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Use of Ultraviolet Light for Surface Decontamination of Raw Chicken Carcasses

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Authors' contributions

This work was carried out in collaboration among all authors. Author RNW designed, overseeing the research project, authors KDM and SVL carried out the experiments under supervision of authors RNW and VVD. Author KDM collected data and authors RNW & VVD interpreted of data and manuscript writing. Authors SVL and KKK helped in writing and review of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Fresh chicken meat is especially susceptible to surface contamination. The researchers are looking into non-thermal and non-chemical preservation techniques for meat. Therefore, the present study was planned to investigate the use of UV-C light for the decontamination of raw chicken carcasses at refrigeration temperature (0-4^{O}C).
Study Design: The study was undertaken in two phases wherein, the first phase standardization of UV dose and later the comparative effect of selected UV light and sodium hypochlorite exposure on the shelf life of poultry carcasses (0-4^{O}C) was carried out.
Place and Duration of Study: The experiment was performed in the Department of Veterinary Public Health, Poultry and Goat Processing Unit, College of Veterinary and Animal Sciences, Parbhani (MH) India, from October 2021 to April 2022.

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Methodology: We performed the microbial, physicochemical, and sensory (odour) evaluation of the chicken carcasses during storage up to 72 hrs. Amongst various UV doses with different exposure times and distances tested, UV-C light exposure generated 233.86, 103.93, 207.87, and 415.75 mJ/cm^2 energy for various groups.
Results: A microbial analysis in a standardization study revealed that a significantly ($p<0.05$) lower total viable count was observed in UV (415.75 mJ/cm^2) group. Similarly, counts of *Staphylococcus* spp. and *E. coli* were significantly ($p<0.05$) lower in UV-C light (207.87 mJ/cm^2 and 415.75 mJ/cm^2) groups. The shelf-life analysis indicated that UV-C light (415.75 mJ/cm^2) and sodium hypochlorite (50 ppm) were equally effective in reducing the microflora of carcasses. The pH and TBA values of both treatment groups did not differ significantly but an increasing trend was recorded for peroxide and tyrosine values throughout the storage period.
Conclusion: The findings of the present study indicate that UV-C light technology may be applied for surface decontamination of raw chicken carcasses.

Keywords: UV-C light; raw chicken carcasses; decontamination; quality; shelf life.

1. INTRODUCTION

The fastest-growing segment of the world's meat demand is poultry meat, and India currently consumes 3.5 kg of chicken meat per person [1] with growth rates of 8.51 and 7.52 percent in egg and broiler output, respectively, India's poultry industry is currently emerging as a sunrise sector after growing at an astounding rate ever since it began [2]. The adaptability of chicken meat, its low cost, and acceptance could be conducive to India's increased intake of chicken meat [3].

However, because the skin, feathers, and intestines of live poultry birds harbour a range of bacteria, there are increased concerns about the microbiological safety of poultry products among consumers, producers, and public health officials (Kozacinski et al. 2006). Bacterial contamination of chicken carcasses during slaughter is nearly unavoidable [4]. Instances of food poisoning, disease outbreaks, and product recalls have been reported often on a global scale [5]. As a result, the safety of chicken products has emerged as a crucial global issue with consequences for public health.

Fresh chicken meat is especially susceptible to surface contamination by pathogenic microorganisms because of its high water and nutrient content [6]. Following processing, the presence of spoilage microorganisms on the surface of fresh poultry meat can result in quality problems such as the development of discoloration, off-odour, and off-flavour during cold storage [7]. Utilizing a variety of physical and chemical techniques, such as ultraviolet (UV) light technology, high pressure processing (HPP), high voltage processing pulsed electric field (PEF), gamma irradiation, lactic acid, acetic acid, ozone, and chlorine treatments, pathogens and spoilage-causing microflora are eradicated from poultry carcasses and their products [8-10]. But even if they are quite effective, heat treatment and chemical antibacterial agents frequently ruin sensory qualities and valuable nutrients like protein and vitamins [11].

