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Hygienic Cutlery Caddy

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Abstract

This study developed and evaluated a Hygienic Cutlery Caddy designed to improve utensil sanitation through touch-free dispensing, UV-C sterilization, and battery-powered operation. Guided by the integration of automation technology, Food Safety Culture, and the Input–Process–Output (IPO) model, the study employed both developmental and descriptive research designs. The device was designed, fabricated, tested, and refined before being evaluated in three food establishments in Kidapawan City. Thirty purposively selected respondents assessed the device's acceptability using a researcher-made, expert-validated questionnaire with a five-point Likert scale, while its efficiency was evaluated through an observation checklist. Microbial performance was assessed using an Aerobic Plate Count (APC) test that compared washed utensils with utensils sterilized using the Hygienic Cutlery Caddy. The findings showed that the prototype successfully integrated automated sensing, controlled dispensing, and UV-C sterilization into a durable utensil management system. The device demonstrated efficient sensing and dispensing performance and achieved a Highly Acceptable overall rating (weighted mean = 4.77), indicating positive user perceptions regarding hygiene, convenience, and functionality. Laboratory testing further showed that washed utensils produced 7 colony-forming units (CFU), whereas UV-C-treated utensils showed 0 CFU, demonstrating the effectiveness of UV-C sterilization in reducing microbial contamination. However, the dispensing mechanism occasionally released multiple utensils when several spoons or forks were loaded simultaneously, limiting the evaluation to one spoon and one fork at a time. Overall, the Hygienic Cutlery Caddy proved to be an effective and highly acceptable innovation for promoting hygienic utensil handling in food service settings. Future improvements should focus on enhancing the dispensing mechanism, cartridge alignment, sensor calibration, and mechanical controls to further improve the device's reliability and performance.This study supports Sustainable Development Goal (SDG) 3: Good Health and Well-Being, SDG 9: Industry, Innovation and Infrastructure, and SDG 12: Responsible Consumption and Production by promoting safer food handling through an innovative sanitation device. The study contributes to public health, technological, institutional, and community sustainability by improving hygiene practices, reducing contamination risks, and supporting the adoption of practical sanitation technologies in food service environments.

Keywords: Acceptability, Food Safety, Hygienic Cutlery Caddy, Microbial Contamination, Touch-Free Dispensing, UV-C Sterilization

1. Introduction

The increasing demand for technological innovation has encouraged the development of solutions that address sanitation challenges in the food service industry. Despite advances in food preparation and service, improper utensil handling and inadequate sanitation continue to contribute to food-borne illnesses. Contaminated utensils remain a significant source of microbial transmission, emphasizing the need for safer and more hygienic food service practices. The proposed Hygienic Cutlery Caddy integrates touch-free dispensing, UV-C sterilization, and battery-powered operation to minimize hand contact, reduce microbial contamination, and improve sanitation in food establishments while providing a practical and sustainable utensil management system (World Health Organization, 2022; Sultana and Tehseen, 2021; Alves et al., 2021; Castro et al., 2024).

1.1 Hygienic Cutlery Caddy for Safe and Sanitary Utensil Distribution

Food-borne illnesses remain a major public health concern despite continuous technological advancements. The World Health Organization (2022) reported that millions of deaths each year are associated with diarrheal diseases linked to contaminated food and utensils. Poor sanitation practices among food handlers contribute significantly to microbial contamination in food establishments (Sultana and Tehseen, 2021). Likewise, Alves et al., (2021) identified high microbial contamination on utensils and food-contact surfaces due to improper handling and storage. Castro et al., (2024) further emphasized that repeated manual handling of utensils increases the spread of microorganisms, highlighting the importance of touch-free dispensing systems. To address these concerns, this study developed a Hygienic Cutlery Caddy equipped with a proximity sensor, UV-C sterilization, and a battery-operated system. The innovation aims to reduce direct hand contact, improve utensil sanitation, and provide a safe, efficient, and portable dispensing system suitable for food establishments.

