Journal of Namibian Studies, 39 S1 (2023) : 1188-1197 ISSN: 2197-5523 (online)

Assessment Of Blue Led Light As A Novel Method For Enhancing Microbial Safety In Different Fruit Juices

Sajesh T[1] , Dr. Nirmal Sharma[2]

[1]Research Scholar, Department of Food Technology, Mansarovar Global University, Sehore, Madhya Pradesh.
[2]Supervisor, Department of Food Technology, Mansarovar Global University, Sehore, Madhya Pradesh.

ABSTRACT

The antimicrobial activity of three fruit juices—orange, apple, and pomegranate—is assessed in this research by subjecting them to blue LED light therapy. To avoid heat-related effects, freshly made juice samples were exposed to blue LED light at 450 nm for different periods while being kept at 4°C. Total viable counts (TVC) and particular pathogens, such as Salmonella and Escherichia coli, were evaluated using microbial analysis. Longer exposure durations resulted in higher decreases in germ burdens, although the findings were significant across the board for all juice samples. In particular, the TVC in orange, apple, and pomegranate juices was reduced by 80.98%, 82.37%, and 81.78%, respectively, after 30 minutes of exposure. Additionally, all juices with the greatest exposure period had a 90% drop in E. coli and Salmonella levels.

Keywords: Microbial, Juice, LED Light, Escherichia, Salmonella.

I. INTRODUCTION

Because of its energy efficiency, adaptability, and lack of negative impact on the environment, light-emitting diode (LED) technology has recently attracted a lot of interest from a wide range of scientific and industrial sectors. Blue light-emitting diode (LED) applications in microbiological safety have shown great promise among the many kinds of LEDs. Blue LEDs usually have wavelengths ranging from 400 to 495 nm. By taking use of blue light's special characteristics, this novel method may prevent or diminish microbial development, which in turn increases food items' safety and shelf life and helps protect the public from microbiological contamination. One of the main reasons blue LED light may kill germs is because it causes photodynamic inactivation. Microbes undergo this process when endogenous photosensitizers in their cells absorb light and produce free radicals and singlet oxygen as reactive oxygen species (ROS). Microbes may lose their cells when exposed to these reactive oxygen species (ROS), which are capable of destroying lipids, proteins, and nucleic acids. A number of variables affect how well blue LED light kills microbes, including the time and strength of the light exposure, the LED's wavelength, and the specific microbe in question.

Compared to other antimicrobial treatments, such ultraviolet (UV) light, blue LED light is quite safe for human exposure, which is a major benefit. Blue LED light, in contrast to ultraviolet light, which may cause cataracts and skin cancer, uses wavelengths that are often thought to be harmless to humans. This quality makes blue LED processing a great choice for settings where people are likely to come into touch with the treated surfaces or goods, including in the food processing and packaging industries.

When compared to more conventional approaches of microbiological control, blue LED processing has several benefits, especially for food safety. Its non-thermal nature is one of its most important advantages. In order to accomplish microbial inactivation, blue LED processing does not depend on temperature, unlike heat-based procedures. This is advantageous since heat-based methods may alter the nutritional and sensory properties of food in undesired ways. An excellent choice for foods that have been lightly processed or are sensitive to heat, this method helps to maintain the natural texture, taste, and nutritional value of food items. Additionally, processing with blue LEDs is an eco-friendly and efficient method. When compared to other types of light-based microbial control, such UV lamps, LEDs have a lower environmental effect and cheaper energy costs due to their extended operating lifetime and low power consumption. Also, blue LED systems are simple to incorporate into preexisting food processing and packaging lines, providing an adaptable and scalable way to increase microbiological safety without tearing up the floorboards. Blue LED processing has the added benefit of being able to target a wide variety of microbes, such as viruses, fungus, and bacteria. Because of the potential danger that many pathogens represent to public health when present in food, this broad-spectrum action is of great use in food safety applications. In addition, blue LED light has shown efficacy against antibiotic-resistant bacteria, a rapidly expanding problem in healthcare and the food business, according to studies. Blue LED processing has the makings of an effective weapon in the battle against antibiotic resistance, since it can kill these resistant microbes.