In the past few decades, researchers have looked into alternative non-thermal and non-chemical preservation techniques for food processing. For instance, sodium hypochlorite inhibits glucose oxidation to produce its bactericidal effects. However, excessive chlorine use can produce hazardous and cancer-causing tri-halo methane molecules by reacting with meat [12]. Ultraviolet (UV) light technology, high-pressure processing (HPP), high voltage processing pulsed electric field (PEF), and gamma rays are few more options for developing alternative preservation techniques. Non-ionizing radiation with germicidal qualities, UV light provides a number of benefits over competing technologies, including being simple to use and being more affordable. As an alternative to heat treatment, UV-C (200 to 280 nm) has been used to pasteurize food items such as fruit juice, milk, vegetables, raw meat, and cooked meat. The type of food, microbiota (load and type), and dose employed are the primary factors affecting the usage of UV-C for food preservation [10]. The photochemical transformation of DNA bases, which results in connections between succeeding bases to create dimers, is thought to be the cause of UV's bactericidal effects. DNA transcription and replication are therefore prevented, which compromises cellular functions and ultimately results in cell death.

Despite the advantages of UV-C in food processing and preservation, the technology's acceptance in meat preservation has lagged because there isn't enough published evidence to back up its usage in meat decontamination. The current study seeks to address this by examining the possibility of UV-C light exposure for surface disinfection of raw chicken carcasses and contrasting its effectiveness with sodium hypochlorite.

2. MATERIALS AND METHODS

2.1 Preparation of Ultraviolet-C (UV-C) Chamber Prototype

Raw chicken carcasses were exposed to UV light using a UV radiation device created by the Department of Veterinary Public Health and Epidemiology at the College of Veterinary and Animal Sciences (COVAS), Parbhani, India. It was created to clean the carcasses that were hung 144 cm off the ground on shackle lines (Fig. 1). The device was made up of 2 distinct rectangular plywood frames attached with 2 UV tubes (each emitting UV-C light of 4.9 W and 254 nm). The interior side of plywood frames towards the carcasses received the tubes. The dorsal and ventral UV tubes were positioned so that the carcasses suspended from the shackles would receive the maximum exposure. By controlling the pace of the shackle line, the length of UV exposure on the carcasses was determined. The precautions were taken to prevent UV light exposure for people.

2.1.1 Calculation of UV dose

As described earlier by Semi [13], the dosage (transmitted energy) in a UV radiation apparatus was calculated and expressed as J/cm^2 by the following equation:

$$Dc = \frac{S}{4\pi d^2} \times t$$

Where in,

Dc = Total dose of UV light expressed in J/cm^2,
S = Power output from the source of light expressed in Watt,
d = Distance of an object from the power source expressed in cm, and t is exposure time expressed in seconds.

2.2 Study Plan and Sample Collection

There were two phases of the investigation. By examining its impact on the microbiota of processed poultry carcasses, the initial phase entails standardisation and later selection of UV dose for shelf-life testing. The comparative effects of certain UV and sodium hypochlorite (CL) on poultry carcasses maintained at refrigeration temperature were studied in the second phase (0-4 OC). Raw skinned chicken carcasses were obtained immediately after evisceration from the institute's Poultry and Goat Meat Processing Demonstration Unit for study.

Six carcasses per group were treated with UV radiation (04 group), sodium hypochlorite treatment, and control in the study's initial phase. Dorsal and ventral swab samples were taken from the corpses immediately after treatment for sensory evaluation of the scent and additional microbiological examination (Total Viable Count (TVC), *Staphylococcus* spp., and *E. Coli*).

The shelf life of chicken carcasses was studied in the second phase using sodium hypochlorite group and one selected superior UV treatment from the first phase. The 06 duplicates of chicken carcass samples maintained at 4 ^{o}C were obtained by destructive method at 0, 24, 48, and 72 hours after treatment. Tempnote Data Logger was used to continuously monitor the refrigerator's temperature. The obtained samples were processed for microbiological (TVC and Pseudomonas spp.), physico-chemical (pH, TBA, Tyrosine value, and POV) examination, as well as sensory (odour) analysis.

2.3 Decontamination of Chicken Carcasses by *UV-light and Sodium Hypochlorite*

The chicken carcasses were held on shackle line in the poultry processing unit and then passed through the UV chamber for various time intervals in seconds with variable distances in centimeter. Based on the time intervals and distances four groups, UV- I (30 sec &10 cm), UV-II (30 sec &15 cm), UV- III (60 sec &15 cm) and UV-IV (120 sec &15 cm) were prepared. Further, the poultry carcasses were decontaminated by sodium hypochlorite (CL) solution by individually dipping in 50 ppm for 60 seconds.