1.2 Themes and Insights on Hygienic Cutlery Caddy Design and Food Safety

Previous studies consistently demonstrate that hygienic utensil dispensing and proper sanitation reduce contamination risks in food service operations. Touch-free dispensing systems effectively minimize direct contact during utensil retrieval (Snyder et al., (2017)), although many existing devices lack integrated sterilization mechanisms. Smith (2020) likewise observed that conventional dispensers remain vulnerable to contamination through manually operated components, indicating the need for more hygienic and efficient designs. Research further shows that improperly sanitized cutlery commonly harbors pathogens including Escherichia coli, Staphylococcus aureus, Salmonella spp., and Pseudomonas spp.. Studies conducted by Akwila et al., (2022), Putri and Maulida (2024), and Okoye et al., (2023) revealed that reusable utensils frequently exceed acceptable microbial standards due to inadequate cleaning, drying, and storage. Studies by Rahimi et al., (2020), Viana et al., 2023, Moreira et al. (2021), and Microbial Status and Sanitation Level of Food Contact Surfaces (2024) further confirmed that food-contact surfaces often contain harmful microorganisms despite conventional cleaning, reinforcing the importance of improved sanitation technologies. Existing cutlery dispensers emphasize organized storage and controlled dispensing but generally lack UV sterilization, motion sensors, touchless operation, and integrated power systems (Smith, (2011); Vending Times (2022)). Advances in battery technology (International Energy Agency, 2021), UV-C sterilization (Kim and Kang (2020); Di Cerbo et al., (2021); Liang et al., (2021); Lee et al., (2022)), motion sensor technology (CWS Hygiene, 2022), and automated dispensing systems (BioMed Central, 2020; Gibson et al., (2020)) provide strong support for integrating these technologies into a single hygienic dispensing device. Laboratory evidence also demonstrates that Aerobic Plate Count and colony-forming unit analyses remain reliable indicators of sanitation quality (U.S. Food and Drug Administration (FDA), 2023; Madigan et al., 2021; Waldhans et al. (2023)). These findings collectively support the development of a portable, battery-operated, UV-C sterilized Hygienic Cutlery Caddy capable of improving food safety and reducing microbial contamination.

1.3 Global and Local Context of Hygienic Utensil Sanitation

Globally, microbial contamination of food-contact surfaces remains a major food safety concern. Studies conducted across Indonesia, Nigeria, South America, Egypt, and other countries consistently report bacterial contamination of reusable utensils and food-contact surfaces despite routine cleaning (Akwila et al., (2022); Putri and Maulida (2024); Okoye et al., (2023); Viana et al., 2023; Moreira et al. (2021)). These findings demonstrate the continuing need for improved sanitation technologies that reduce contamination risks in food service environments. Current cutlery dispensing technologies provide organized storage and controlled dispensing but generally rely on manual operation and lack integrated sterilization, touchless activation, and battery-powered portability (Smith, (2011); Vending Times (2022)). These limitations provide opportunities for developing more effective sanitation systems capable of meeting current food safety standards.

1.4 Theoretical and Conceptual Basis of the Hygienic Cutlery Caddy

This study is anchored on the integration of automation technology, UV-C disinfection, and food safety principles to improve sanitation and efficiency in utensil handling. UV-C LED technology has been proven effective in reducing harmful microorganisms on food-contact surfaces. Wand et al. (2024) demonstrated that handheld UV-C LED devices significantly reduce microbial contamination, with effectiveness influenced by exposure time and surface characteristics. Likewise, modern cutlery dispensing systems improve utensil organization and dispensing efficiency but generally lack integrated sterilization and automation features required for enhanced microbial control (Novolex, 2019). The study is further guided by the Food Safety Culture, which emphasizes that food hygiene depends on the collective attitudes, practices, and behaviors of individuals involved in food service operations. According to Ermeje, et al (2025), maintaining consistent hygienic practices—including proper cleaning, disinfection, and storage of utensils—reduces contamination risks and strengthens food safety. Similarly, Palupi, et al (2021) stressed that proper washing, drying, and hygienic storage are essential in minimizing microbial transmission. Guided by these principles, the Hygienic Cutlery Caddy integrates battery-powered UV-C sterilization and motion-activated dispensing to promote hygienic, touch-free, and efficient utensil management. Conceptually, the study follows the Input–Process–Output (IPO) model. The inputs consist of design concepts, references, materials, tools, and equipment. The process includes designing, fabricating, testing, revising, laboratory evaluation, and performance assessment. These processes produce the Hygienic Cutlery Caddy as the final output, demonstrating the systematic development of an automated sanitation device.