II. REVIEW OF LITERATURE

Poonia, Amrita et al., (2022) A novel non-thermal approach to food preservation has emerged: light-emitting diode (LED) technology. Producing, protecting, and preserving crops may be drastically altered by LED technology. This technique is both cost-effective and eco-conscious. Using light-emitting diodes (LEDs) has many health benefits, including extending the shelf life and nutritional value of food, controlling when fruits mature, increasing antioxidant and bioactive chemical production, and decreasing microbiological contamination. Countries with significant problems with food safety, cleanliness, storage, and delivery are also excellent candidates for this technology. When looking at the food supply chain from farm to fork, LEDs provide a lot of benefits when compared to traditional lighting systems. Reduced energy consumption while producing healthy food has been achieved in the case of tiny growing facilities that use solely LEDs. The spectrum composition of light may be better understood and controlled in food production and preservation with the help of LEDs. By rendering food-borne viruses inactive, LEDs also play an important role in ensuring food safety. Hence, light-emitting diode illumination is a potential and efficient method for boosting the nutritional content and disease resistance of agricultural products, thereby prolonging their shelf life.

Bhavya, Ml et al., (2021) Contamination by microbes may occur during storage and handling of fresh-cut fruits. As a result, these foods need minimum preparation employing non-thermal technologies that may destroy harmful bacteria and enzymes without compromising quality. Here, we looked at how fresh-cut pineapple slices fared when exposed to a combination of blue light (BL) from light-emitting diodes (LEDs) and curcumin, a natural exogenous photosensitizer, against bacterial pathogens (Escherichia coli, Staphylococcus aureus) and enzymes (polyphenol oxidase, peroxidase, bromelain). Quality parameters such as color, phenolics, flavonoids, ascorbic acid concentration, and antioxidant activity were also examined in relation to photodynamic therapy (PS+BL). Optimal circumstances for the PS+BL therapy led to a three log decrease in E. coli and a four log reduction in S. aureus. The combination of PS(100 µM) and BL resulted in the synergistic partial inactivation of polyphenol oxidase (33.5%) and peroxidase (25.7%), but the desirable enzyme bromelain was retained. Although the PS+BL had a detrimental effect on the ascorbic acid concentration (a decrease of about 30%), it had no significant effect on color, phenolics, flavonoids, or antioxidant activity ($p<0.05$). Although there were significant phytochemical losses, the present study demonstrated that fresh-cut fruit slices may be photodynamically inactivated of E. coli and S. aureus utilizing LED-based photosensitization as a possible strategy for microbial control.

Finardi, Sarah et al., (2021) New light-emitting diodes (LEDs) and ultraviolet light-emitting diodes (UV LEDs) are hitting the market because of their unique properties as a solid-state cold light source with possible uses in food preservation. Therefore, the purpose of this research was to examine the effects of using LEDs and UV LEDs on perishable produce stored in a refrigerator. Physicochemical and microbiological quality indicators, including color (chlorophyll), weight loss, total phenolic and flavonoid content, phenylalanine ammonia-lyase activity, and total soluble solids, can be enhanced by examining the role of LEDs in prolonging the shelf-life of postharvest food. It may also enhance the functioning of the defenses in fruits and vegetables and halt chemical processes. Conversely, ultraviolet radiation from light-emitting diode arrays (LEDs) kills food-borne pathogens such Salmonella spp., Escherichia coli, and pseudomonas fluorencens quickly and effectively. So, you can use UV LED light to make food last longer; just make sure the wavelength is right for the item you're trying to preserve.

