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Innovative Design of an Anti-bacterial Shopping Cart Attachment

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***Abstract*—The handles of shopping carts can contain numerous bacteria, including staphylococcus aureus and Escherichia coli. Legislation has also been passed that requires purveyors to regularly clean shopping carts. This study proposed a shopping cart with an anti-bacterial handle that employs ultraviolet sterilization to prevent bacterial infections. The system comprised the cart body, an anti-bacterial unit, and an charger unit. The anti-bacterial unit on the handle can help prevent shopping carts from spreading bacteria. The charger unit underneath the cart serves as an additional power source. The circuitry in this study used the LM2577S-ADJ adjustable high efficiency step-up voltage integrated circuit. The results indicated that the optical wavelengths of the anti-bacterial unit were between 385 and 700 nm with a peak wavelength at 414 nm. After 120 minutes of ultraviolet irradiation, Staphylococcus aureus was inhibited 99.1% and escherichia coli was inhibited 94.1%.**

Keywords—shopping cart handle; ultraviolet light; inhibition rate

I. INTRODUCTION

The official introduction of the cash and carry business model into the Taiwan market by Makro in 1989 started a revolution in retail sales and marked the beginning of large scale "self-service, low price, bulk" shopping centers. With favorable market development potential and the benefits to cash turnover provided by cash profits, wholesale stores in Taiwan began to grow rapidly, affecting department stores, supermarkets, and traditional retail and increasing competition within non-specialized retail markets. According to the consumer purchasing behavior report by AC Nielson, there is increasing price competition in food and general retail in the Asia-Pacific region. The increase in general merchandise channels in Taiwan is only second to that in South Korea, making Taiwan the second most dense country in Asia in terms of wholesale stores. AC Nielson pointed out that up to 50% of daily expenditures in Taiwan are spent in wholesale stores, 20% is spent in convenience stores, and 12% is spent in traditional markets and supermarkets. This shows that wholesale stores are consumers' first choice in saving money.

The Korea Consumer Protection Board conducted bacterial and chemical analysis of items people commonly come in contact with at the workplace. The results indicated that the average bacterial density was highest on shopping cart handles, followed by Internet café mice, bus handles, and public restroom door handles. According to the report, every 1.55 square inch on shopping cart handles had 1100 colony-forming units (CFUs). In this same area, Internet café mice had an average of 690 CFUs, bus handles had 380 CFUs, and restroom door handles had 340 CFUs.

The increasing number of hypermarkets in Taiwan is plainly evident; many people wander through several large shopping centers as they continue to appear across the island. Competition among wholesale stores and hypermarkets is increasingly fierce, so how do hypermarkets attract consumers? Consumers' assessments of shopping markets differ along with the size of each store; therefore, store operators must be flexible in their operational management and endeavor to innovate in order to become more competitive. However, regardless of the advertising methods used to attract customers, the key to the sustainable operation of a hypermarket is to care for and protect customers' health.

Shopping carts are essential for hypermarkets, yet the handles can harbor numerous unknown bacteria which can harm human health [1-3]. A study from Arizona State University found more saliva, bacteria, and filth on shopping cart handles than on escalators, public telephones, and in public restrooms. Shopping carts can contain bacteria such as Staphylococcus aureus and Escherichia coli. These can easily be transmitted through the liquid from raw chicken or beer, used diapers, or contaminated hands. E. coli is naturally found in soil, vegetables, and human and animal intestinal tracts. The amount of E. coli is often used as an indicator of cleanliness.

Generally, small amounts of E. coli are harmless to humans; however, larger amounts can breed harmful bacteria which may cause illness. Staphylococcus is transmitted through skin contact and can be found everywhere as it is easily spread by human skin.

Staphylococcus may cause skin infections or food poisoning and some strains are resistant to medications. Thus, many shopping centers in various countries have begun providing customers with wet wipes to wipe shopping carts. The state of Arkansas has even passed legislation that requires purveyors to regularly clean shopping carts.

Some visionary stores, such as the global wet wipe company Nice-Pak, have marketed new one time use wet wipes for all stores in America. These new wet wipes are made from materials certified by the Environmental Protection Agency and have been tested and confirmed to kill common bacteria. However, mass distribution of one-use wet wipes may cause another form of environmental crisis. While there are many methods for sterilization and disinfection, such as chemical sterilization and physical sterilization; however, ultraviolet sterilization is the preferred method for the disinfection of large surfaces and air sterilization [4-6].