2.4 Microbial Analysis

2.4.1 Collection of carcass surface swabs and microbial analysis for standardization of UV dose

Swab samples from carcasses were taken using the technique outlined in ISO 18593:2018. The

100 cm (10 cm^2) ventral and dorsal areas of each carcass were exposed using a 10 × 10 cm sterile template made of aluminium foil. The TVC, *Staphylococcus* spp., and *E. coli* counts were performed after the swab was aseptically put into 1ml of sterile peptone water and applied to the designated area of the carcasses.

Pouring the necessary dilutions onto plate count agar and spreading them onto sterilised Baired and Parker Agar and Eosin Methylene Blue (EMB) agar were the plating methods used [14-16]. After that, all innoculated plates were incubated for 24-48 hours at 37 °C. As advised by Bailey and Scott (2007), Gram staining results and biochemical assays verified the presence of *Staphylococcus* spp. in the culture. For chicken carcasses, the data were expressed as cfu/cm^2.

2.4.2 Collection of carcass samples and microbial analysis in shelf life study

Chicken meat samples weighing 10 grams (gm) were taken from the entire chicken carcass, along with the skin, and placed in 90 ml of normal saline solution. To obtain a 10-fold dilution, the homogenate sample was serially diluted in 9 ml of buffer peptone water that was 0.1% sterilised. The necessary dilutions were spread plated on sterilised Pseudomonas Isolation Agar then pour plated on plate count agar [14,17]. For chicken carcasses, the data were expressed as cfu/cm^2.

2.5 Physico-chemical Analysis in Shelf Life Study

The AOAC method was used to determine the pH of chicken breast sample (1995). Using a digital pH meter (Green Genome LMPH-10), homogenates were made from 10 g of materials and 50 ml of distilled water. TBA value was calculated using a slightly modified version of the procedure outlined by Strange et al. [18]. Twenty gram of sample meat were blended for two minutes in fifty milliliters of cold, 20 percent trichloro acetic acid to create trichloro acetic acid (TCA) extract. The blended material was rinsed with 50 ml of distilled water, combined with Whatman No. 1 filter paper, and then filtered. The volume of filtrate was then measured and used to estimate the TBA number. Test tubes containing 5 ml of TCA extract and 5 ml of 0.01 M thiobarbituric acid were then put in a boiling water bath (1000C) for 30 minutes. Along with the sample, a blank constitute of 5 ml of 10% trichloroacetic acid in another test tube was placed in a boiling water bath. The test tubes were removed after 30 minutes and chilled in running water for roughly 10 minutes. The generated colour was quantified as malonaldehyde (MDA)/kg and reported as an absorbance value at 532 nm.

The method used by Strange et al. [18] for determining tyrosine value was followed with a little modification. 2.5 ml of TCA extract (as described above) was diluted with an equal amount of distilled water in a test tube, and 10 ml of sodium hydroxide solution was then added. Finally, 3 ml of diluted folin-ciocalteu phenol reagent was added. Following a thorough mixing, the solution was left at room temperature for 15 minutes. Using a blank sample (5 ml of 5% TCA) as a standard, the generated blue hue was quantified as an absorbance value at 660 nm and reported as mg/g.

Peroxide value (POV) was determined according to the method of Sallam et al. [19]. In a 250 ml Erlenmeyer flask with a rubber cap, the sample (3 g) was weighed. It was then cooked in a water bath for three minutes at 600 C. After that, the flask was thoroughly stirred for three minutes with a 30 ml solution of acetic acid chloroform (3:2 v/v) to dissolve the fat. To filter out chicken particles from the filtrate, Whatman filter paper (Number 1) was employed. The filtrate was then mixed with 0.5 ml of saturated potassium iodide solution, along with starch solution as an indicator. The sodium thiosulfate standard solution was used to continue the titration. The following equation was used to compute the peroxide value (POV), which is represented as milli equivalents of peroxide per kilogram of sample:

$$\text{Peroxide value (meq/ kg)} = \{(SxN)/W\} \times 100$$

Where

"S" = the volume of titration (ml),
"N" = normality of sodium thiosulfate solution (N=0.01) and "w" = the sample weight (g).