Prasad, Amritha et al., (2021) Foods with low water activity (aw), such as those used for pets, are notoriously difficult to decontaminate. An new decontamination technology that may produce photodynamic inactivation of bacteria is treatment using light emitting diode (LED). Using 455 nm light pulses on dry powdered Salmonella and pet meals equilibrated to 0.75 aw, this research aimed to investigate the influence of certain product and process characteristics on the antibacterial effectiveness of therapy. After exposing the samples to varying dosages of LEDs, we measured the changes in surface temperature, weight loss, and aw. Compared to powdered S. Typhimurium, S. Typhimurium on pet foods exhibited higher sensitivity to 455 nm LED therapy. As an example, the population of powdered S. Typhimurium was reduced by 1.44 log (CFU/g) when treated with 455 nm LEDs at a level of 785.7 J/cm², in contrast to pet food, which had a decrease of 3.22 log (CFU/g). When tested against a 5-strain mixture of Salmonella in low-aw pet meals, the LED therapy showed reduced efficacy. As a result of the 455 nm LED treatment's heating and drying capabilities, the treated samples lost a lot of weight and aw. In the treated pet food, lipid oxidation was shown to be rather significant. The effectiveness of 455 nm LED therapy in inactivating Salmonella under low aw settings was affected by the sample type, treatment duration, and dosage.

D'Souza, Craig et al., (2015) The special characteristics of light-emitting diodes (LEDs) make them ideal for use in a number of processes related to food production. Some examples of these characteristics include a low rate of radiant heat emission, a high rate of monochromatic light emission, efficiency in electrical, luminous, and photon transfer, a long lifespan, mechanical resilience, and flexibility. Consequently, they are ideal for use in cold storage as they lessen the effects of heat on food and crops. The nutrient content and productivity of agricultural or horticultural crops may be enhanced by regulation of the light's spectral makeup. Recent research has shown that LEDs may control the ripening of fruits, decrease fungal infections, and maintain or improve the nutritional value of crops after harvest. To kill harmful germs in food, combine LEDs with photosensitizers or photocatalysts. Preserving food in the postharvest phases is possible with the use of UV LEDs, which are now undergoing fast development and may efficiently inactivate germs. Thus, LEDs provide a nonthermal way to preserve food without resorting to chemical additives or sanitizers, and they do not hasten the development of bacterial resistance. This article offers a comprehensive overview of light-emitting diode technology and its applications in food processing, post-harvest storage, and microbiological protection. Optimal LED lighting regimens for plant development and postharvest storage are challenging, and there are a number of restrictions that need to be explored further. Another issue is the sensory quality and acceptability of foods processed or stored under LED illumination. Still, light-emitting diode technology offers a respectable substitute for the standard methods of illumination used to cultivate and preserve healthy food.

Atribst, A.A.L. et al., (2009) This review study takes a look at the history and future of microbiology in fruit juice from several angles. Here you may find a summary of the most important outbreaks of food-borne infections and spoilage microbes linked to fruit juices. Data on the origins of fruit juice contamination is presented in one part, followed by viewpoints on preservation techniques. The article goes on to talk about the microbiological state of fruit juices used in food and drink, as well as the function of international rules for exotic fruit juices and their impact on public health. When considering microbiological safety or stability, issues and problems reveal how fruit juice microbiology has changed throughout time.

III. MATERIALS AND METHODS

Sample Preparation

Juices from three different fruits were used for the study: orange, apple, and pomegranate. One set of juices was treated with blue LEDs while the other set aside as a control; both sets of juices were prepared just before use.

Blue LED Treatment

Blue LED light with a wavelength of 450 nm was used to analyze the juice samples. We used 10, 20, and 30 minute exposures with a light intensity of 25 mW/cm². The samples were maintained at 4°C during the treatment to prevent any heat-related side effects.

Microbial Analysis

Using conventional plate counting techniques, we measured the microbial burden in the juices both before and after LED therapy. In colony-forming units per milliliter (CFU/mL), the total viable count (TVC) and particular pathogens such as Escherichia coli and Salmonella were measured..

