests that a significant portion of the bacterial population survived the UV exposure, potentially leading to continued microbial contamination or growth.

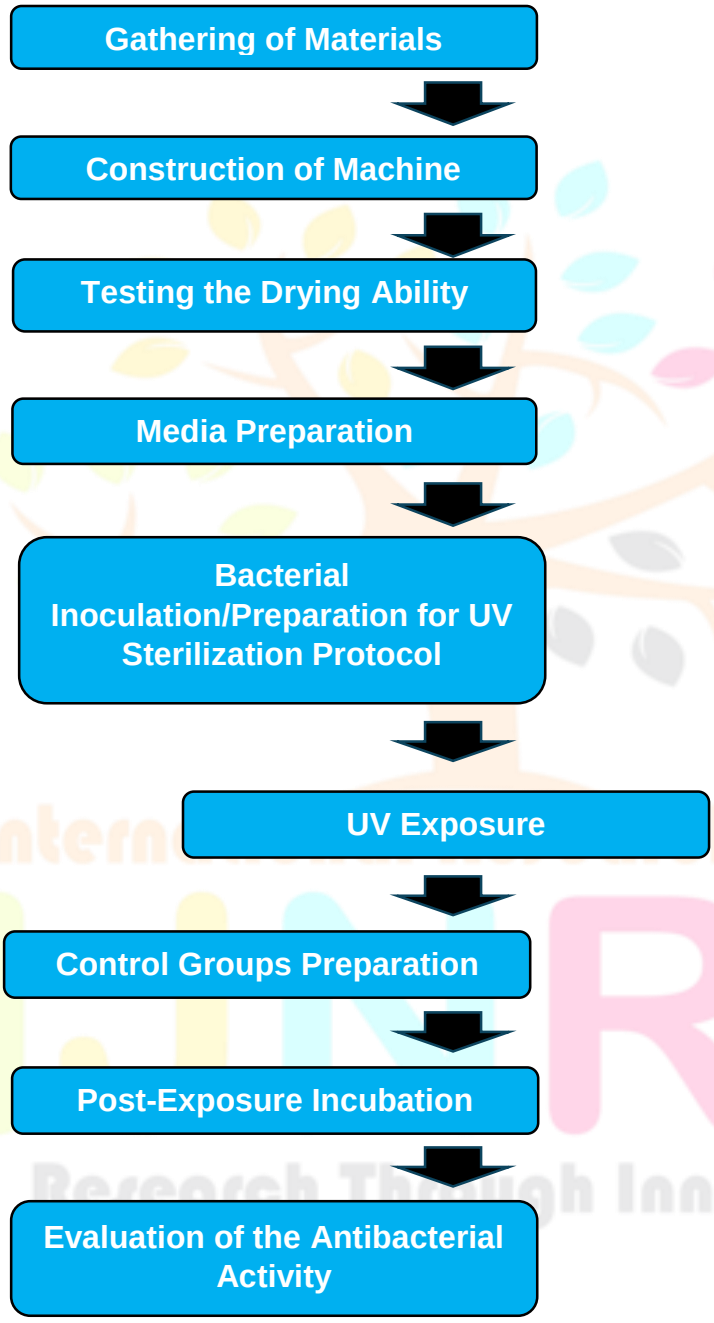

Figure 3. The Procedure Flow Chart

RESULTS AND DISCUSSIONS

This chapter deals with the presentation, analysis, and interpretation of data. The results are presented in the succeeding tables and arranged according to the tasks and sub-problems.

Designing the Machine

This study utilized the integration of a dryer and a UV sterilization in one mechanism. This aimed to provide access and convenience when it comes to its functionality and usage. First, the researchers gathered the needed materials, tools, and paraphernalia that were used in the conduct of this study. Second, the researchers then assembled the body structure of the machine by cutting and scraping excess parts to follow the exact measurements in the diagram. Third, the researchers then added two (*2*) dryer fans on each side, five (*5*) *254*nm Ultraviolet (UV) lights on top of the machine, two (*2*) switches, and a timer.

Drying Ability of the Machine

After the assembly of the machine, the researchers then tested the drying ability of the machine. First, the materials were washed on room-temperature tap water. Second, after the washing, damp materials were placed on the rack inside the machine. Third, the dryers were turned on to test their drying ability. Table *1* shows the results of the drying ability of the machine.