UV light has been researched, developed, and tested for over two hundred years; its properties are currently well-understood and it is widely used in technologies [7-11]. UV light is a naturally occurring form of light undetectable by the naked eye. UV light can kill most harmful viruses and bacteria [5]; however, it can also be harmful to the human body [12,13]. Direct skin and eye exposure to UV light should be avoided; thus, the applications of UV light may be limited. This study applied UV anti-bacterial technology to shopping carts to disinfect not only the handle, but also sterilize the entire shopping cart.

II. Methods

This study designed a self-disinfecting shopping cart comprised of the cart body, an anti-bacterial UV light unit, and an auxiliary charger (Figure 1). The anti-bacterial UV light unit was installed in the handle to kill bacteria and viruses. The UV light handle is made up of a UV LED, a transparent handle, and a support.

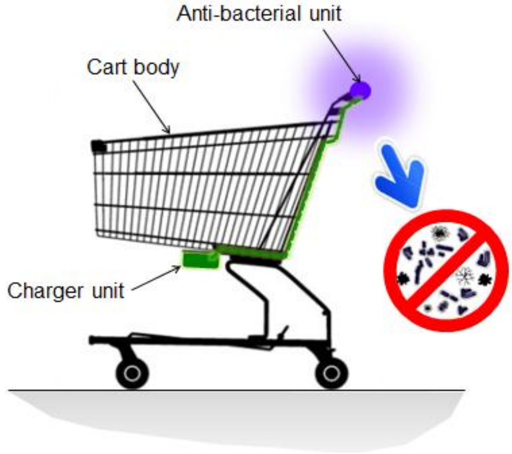

Figure 1 - Anti-bacterial shopping cart handle design.

UV light is divided into three subtypes based on wavelengths: UV-A (320-400nm), UV-B (280-320nm), and UV-C (100-280nm). Wavelengths between 240 and 260nm are optimal for disinfection [14]. The intensity of UV light is dependent on distance; the standard strength parameter used for all UV lights is measured in micro-watts per square centimeter (μW/cm2) at a distance of one meter. The effectiveness of germicidal UV and the degree of microbial activity are determined by UV intensity and exposure time. Generally, UV dose (K) is calculated by multiplying UV intensity (I) by exposure time (t):

$$K = I \times t \quad (1)$$

Equation 1 shows that the same effect is achieved by high intensity for short periods of time and low intensity for long periods of time. Normally, UV intensity above 70μW/cm2 is required for ideal disinfection. As long as the intensity is greater than 40μW/cm^2, the efficacy of exposure for short periods at high intensity and for long periods at low intensity are the same. At an intensity lower than 40μW/cm2, disinfection results are suboptimal regardless of prolonged exposure.

To maintain normal operation of the UV LED and convenient use of the shopping cart, the LED lights were encased in a transparent handle. When the LED light passes through the transparent casing, the intensity decreases due to reflection, absorption, and scattering. The handle transparency must be maintained in order to ensure light intensity. In order to investigate the influence of the transparent handle on the UV wavelength, a microspectrometer was used for spectral analysis of wavelengths 250-800nm with a resolution of <2.5nm.

An auxiliary charger was used to provide electricity to the anti-bacterial UV light unit. When the charger is drained of power, an external power source can be used to recharge the battery. The charger was installed underneath the shopping cart and is made up of a rechargeable battery, transformer, and fuse. Before the transformer supplies electric current to the battery, the fuse ensures there is no damage to the rechargeable battery; if battery operation is normal, the current is supplied until capacity is full and then automatically stops power supply.

III. Results and Discussion

The prototype of this invention is shown in Figure 2. The original handle was replaced with the transparent UV LED handle and the charging device was secured underneath the carriage of the shopping cart; the original functionality of the shopping cart was not affected by these modifications.

Figure 2 - Anti-bacterial shopping cart handle prototype.

The core of the anti-bacterial UV device is the UV LED light. The principal specifications of the light were 5mW output power, 20-40mA operating current, 3.4-3.6V operating voltage, 160° light angle, and geometric dimensions of (D) 5.8mm x (H) 5.8mm x (W) 2.54mm. The anti-bacterial UV device used an adjustable high efficiency step-up voltage integrated circuit. This module used premium LM2577 chips with low heat for a simple, stable, and efficient circuit. The test results showed that at 12V and 0.05A, three rows each with 30 UV LEDs had a total power of 2.25W.