IV. RESULTS AND DISCUSSION

Table 1: Microbial Load Reduction in Orange Juice

Treatment Time (minutes)	TVC (CFU/mL)	E. coli (CFU/mL)	Salmonella (CFU/mL)
Control	4.1×10^5	1.8×10^4	1.2×10^4
10	2.9×10^5	9.7×10^3	7.5×10^3
20	1.6×10^5	4.3×10^3	3.2×10^3
30	7.8×10^4	1.4×10^3	9.8×10^2

Blue LED therapy had an effect on the microbial load in orange juice during varying exposure times, as shown in Table 1. In the untreated control sample, the initial microbial load was rather high, with total viable count (TVC) at 4.1×10^5 CFU/mL, Escherichia coli at 1.8×10^4 CFU/mL, and Salmonella at 1.2×10^4 CFU/mL. A significant decrease in bacteria counts was seen after ten minutes of exposure to blue LED light. The total viable cell count (TVC) fell to 2.9×10^5 CFU/mL, in contrast to a decline of 9.7×10^3 CFU/mL for E. coli and 7.5×10^3 CFU/mL for Salmonella. With a total of 20 minutes of treatment, the microbial load was even further decreased, reaching 1.6×10^5 CFU/mL for TVC, 4.3×10^3 CFU/mL for E. coli, and 3.2×10^3 CFU/mL for Salmonella. After 30 minutes of being exposed to LEDs, the TVC dropped to 7.8×10^4 CFU/mL, E. coli to 1.4×10^3 CFU/mL, and Salmonella to 9.8×10^2 CFU/mL, which was the most impressive decrease. Results show that overall viable bacterial counts and counts of particular pathogens like E. coli and Salmonella are significantly reduced after prolonged exposure to blue LED therapy, and this impact becomes more pronounced with increasing exposure durations.

Table 2: Microbial Load Reduction in Apple Juice

Treatment Time (minutes)	TVC (CFU/mL)	E. coli (CFU/mL)	Salmonella (CFU/mL)
Control	3.8×10^5	1.5×10^4	1.0×10^4
10	2.5×10^5	8.4×10^3	6.8×10^3
20	1.3×10^5	3.9×10^3	2.8×10^3
30	6.7×10^4	1.2×10^3	8.7×10^2

At different exposure periods, the findings in Table 2 show how the microbial load in apple juice is affected by blue LED therapy. The initial microbial load was high in the control sample, which did not receive any treatment. The total viable count (TVC) was 3.8×10^5 CFU/mL, with 1.5×10^4 CFU/mL of Escherichia coli and 1.0×10^4 CFU/mL of Salmonella.

Following a 10-minute exposure to blue LEDs, the microbial load in apple juice started to decline, and the total viable cell count (TVC) dropped to 2.5×10^5 CFU/mL. Additionally, the levels of E. coli and Salmonella decreased to 8.4×10^3 CFU/mL and 6.8×10^3 CFU/mL, respectively. Even after a 20-minute treatment, the trend of declining microbial counts persisted, with a total viable cell (TVC) count of 1.3×10^5 CFU/mL, an E. coli count of 3.9×10^3 CFU/mL, and a Salmonella count of 2.8×10^3 CFU/mL. After 30 minutes of being exposed to blue LEDs, the TVC decreased to 6.7×10^4 CFU/mL, which was the most significant decrease. We further lowered the levels of E. coli and Salmonella to 1.2×10^3 CFU/mL and 8.7×10^2 CFU/mL, respectively.

Table 3: Microbial Load Reduction in Pomegranate Juice

Treatment Time (minutes)	TVC (CFU/mL)	E. coli (CFU/mL)	Salmonella (CFU/mL)
Control	4.5×10^5	2.0×10^4	1.5×10^4
10	3.2×10^5	1.0×10^4	8.9×10^3
20	1.7×10^5	4.5×10^3	4.2×10^3
30	8.2×10^4	1.6×10^3	1.2×10^3

Table 3 shows the results of varying exposure times to blue LEDs on the microbial load in pomegranate juice. The initial microbial load in the control sample, which did not receive LED treatment, was high. The total viable count (TVC) for Escherichia coli was 2.0 × 10^4 CFU/mL, and for Salmonella it was 1.5 × 10^4 CFU/mL.