2.6 Sensory Evaluation

Prior to conducting a microbiological investigation of the samples, sensory characteristics in terms of odour were first observed. Graduate students and teaching staff from the institute were among the panelists who participated in the study's sensory examination of chicken meat. In the first stage of UV dose

standardization, samples taken right after exposure were examined. While the shelf life study assessed the chicken sample storage for 0, 24, 48, and 72 hours. The panelists used an 8-point descriptive scale to rate the samples for odour [20]. A scale of 1–extremely unwanted, 8–extremely desired, 7–very desirable, 6–moderately desirable, 5–slightly desirable, 4–slightly unattractive, 3–moderately undesirable, 2–very undesirable, and 1–extremely unfavorable—was employed for the hedonic test.

2.7 Data Analysis

Using the WASP 1 and WASP 2 software created by ICAR, all the data were analyzed using a Randomized Block Design and the T-test. In regard to microbiological, physico-chemical, and sensory analysis, the "f" value and "CD" value were computed, and the means of various groups were compared both within and across groups.

3. RESULTS AND DISCUSSION

3.1 Calculating UV-C Light Exposure Dose

The energy generated during UV-C light exposure in mJ/cm^2 of various treatments was calculated. The UV-C light exposure generated energy in mJ/cm^2 for groups UV-I, UV-II, UV-III and UV-IV were 233.86, 103.93, 207.87 and 415.75 mJ/cm^2, respectively.

3.2 Standardization of Dose of UV Light

3.2.1 The comparative efficacy of various dosages of UV-C light (UV I - IV) and sodium hypochlorite (CL) on microbial quality

Table 1 compares how TVC, *Staphylococcus* spp., and *E. coli* counts of chicken carcasses were affected by UV - I, UV - II, UV - III, UV - VI, Sodium hypochlorite (CL), and Control. Average mean TVC showed that chicken at processing units was kept in the best possible hygienic conditions. In comparison to other treatments, "UV-IV" and "CL" treatments were found to be significantly more effective (p 0.05). It was found that TVC of raw chicken carcasses might be reduced by UV-C light as well. The findings were consistent with earlier research by Lázaro et al. [21]. Similarly, Phillip et al. [6] observed a reduction with a UV-C dosage of 50 to 300 mJ/cm^2, the aerobic mesophilic count (AMC) ranged from 1.69 to 2.98 log cfu/cm^2. The results of several prior studies [22,23] however, indicated lesser AMC (0.05 to 0.14 log cfu/cm^2) with exposure to UV-C dosages of 50–200 mJ/cm^2. It might be because the dosages utilised were lower in mJ/cm^2 than in the present investigation. The very uneven structure of chicken's surface may shield bacteria from UV-C rays [23]. The effectiveness of UV-C technology for decontaminating carcasses may vary depending on a number of variables, including the initial bacterial density, bacterial strains and their growth rate, composition, skin-on and skinless chicken carcasses, and UV irradiation dosage [24].

Staphylococcus spp. (Plate 01) isolation from chicken carcasses points to insufficient sanitary conditions in poultry meat processing [25]. The observation of Table 1 clearly shows that the application of "UV-III," "UV-IV," and "CL" treatment might result in a significant (P<0.005) decrease in *Staphylococcus* spp. contamination. The results were consistent with earlier findings by Liu et al. [26], who found that pulsed UV light irradiation at a distance of 11 cm, a power of 6 watts, and an exposure time of 5 minutes was sufficient to lower the *Staphylococcus* spp. count from 6.49 to 4.10 log cfu/gm. Even while some other studies supported the potential of UV-C irradiation to reduce the number of *Staphylococcus* spp. [27], it was also reported that gram-positive bacteria were found to be more resistant to the influence of UV irradiation than Gram negative bacteria [28].

Comparison of effect of various treatments on *E.coli* counts (Table 1, Plate 2) indicated that ‘UV-III’, ‘UV-IV’ and ‘CL’ were significantly (P<0.005) able to reduce *E.coli* count. These observations were in agreement with earlier studies wherein *E.coli* count was a reduction of 0.36 to 1.28 log was recorded with UV-C treatment at 500 µw/cm^2 for 3 minutes [29]. Besides, a significant reduction of 0.77 log cfu/gm was observed for *E.coli* on chicken skin after UV treatment up to 0.192 J/cm [23] which also corresponds to present observations.