The shopping cart handle was a hollow tube made of transparent polymethyl methacrylate acrylic with 92%-93% light transmission and superior mechanical properties, making it an excellent choice for application in the shopping cart handle. The geometric dimensions of the acrylic handle were outer diameter 36mm, length 508mm, and tube wall thickness 2mm. The microspectrometer was used to measure the LED light at a distance of 2cm from the handle. Figures 3 and 4 show the LED UV spectral energy distributions before and after installation of the tube. The distribution curve in Figure 3 shows that the LED intensity differs with wavelength; before installation of the transparent acrylic tube, the wavelengths were between 375nm and 450nm with a peak at 393-417nm. After installation of the acrylic tube (Figure 4), the wavelengths shifted to 385-700nm with a peak at 414nm. Comparison of the vertical axes (intensity) shows that after installation, the peak light intensity dropped from 16,385 to 1,283. This shows that while the acrylic tube widened the wavelength range, it greatly reduced the intensity of the UV LED lights.

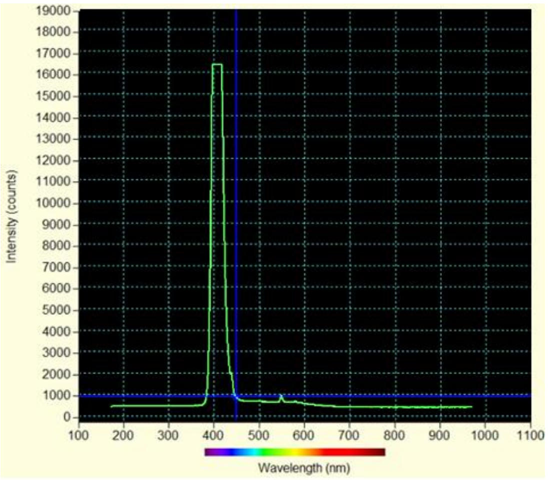

Figure 3 - UV spectral energy distribution curve prior to installation of the tube.

Generally, UV lights are manufactured using natural quartz glass crystals; however, due to costs and usage, these may be replaced with borax glass tubes. As a result, the characteristics and effectiveness of these two differ greatly. A quartz tube has a transmittance of over 80% and a decay rate of less than 20% over 1000 hours. A UV light with a suitable intensity of >70 μW/cm2 has a life span of 6000 hours. In contrast, a borax glass tube has a transmittance of <70%, a decay rate of <30% over 200 hours, and an intensity <70μW/cm2. In consideration of the usage rate, endurance, and installation costs for the shopping cart handles, the hollow acrylic tube was chosen for this study. As the acrylic tube caused a great drop in light intensity, the exposure time must be increased to improve the UV dose and effectively kill bacteria. The UV-C dose required to sterilize Staphylococcus aureus (SA) and Escherichia coli (EC) is 6,600μW.s/cm2. Using Equation 1, despite the decrease in intensity due to the low-cost and high-durability acrylic tube used in this study, this required dose can be achieved by increasing the exposure time.

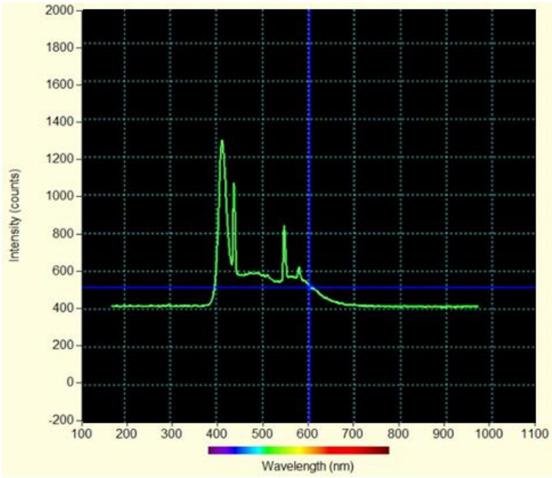

Figure 4 - UV spectral energy distribution curve after installation of the tube.