Table 1. Materials Tested Under Uniform Temperature and Time of Drying

MATERIALS TESTED	TEMPERATURE	TIME OF DRYING
Wet Handkerchief	37°C	25 minutes
Wet Plastic Cup		20 minutes
Wet Fruit (Apple)		17 minutes

In the table above, it is shown that the wet fruit dries faster compared to a wet plastic cup and wet handkerchief as evidenced by its drying time of *17* minutes, *20* minutes, and *25* minutes, respectively upon exposure to the drying machine. This implies that the faster drying time of the fruit suggests it has a lower water retention capacity compared to the plastic cup and handkerchief. Fruits, being organic and porous, allow water to evaporate more quickly. Further, the drying machine appears to be more effective on organic and porous materials. This insight may help in adjusting settings or methods for drying different types of materials more efficiently (UI Prospector Knowledge Center, 2008).

Moreover, designers of drying machines may use this data to improve machine performance across different materials. It may also influence the design of products that need to be dried quickly. Also, faster drying times generally mean lower energy consumption, which can be environmentally beneficial.

Optimizing drying processes for different materials can contribute to more sustainable practices (UI Prospector Knowledge Center, 2008).

Antibacterial Effectiveness of the Machine

After testing its drying ability, the researchers then proceeded with testing the antibacterial effectiveness of the developed combined dryer and sterilizing machine using UV light. First, the researchers cultured different samples of bacteria, i.e., *S. aureus* and *E. coli*. Second, after the media preparation, samples underwent a sterile diffusion. Third, the researchers inoculated four (*4*) Petri dishes with *S. aureus* and four (*4*) Petri dishes with *E. coli* on agar plates with *100* microliters of *0.1* milliliters of bacterial culture. Fourth, the six (*6*) inoculated Petri dishes (positive controls) were placed inside the SAFEBITE machine with UV light, emitting light at a wavelength of *254*nm, ideal for microbial sterilization. While the other two (*2*) Petri dishes (negative controls) were placed on the table (outside the SAFEBITE machine).

Fifth, all the Petri dishes both the positive and negative controls, after their exposure and non-exposure to UV light, respectively, were placed in the incubator at an appropriate temperature (usually around *37*°C) for the growth of *S. aureus* and *E. coli*, then incubated the plates for *18* to *24* hours to allow bacterial growth and colony formation. Sixth, the researchers evaluated the number of colony-forming units (CFUs) to observe whether or not there was growth of bacteria. Table *2* shows the comparative results on the number of CFUs present in different samples.

Table 2. Comparative Results of Colony-Forming Units of Bacteria Used at Varying Time Frames of Both Positive and Negative Controls

Bacteria Used: *Staphylococcus aureus*			
Plate No.	**Time of Exposure (in minutes)**	**Temperature of Incubation**	**Colony-Forming Units (in CFUs)**
Positive Control (*S. aureus exposed to UV Sterilizer)*	15	37°C	0
Positive Control (*S. aureus exposed to UV Sterilizer)*	30		0
Positive Control (*S. aureus exposed to UV Sterilizer)*	60		0
Negative Control (*S. aureus not exposed to UV Sterilization)*	60		50
Bacteria Used: *Escherichia coli*			
Plate No.	**Time of Exposure (in minutes)**	**Temperature of Incubation**	**Colony-Forming Units (in CFUs)**
Positive Control (*E. coli exposed to UV Sterilizer)*	30	37°C	0

Positive Control (*E. coli exposed to UV Sterilizer)*	60		0
Positive Control (*E. coli exposed to UV Sterilizer)*	60		0
Negative Control (*E. coli not exposed to UV Sterilization)*	60		10

The above table shows that all the positive controls, i.e., *S. aureus* and *E. coli* (all exposed to UV light through the SAFEBITE machine) at varying time frames indicated no presence of CFU as demonstrated by the numerical data, which is 0, while all the negative controls (non-exposure to UV light) indicated CFU which is *50* for *S. aureus* and *10* for *E. coli*.

This means that the SAFEBITE machine's UV light effectively eliminates both *S. aureus* and *E. coli*, as evidenced by the complete absence of CFUs in the exposed samples. This suggests a high level of efficacy in sterilizing surfaces or items contaminated with these bacteria. Since the UV light effectively kills both Gram-positive (*S. aureus*) and Gram-negative (*E. coli*) bacteria, it indicates that the UV light has a broad-spectrum antimicrobial action. Further, the ability of UV light to eliminate bacteria so effectively can be crucial in healthcare settings for controlling the spread of infections. It suggests potential applications in sterilizing medical instruments, surfaces, and environments where pathogens are a concern.