Plate 1. Colonies of *Staphylococcus* spp. on baired and parker agar

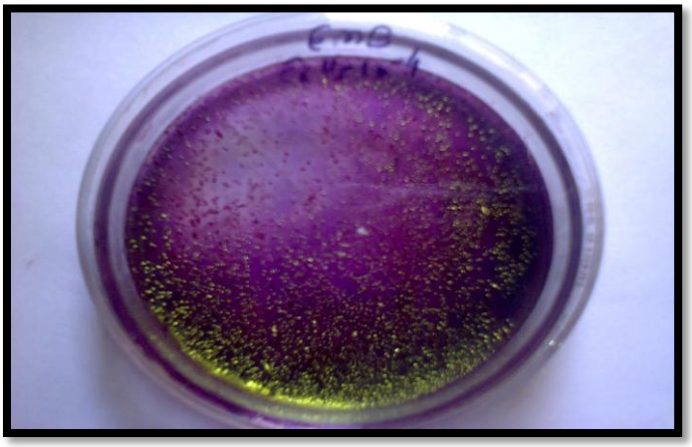

Plate 2. Colonies of *E. coli* on eosin methylene blue agar

3.2.2 Effect of various doses of UV-C light and chlorine wash on Sensory property (odour) of raw chicken carcasses

The results of hedonic scale (Table 1) showed that the mean odour attributes of raw chicken carcasses were found to be 7.818±0.011, 7.967± 0.010, 7.837±0.021, 7.777±0.096, 5.907± 0.150 and 7.822±0.009 for 'C', 'UV-I', 'UV-II' 'UV-III', 'UV-IV' and CL groups, respectively. Raw chicken carcasses' odour was unaffected, although 'UV-IV' demonstrated substantially slight to moderately desirable grade due to light burnt odour following exposure. Except for "UV-IV," there was no difference between the control, "UV-I," "UV-II," "UV-III," and "CL" groups on the hedonic scale test for odour ($p<0.01$).

The findings are consistent with earlier research by Phillip et al. [6], who also noted a burnt odour on chicken samples that had been exposed to UV-C radiation. Additionally, Mc Leod et al. [30] noted an off-odour just after receiving UV-C treatment. Other investigations have shown no negative impact on the sensory quality of broiler meat after UV irradiation, including Stermer *et al* [31], Wallner Pendleton, [32], Lyon et al., [33], and Issohani, [34].

3.3 Effects of Selected UV C Light (UV-IV group) and CL on Shelf Life of Chicken Carcass

Based on the findings of the standardisation of UV light exposure trial, the shelf life and decontamination of chicken carcasses stored at refrigeration temperature (0 –4ºC) were studied using the UV-IV group (415.75 mJ/cm^2) and sodium hypochlorite group. The results are shown in Table 2.

3.3.1 Analysing microbial quality

It was found that the TVC of raw chicken carcasses treated with UV-C light and sodium hypochlorite and stored at refrigeration temperature (3.87±0.377 to 4.07±0.173^{0}C) also increased with ambient increase in storage time (Table 2). For samples treated with UV-C light and sodium hypochlorite, the initial TVC of raw chicken carcasses at 0 hours was 4.33±0.105 and 5.30±0.16 log cfu/gm, respectively. After 72 hours, the TVC of beef samples that had been exposed to UV-C light and sodium hypochlorite was 6.17±0.02 and 6.55±0.124, respectively. These values fell within the FSSAI, New Delhi, legal parameters.

The microbial development of raw chicken carcass samples appeared to be slowed down by UV-light treatment. Throughout the storage period, raw chicken carcass samples treated with sodium hypochlorite and UV-C light showed significantly different microbial counts ($p<0.05$). While samples from sodium hypochlorite-treated groups were shown to be advantageous for *Pseudomonas* spp. growth at 48 and 72 hours of storage, *Pseudomonas* spp. was not observed in the UV-C light treated group throughout the storage period.

The findings of this investigation indicated that TVC of raw chicken carcass samples exceeded the recommended limit on day 3 (72 hours). These findings demonstrated that the UV-C light decontamination approach is comparable to that of sodium hypochlorite. These results, however, differ from those published by Phillips (2020), who said that the shelf lives for the control and UV-C treated raw chicken samples, respectively, were 7 and 5 days. These variations in the results could be brought on by the initial microbial load, temperature swings, and storage conditions [35].