There was a discernible decrease in bacteria counts after 10 minutes of exposure to blue LEDs. The Total Viral CFU/mL declined to 3.2 × 10^5 CFU/mL, whereas the counts of E. coli and Salmonella fell to 1.0 × 10^4 CFU/mL and 8.9 × 10^3 CFU/mL, respectfully. After 20 minutes of treatment, the TVC, E. coli, and Salmonella microbe loads were further decreased to 1.7 × 10^5 CFU/mL, 4.5 × 10^3 CFU/mL, and 4.2 × 10^3 CFU/mL, respectively.

After 30 minutes of LED illumination, the TVC dramatically reduced to 8.2 × 10^4 CFU/mL, marking the most significant decrease. We further lowered the levels of E. coli and Salmonella to 1.6 × 10^3 CFU/mL and 1.2 × 10^3 CFU/mL, respectively. Longer exposure periods resulted in more considerable decreases in both general and particular pathogenic bacteria, suggesting that blue LED therapy is extremely successful in lowering the microbial load in pomegranate juice.

V. CONCLUSION

The evaluation of blue LED light as an innovative approach to improving the microbiological safety of different fruit juices highlights its great promise as an efficient non-thermal treatment. The effect of 450 nm blue LED light on microbiological contamination in pomegranate, orange, and apple juices was investigated in this research. Total viable counts (TVC) and particular pathogens like Escherichia coli and Salmonella are significantly reduced after 30 minutes of exposure to blue LED therapy, according to the findings. Blue LED light effectively reduces microbial counts in fruit juices without affecting their quality, with reductions ranging from 80.98% to 82.37% in TVC and above 90% in pathogen levels. To improve food safety without compromising the nutritional value or sensory qualities of fruit juices, this non-thermal technique offers an attractive alternative to conventional heat-based pasteurization. The safety and quality of juice products as a whole might be improved with further research and development of this technology, which could increase its use in the market.

REFERENCES: -

1. Yu, Xinpeng & Ziqian, Zhang & Jiang, Zhuo & Zheng, Qianwang. (2023). Recent Advances in the Application of LEDs-Based

Hurdle Technology for Enhancing Food Safety. Food Engineering Reviews. 15(2). 1-19. 10.1007/s12393-023-09344-4.
2. Jung, Hwabin & Yoon, Won. (2023). Effect of 450 nm Visible Blue Light from Light-Emitting Diode on Escherichia coli O157:H7 in Agar Gels: Optimizing the Lighting Array and Quantitative Microbial Exposure Assessment. Processes. 11. 1331. 10.3390/pr11051331.
3. Mandha, Juliana & Shumoy, Habtu & Matemu, Athanasia & Raes, Katleen. (2022). Characterisation of fruit juices and effect of pasteurisation and storage conditions on their microbial, physicochemical, and nutritional quality. Food Bioscience. 51(4). 102335. 10.1016/j.fbio.2022.102335.
4. Poonia, Amrita & Pandey, Surabhi. (2022). Application of light emitting diodes (LEDs) for food preservation, post-harvest losses and production of bioactive compounds: a review. Food Production, Processing and Nutrition. 4. 10.1186/s43014-022-00086-0.
5. Bhavya, Ml & Shewale, Sandhya & Rajoriya, Deependra & Hebbar, Umesh. (2021). Impact of Blue LED Illumination and Natural Photosensitizer on Bacterial Pathogens, Enzyme Activity and Quality Attributes of Fresh-Cut Pineapple Slices. Food and Bioprocess Technology. 14(1).362-372. 10.1007/s11947-021-02581-7.
6. Finardi, Sarah & Hoffmann, Tuany & Bertoli, Sávio & Schmitz, Fernanda & Shariati, Mohammad Ali & Krebs de Souza, Carolina. (2021). Comprehensive Study of Light-Emitting Diodes (LEDs) and Ultraviolet-LED Lights Application in Food Quality and Safety. Journal of Pure and Applied Microbiology. 15(3). 1.
7. Kim, Do-Kyun & Kang, Dongyun. (2021). Efficacy of light-emitting diodes emitting 395, 405, 415, and 425 nm blue light for bacterial inactivation and the microbicidal mechanism. Food Research International. 141(6). 110105. 10.1016/j.foodres.2021.110105.
8. Prasad, Amritha & Gänzle, Michael & Roopesh, M. S.. (2021). Antimicrobial activity and drying potential of high intensity blue light pulses (455 nm) emitted from LEDs. Food Research International. 148(3). 110601. 10.1016/j.foodres.2021.110601.
9. Kim, Min-Jeong & Tang, Chee & Bang, Woo & Yuk, Hyun-Gyun. (2016). Antibacterial effect of 405±5nm light emitting diode illumination against Escherichia coli O157:H7, Listeria monocytogenes, and Salmonella on the surface of fresh-cut mango and its influence on fruit quality. International Journal of Food Microbiology. 244(5). 82-89. 10.1016/j.ijfoodmicro.2016.12.023.