1.5 Research Gaps and Rationale

Previous studies have demonstrated the effectiveness of touch-free dispensing systems in minimizing utensil contamination (Snyder et al., (2017); Smith (2020)). Likewise, research has consistently shown that reusable utensils remain vulnerable to microbial contamination due to inadequate cleaning and storage practices (Akwila et al., (2022); Putri and Maulida (2024); Okoye et al., (2023); Moreira et al. (2021)). Although existing cutlery dispensers provide organized storage and controlled dispensing, they generally lack integrated UV sterilization, motion-sensor activation, touchless operation, and battery-powered portability. The review of prior technologies also revealed that existing dispenser designs incorporate separate compartments, hygienic covers, and large storage capacities, but most rely on manual dispensing and do not include UV sterilization, motion detection, touchless operation, or independent power sources. These limitations indicate the need for a more comprehensive sanitation system that combines automatic dispensing, UV-C sterilization, and battery-powered operation to improve food safety while maintaining user convenience. This study addresses these gaps through the development and evaluation of the Hygienic Cutlery Caddy, which integrates these features into a single hygienic dispensing system.

1.6 Alignment with Relevant Sustainable Development Goals (SDGs)

This study primarily supports SDG 3 – Good Health and Well-Being by promoting safer food handling practices and reducing the risk of food-borne illnesses through improved utensil sanitation. The integration of UV-C sterilization and touch-free dispensing contributes to healthier dining environments by minimizing microbial contamination. The study also aligns with SDG 9 – Industry, Innovation and Infrastructure through the development of an innovative battery-operated hygienic cutlery dispenser that integrates automation, sensor technology, and UV-C sterilization to improve sanitation in food service operations. In addition, the battery-powered design and efficient UV-C disinfection system support SDG 12 – Responsible Consumption and Production by encouraging efficient resource utilization, promoting hygienic food service practices, and reducing reliance on chemical disinfectants while improving operational efficiency.

1.7 Importance of the Study to Multidisciplinary Sustainability

The study contributes to public health sustainability by promoting safer utensil handling practices that help reduce microbial contamination and food-borne diseases in food establishments. It also supports technological sustainability through the integration of automation, UV-C sterilization, battery-powered operation, and sensor technology into a practical sanitation device. From an institutional and community sustainability perspective, the Hygienic Cutlery Caddy provides food establishments with a reliable method of improving hygiene standards, strengthening consumer confidence, and supporting compliance with food safety practices. Furthermore, the study contributes to innovation sustainability by providing future researchers and developers with a practical foundation for advancing automated sanitation technologies and hygienic food service systems. These contributions demonstrate the potential of the innovation to enhance food safety, operational efficiency, and sustainable technological development within the food service industry.

2. Material and methods

2.1 Research Design

This study employed both developmental and descriptive research designs. The developmental design guided the design, fabrication, testing, and refinement of the Hygienic Cutlery Caddy, while the descriptive design evaluated its efficiency, hygiene, functionality, and acceptability. The Hygienic Cutlery Caddy was developed as a battery-operated, UV LED-equipped, and sensor-based automatic utensil dispenser. Its design established the structural layout and arrangement of the major components, including the utensil organizer, UV sterilization system, motion sensor, dispensing mechanism, battery compartment, and stainless-steel frame, to ensure proper assembly and operation. The prototype was fabricated using stainless steel materials, electronic components, UV LED lights, sonar sensors, an Arduino-based control system, and other necessary hardware, with a total project cost of Php 42,750.00, covering both materials and labor. Fabrication involved metalworking, electrical assembly, programming, and functional testing using appropriate tools and equipment. The construction process included planning, material preparation, fabrication, assembly, testing, revision, and final evaluation. Initial testing identified design limitations that were corrected by converting the open-top structure into an enclosed design, incorporating an OLED display, and replacing the UV tube light with a more efficient UV LED system, resulting in improved hygiene, functionality, and overall performance.

2.2 Locale of the Study

The study was conducted in Kidapawan City, where the Hygienic Cutlery Caddy was evaluated under actual food service conditions. The evaluation was carried out in Bogrit's Deli, Boylyn Pension Plaza, and Kuya Rey's Foodhouse and Catering Services because these establishments actively provide food services and offer appropriate settings for assessing the functionality, practicality, and performance of the developed device. The geographical distribution of these establishments within Kidapawan City further demonstrated their accessibility and suitability for conducting the field evaluation.

2.3 Respondents of the Study

The study involved thirty (30) purposively selected respondents from three food establishments in Kidapawan City. Each establishment was represented by ten (10) employees who regularly perform food service operations and utensil handling. Their direct experience enabled them to evaluate the functionality, hygiene, efficiency, and overall acceptability of the Hygienic Cutlery Caddy in actual workplace conditions.