Societe Generale Surveillance (SGS) was contracted to conduct experiments regarding the UV LED anti-bacterial effectiveness for SA and EC at a distance of 1 cm from the bacterial liquid. The inoculated-pathogen quantities were 4.2×10^5CFU/ml and 2.9×10^5CFU/ml, respectively. The results of the tests are shown in Figure 5. The curves in the figure show that after exposure began, the two strains of bacteria continued to multiply until 24.5 and 30.2 minutes of irradiation. The colonies in the bacterial liquids grew to a maximum of 1.1×10^7CFU/ml and 4.1×10^6CFU/ml, respectively. This implies that at the beginning of exposure, the prototype light had no anti-bacterial properties due to the short exposure time.

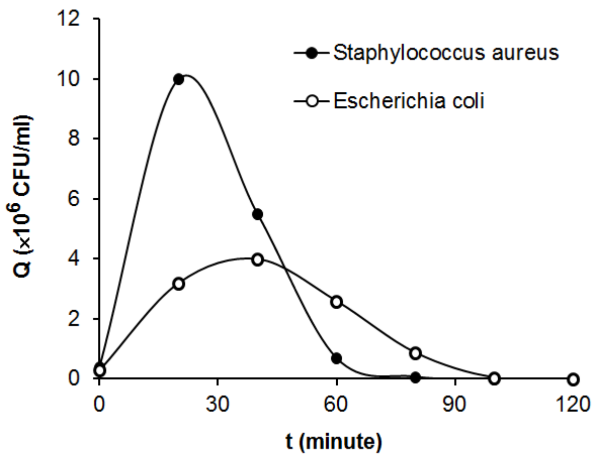

Figure 5 - Anti-bacterial effectiveness of ultraviolet light.

As exposure continued, SA and EC colonies began to decrease in size after 24.5 and 30.2 minutes, respectively. At 64.9 minutes, SA quantity decreased to 4.2×10^5CFU/ml and at 89.1 minutes, EC quantity decreased to 2.9×10^5 CFU/ml. The colonies continued to decrease in size as exposure time lengthened. After 120 minutes, SA and EC quantities decreased to 3.5×10^3CFU/ml and 1.7×10^4CFU/ml, respectively, indicating that the effectiveness of UV disinfection was superior for SA compared to EC. Disinfection was defined as a reduction in bacteria post-test compared to the original inoculated test liquid. Figure 5 shows that at an exposure time of 100 minutes, the SA and EC disinfection rates were 98.7% and 83.1%, respectively; at 120 minutes, the disinfection rates were 99.1% and 94.1%, respectively. Figure 6 shows the changes in bacterial colonies provided in the SGS test report. The image shows that as exposure time increased, the color of the SA culture dish became lighter and more homogeneous and while the spots in the EC culture dish increased significantly, the quantity of the bacteria decreased rapidly.

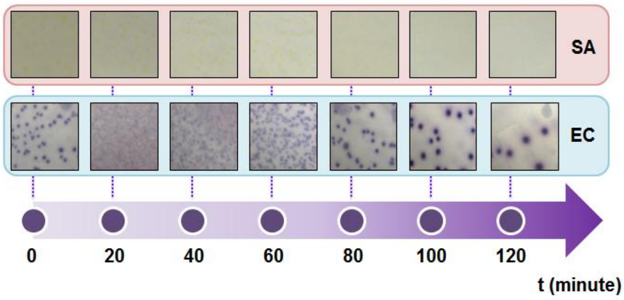

Figure 6 - SGS test report on bacterial change.

IV. Conclusions

As shopping carts are widely used and modern culture stresses hygienic conditions, this study designed a self-disinfecting shopping cart handle. This innovation is a business opportunity for shopping cart manufacturers that can be introduced into hypermarkets to increase profits and as a way to protect consumer health.

A prototype of this invention was successfully built by replacing the original shopping cart handle with the transparent UV LED handle and securing the charging device underneath the carriage. The original functionality of the shopping cart was not affected by these modifications. The experimental results show that the LED intensity before installation of the transparent acrylic tube, the wavelengths were between 375 and 450nm with a peak at 393-417nm. After installation of the acrylic tube, the wavelengths shifted to 385-700nm with a peak at 414nm. As the efficacy of UV disinfection is the same for short periods of exposure at high intensity and for long periods of exposure at low intensity, this study found that when the exposure time reached 100 minutes, the SA and EC disinfection rates were 98.7% and 83.1%, respectively, and at 120 minutes, the disinfection rates were 99.1% and 94.1%, respectively.

Acknowledgment

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