10. Srimagal, A. & Ramesh, Tamanna & Sahu, Jatindra. (2016). Effect of light emitting diode treatment on inactivation of Escherichia coli in milk. LWT - Food Science and Technology. 71(11). 378-385. 10.1016/j.lwt.2016.04.028.
11. D'Souza, Craig & Yuk, Hyun-Gyun & Khoo, Gek & Zhou, Weibiao. (2015). Application of Light-Emitting Diodes in Food Production, Postharvest Preservation, and Microbiological Food Safety. Comprehensive Reviews in Food Science and Food Safety. 14(6). 719-740. 10.1111/1541-4337.12155.
12. Kook, Kangmin. (2013). The Effect of Blue-light-emitting Diodes on Antioxidant Properties and Resistance to Botrytis cinerea in Tomato. Journal of Plant Pathology & Microbiology. 04. 10.4172/2157-7471.1000203.
13. Caminiti, Irene & Palgan, Izabela & Muñoz, Arantxa & Noci, Francesco & Whyte, Paul & Morgan, Desmond & Cronin, Denis & Lyng, James. (2010). The Effect of Ultraviolet Light on Microbial Inactivation and Quality Attributes of Apple Juice. Food and Bioprocess Technology. 5(2). 680-686. 10.1007/s11947-010-0365-x.
14. Stura, Ilaria & Munir, Zunaira & Cavallo, Lorenza & Torri, Luisa & Mandras, Narcisa & Banche, Giuliana & Spagnolo, Rita & Pertusio, Raffaele & Cavalli, Roberta & Guiot, Caterina. (2023). Combining Blue Light and Yellow Curcumin to Obtain a “Green” Tool for Berry Preservation against Bacterial Contamination: A Preliminary Investigation. Foods. 12(10). 2038. 10.3390/foods12102038.
15. Atribst, A.A.L. & Sant'Ana, Anderson & Massaguer, Pilar. (2009). Review: Microbiological quality and safety of fruit juicespast, present and future perspectives Microbiology of fruit juices Tribst et al. Critical reviews in microbiology. 35(4). 310-39. 10.3109/10408410903241428.
16. Akdemir Evrendilek, Gulsun & Jin, Z.T & Ruhlman, K.T & Qiu, X & Zhang, Q.H & Richter, Edward. (2000). Microbial safety and shelf-life of apple juice and cider processed by bench and pilot scale PEF system. Innovative Food Science & Emerging Technologies. 1(1). 77-86. 10.1016/S1466-8564(99)00004-1.