2.4 Sample and Sampling Procedure

Purposive sampling was employed to select respondents with direct involvement in food service operations. This technique ensured that participants possessed relevant knowledge and experience in utensil handling, sanitation practices, and customer service, enabling them to provide informed evaluations of the Hygienic Cutlery Caddy. The device's sanitation performance was assessed through an Aerobic Plate Count (APC) test conducted by the Department of Science and Technology (DOST) Central Regional Office in Marbel. Two pairs of spoon and fork samples were examined: one pair was washed only, while the other was washed and sterilized using the Hygienic Cutlery Caddy. After incubation for 48 hours, colony-forming units (CFU) were counted to compare microbial contamination between the two treatments.

2.5 Research Instrument

A researcher-made questionnaire was used to evaluate the acceptability of the Hygienic Cutlery Caddy in terms of ease of use, convenience, design, hygiene, and overall user preference. The instrument was validated by experts and utilized a five-point Likert scale ranging from Highly Acceptable to Not Acceptable. Device efficiency, particularly the sensing and dispensing functions, was assessed separately using a researcher-developed evaluation checklist.

2.6 Data Gathering Procedure

Prior to data collection, permission was obtained from the selected food establishments, and informed consent was secured from all participants. Respondents were informed of the study's purpose, procedures, voluntary participation, confidentiality, and their right to withdraw at any stage. Data collection consisted of three activities: administering the acceptability questionnaire, evaluating the device's sensing and dispensing performance using an observation checklist, and conducting laboratory microbial testing to compare bacterial counts between utensils without UV exposure and those sterilized using the Hygienic Cutlery Caddy. The collected data were organized and prepared for statistical analysis to determine the device's efficiency, acceptability, and hygienic performance.

2.7 Data Analysis Techniques

The collected data were organized, tabulated, and analyzed using descriptive statistics. Frequency count, percentage distribution, and mode were used to summarize respondents' evaluations, while the five-point Likert scale provided the corresponding verbal interpretations of acceptability. Laboratory microbial test results were compared to determine the sanitation performance of the Hygienic Cutlery Caddy, providing the basis for evaluating its overall efficiency and acceptability.

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3. Results and Discussion

3.1 Performance Evaluation of the Hygienic Cutlery Caddy

3.1.1 Design and Construction of the Hygienic Cutlery Caddy

The Hygienic Cutlery Caddy was successfully designed and fabricated using computer-aided design (CAD) as the basis for its structural layout, dimensions, and component placement. The prototype incorporated stainless steel construction, a cutlery cartridge, UV LED sterilization, a sonar proximity sensor, servo motor, Arduino-based controller, and power supply. These mechanical and electronic components were integrated into a single automated system capable of detecting utensils, dispensing them individually, and providing UV-C disinfection. The completed prototype demonstrated a durable, hygienic, and automated utensil dispensing system suitable for food service establishments. The successful integration of stainless-steel construction with automated sensing, controlled dispensing, and UV-C sterilization demonstrates that the developed device achieved its intended design objectives. The combination of mechanical durability and automated electronic control provides a practical solution for improving food safety through hygienic utensil handling.

3.1.2 Efficiency of the Hygienic Cutlery Caddy in Sensing and Dispensing

The Hygienic Cutlery Caddy demonstrated efficient sensing and dispensing performance. After an initialization period of approximately three to five minutes, the sonar proximity sensor consistently detected utensils within an effective range of about 5 cm. The sensing response ranged from three to five seconds, with average sensing times of 3.95 seconds for spoons and 3.60 seconds for forks. The dispensing mechanism released one utensil per activation cycle, producing average dispensing times of 4.00 seconds for spoons and 3.60 seconds for forks. The system also activated UV-C sterilization before dispensing, ensuring hygienic utensil handling. The consistent sensing response and controlled dispensing indicate that the automated mechanism operated reliably under the testing conditions. The slight variation in response time may be attributed to environmental factors and sensor positioning, which are common in embedded automation systems (Kumar & Singh, 2021; Sharma et al., 2020). Likewise, the controlled release of one utensil at a time supports efficient dispensing while preventing mechanical jamming (Zhang & Li, 2019). Although UV-C sterilization served as a supplementary feature, its integration further enhanced hygienic performance by reducing microbial contamination through nucleic acid inactivation (Hessling et al., 2017).