These results support the observation of Lu, Li, Wei, Cai, Yang, and Zhang (2022) that UV sterilization can eliminate the growth of *E. coli* and *S. aureus* within *15-60* minutes, as evidenced by the CFU counts of *0* on the treated plates compared to the higher counts on the negative controls.

In summary, the results provide strong evidence of the SAFEBITE machine's effectiveness in killing bacteria through UV light exposure, with wide-ranging implications for healthcare, sanitation, product development, research, regulatory considerations, and economic impact.

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This part deals with the summary of findings, conclusions, and recommendations.

Summary of Findings

The pressing struggles in terms of food and health safety encountered by the public are alarming and need to be addressed. Therefore, the researchers developed dryer and UV sterilization machine that aims to provide safe and cost-efficient substitution against commercial machines. It was successfully utilized by integrating a dryer with an electric requirement of *220*V, and UV light with an emission of *254*nm. This manual machine operates using electric power that can suffice the needed electric charge for the machine.

Furthermore, the researchers tested its drying ability to manifest its efficacy in eliminating excess water on the surface of a material, which is a breeding point for microbes and pathogens. The researchers tested its drying ability using three common materials, i.e. plastic cups, fruit, and a piece of handkerchief that is being washed thoroughly. After such a drying process, it was shown that upon exposure to two dryers, the apple dried fastest with a time of drying of *17* minutes. It was followed by the plastic cup at *20* minutes, and finally the handkerchief at *25* minutes.

Moreover, after testing its drying ability, the researchers tested its antibacterial efficacy. First, the researchers cultivated different samples of *S. aureus* and *E. coli* to test their antibacterial activity. Second, after the media preparation, samples underwent a sterile diffusion. Third, the researchers inoculated four (*4*) Petri dishes with *S. aureus* and four (*4*) Petri dishes with *E. coli* on an agar plate with *100* microliters of *0.1* milliliters of bacterial culture. Fourth, the inoculated Petri dishes were placed inside the machine with UV light, emitting light at a wavelength of *254*nm, which is effective in microbial sterilization. Fifth, after exposure in different time frames, the inoculated Petri dishes were placed on the incubator at an appropriate temperature (usually around *37*°C) for the growth of *S. aureus* and *E. coli*, then incubate the plates for *18* to *24* hours to allow bacterial growth and colony formation. Sixth, the researchers evaluated the number of colony-forming units (CFUs) to observe whether or not there was growth of bacteria.

In respect of the bacteria *S. aureus,* both plates *1*, *2*, and the positive control shows that the UV sterilization can eliminate the growth of the bacteria *S. aureus,* with a CFU count of *0*. Unlike the negative control with *50* CFUs, which is higher than the rest of the samples of *S. aureus,* it proves that within *15-60* minutes, bacterial growth of *S. aureus* can be eliminated using the UV sterilizer.

Along with this, in respect of the bacteria *E. coli,* both plate *1*, *2*, and the positive control shows that the UV sterilization can eliminate the growth of the bacteria *E. coli,* with a CFU count of *0*. Unlike the negative control with *10* CFUs, which is higher than the rest of the samples of *E. coli,* it proves that within *30-60* minutes, bacterial growth of *E. coli* can be eliminated using the UV sterilizer.

Conclusion

The study successfully provided the efficacy of a combined dryer and UV sterilization machine in both drying various materials and eliminating bacterial pathogens. The machine's drying capability effectively reduced moisture from different items within a range of *17* to *25* minutes, with apple drying the fastest and handkerchiefs the slowest. Additionally, the UV sterilization component proved highly effective, with complete eradication of *Staphylococcus aureus* and *Escherichia coli* observed within *15* to *60* minutes of exposure, as evidenced by zero CFU counts on treated samples. These results underscore the machine's potential as a convenient and efficient tool for drying and sterilizing household items, providing a significant advancement in home sanitation technology.

Recommendations

With the findings and the conclusions, the researchers do hereby recommend the following:

1. Integrate sensors and smart technology to automate the drying and sterilization process using Arduino-based technology.
2. Incorporating energy-saving technologies, such as more efficient UV lights and fans, could reduce power consumption. Solar-powered options or the use of renewable energy sources could also be explored to make the machine eco-friendlier.
3. Venture on using tools that need sterilization aside from kitchen material i.e. smartphones, bags, etc.
4. Future researchers could include the ability to eliminate a wider range of pathogens, including viruses, fungi, and spores. Research and development could focus on optimizing UV wavelength and exposure times for broader microbial efficacy.

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