3.2 Acceptability of the Hygienic Cutlery Caddy

The Hygienic Cutlery Caddy obtained an overall weighted mean of 4.77, interpreted as Highly Acceptable, indicating a consistently positive evaluation from respondents. The highest-rated indicator (4.90) showed that the device effectively reduced direct hand contact and minimized contamination risk. High ratings were also obtained for promoting hygienic practices and respondents' willingness to recommend the device (4.87 each). The lowest ratings, although still interpreted as Highly Acceptable, were recorded for suitability in public dining areas and time efficiency (4.67 each), suggesting opportunities for minor improvements. The consistently low standard deviations reflected a strong agreement among respondents regarding the device's overall performance. The high acceptability ratings indicate that respondents recognized the Hygienic Cutlery Caddy as an effective innovation for improving hygiene and convenience during utensil handling. These findings support the importance of minimizing direct hand contact in reducing contamination risks within shared food service environments (World Health Organization (WHO), 2020). Likewise, the highest-rated hygiene indicator reinforces evidence that limiting contact with shared utensils decreases microbial transmission (Kampf et al., 2020). The slightly lower ratings for time efficiency and adaptability suggest that improving dispensing speed and accessibility may further enhance user satisfaction while maintaining the device's hygienic benefits.

3.3 Microbial Performance of the Hygienic Cutlery Caddy

Laboratory testing revealed a clear difference in microbial contamination between washed utensils and those additionally treated with UV-C LED sterilization. The washed-only spoon and fork sample produced 7 colony-forming units (CFU) after 48 hours of incubation, whereas the sample exposed to UV-C LED light for five minutes showed 0 CFU, indicating complete elimination of detectable aerobic bacteria under the testing conditions. The presence of 7 CFU after washing alone indicates that conventional cleaning may reduce but not completely eliminate microorganisms from food-contact utensils, supporting the findings of Ismail et al. (2021). Since CFU represents viable microorganisms capable of reproduction (Madigan et al., 2021), the absence of detectable bacterial growth following UV-C treatment demonstrates the effectiveness of UV-C LED sterilization in improving utensil sanitation. These findings agree with previous studies showing that UV-C technology effectively inactivates microorganisms by damaging their DNA, thereby enhancing microbial reduction on food-contact surfaces (Dóka & Horák, 2025; Nyhan et al., 2021).

4. Conclusion & Recommendations

The Hygienic Cutlery Caddy was successfully designed and constructed and was found to be highly acceptable among the respondents. The device effectively promoted hygienic utensil handling by reducing direct contact and providing safe, organized, and sanitary storage. Its sensing and dispensing functions operated effectively during evaluation; however, the dispensing mechanism occasionally released multiple utensils after the initial activation when several utensils were loaded. Consequently, the evaluation was limited to one spoon and one fork at a time. Overall, the device demonstrated its suitability for use in schools, food establishments, and similar environments where proper hygiene is essential.

Future improvements should focus on enhancing the dispensing mechanism to ensure that utensils are released one at a time and on redesigning the cartridge to improve alignment and dispensing performance. The monitor display should be enlarged and enhanced to indicate the remaining number of utensils, while a utensil catcher should be incorporated to prevent multiple utensils from dropping simultaneously. Additional testing using different quantities of utensils, along with improvements in sensor calibration and mechanical controls, is recommended to further evaluate and enhance the device's reliability and performance. Regular maintenance and proper handling should also be practiced to preserve cleanliness and efficiency, and the Hygienic Cutlery Caddy is recommended for use in schools and food-related establishments to promote proper sanitation and minimize contamination risks.

The study was limited by the dispensing mechanism of the Hygienic Cutlery Caddy, which did not consistently release utensils one at a time when multiple spoons or forks were loaded. While the first activation dispensed a single utensil, succeeding activations occasionally caused additional utensils to drop simultaneously. Because of this limitation, the evaluation of the sensing and dispensing functions was conducted using only one spoon and one fork at a time, restricting the assessment of the device under multiple-utensil loading conditions.

Compliance with ethical standards

The authors declare no conflict of interest. This study received no external funding and was conducted solely for academic purposes. Participation was voluntary, and informed consent was obtained from all respondents prior to data collection. Data were collected using non-invasive methods, including survey questionnaires, an evaluation checklist, and laboratory testing of utensil samples, and all information was treated confidentially with no identifying information of the participants disclosed.

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