3.3.2 Sensory (Odour) analysis

During the 72-hour storage period, the sensory score for the odour of raw chicken carcasses treated with UV-C light and sodium hypochlorite significantly decreased ($p<0.05$). Among the treatments, the odour score differs significantly ($p<0.05$). The raw chicken carcasses treated with sodium hypochlorite received the highest score when compared to the raw chicken carcasses treated with UV-C light. After 72 hours of storage, there was discernible off-odour in both treatment groups, which may have been caused by microbial growth, lipid oxidation, or an enzymatic response. Some panelists mentioned having an irradiated odour the day after receiving UV-C light treatment [36,37]. The surprising odour was not present in samples that had been treated with sodium hypochlorite, though. The findings of the current study agreed with those of the Park et al., (2014) study. Meat exposed to UV light can develop off odour because of photochemical effects on lipid content of meat [38].

3.3.3 Physicochemical parameters

Table 2 shows the findings on the physicochemical parameters of raw chicken carcasses treated with sodium hypochlorite and UV-C light at refrigeration temperature (3.870.377 to 4.070.173 0C) as a result of storage-related modifications.

pH: From the data presented in Table 2 it is evident that pH of raw chicken carcasses did not differ significantly throughout the storage period (72 hours) between both the treatment groups. It is clear from the data in Table 2 that over the storage period of 72 hours, the pH of raw chicken carcasses did not substantially differ between the two treatment groups. For samples that had been exposed to UV-C radiation or sodium hypochlorite, the initial pH of the chicken breast was 5.970.115 and 5.610.115, respectively. During the storage period, the pH decreased in both treatment groups. The current research supported earlier findings by Chun et al. [39] and Liu et al. [26].

Lipid oxidation: Lipid oxidation is analyzed during the study to assess non-microbial quality characteristics in fresh beef products [40]. Higher lipid oxidation is a sign of poor quality in meat and meat products [41]. The samples' level of lipid oxidation is indicated by the data on TBA and peroxide value. In order to determine how much lipid oxidation had occurred while raw chicken samples were stored in refrigerators after being exposed to UV-C light and sodium hypochlorite, respectively [42,43].

a) TBA

It was observed that the mean TBA of raw chicken carcasses ranged from 0.383±0.010 to 0.77±0.010 MDA/kg and 0.363±0.010 to 0.700±0.010 MDA/ kg of groups UV-C light and sodium hypochlorite treatment, respectively. When compared to a chicken sample that had been treated with sodium hypochlorite during the

period of refrigeration, the TBA results revealed that UV-C light treatment had no discernible impact on the rate of lipid oxidation ($p>0.05$). Similar findings were made earlier by Chun et al. [39], who reported that samples of chicken breasts kept at 4 °C for six days under UV-C exposure did not significantly increase the amount of lipid oxidation.

b) Peroxide value

Meat has been found to include a number of enzyme systems that can start the process of lipid oxidation, with microsomal enzyme peroxidase being one of these systems [44]. The greater peroxide value denotes the production of more intermediate lipid oxidation products [26].

Despite UV-C light and sodium hypochlorite treatment, a growing trend in peroxide values was seen in the current investigation when raw chicken carcasses were stored at refrigeration temperature (Table 2). When compared to samples treated with sodium hypochlorite, the peroxide values in UV-C light-treated raw chicken carcasses were considerably ($p<0.05$) greater. Previously, after using UV-C to decontaminate chicken, Paskeviciute et al. [45] also reported significant changes in lipid oxidation.

c) Tyrosine value

Tyrosine levels in raw chicken carcasses at 0 hours were 0.169± 0.009 and 0.167 ±0.017 mg/kg for samples treated with UV-C light and sodium hypochlorite, respectively. Regardless of treatments, the tyrosine value of raw chicken carcasses increased as the storage period progressed. Tyrosine values of raw chicken carcasses after 72 hours of storage ranged from 0.523±0.023 to 0.519±0.025 for samples treated with UV-C light and sodium hypochlorite, respectively.

Tyrosine value data revealed that, in contrast to samples treated with sodium hypochlorite, UV-C light therapy had no appreciable impact on proteolytic rate during storage. Biswas et al. [46] have reported an increase in tyrosine value of meat with storage time but there are limited published data on effect of UV-C treatment on raw chicken carcasses with respect to tyrosine values.

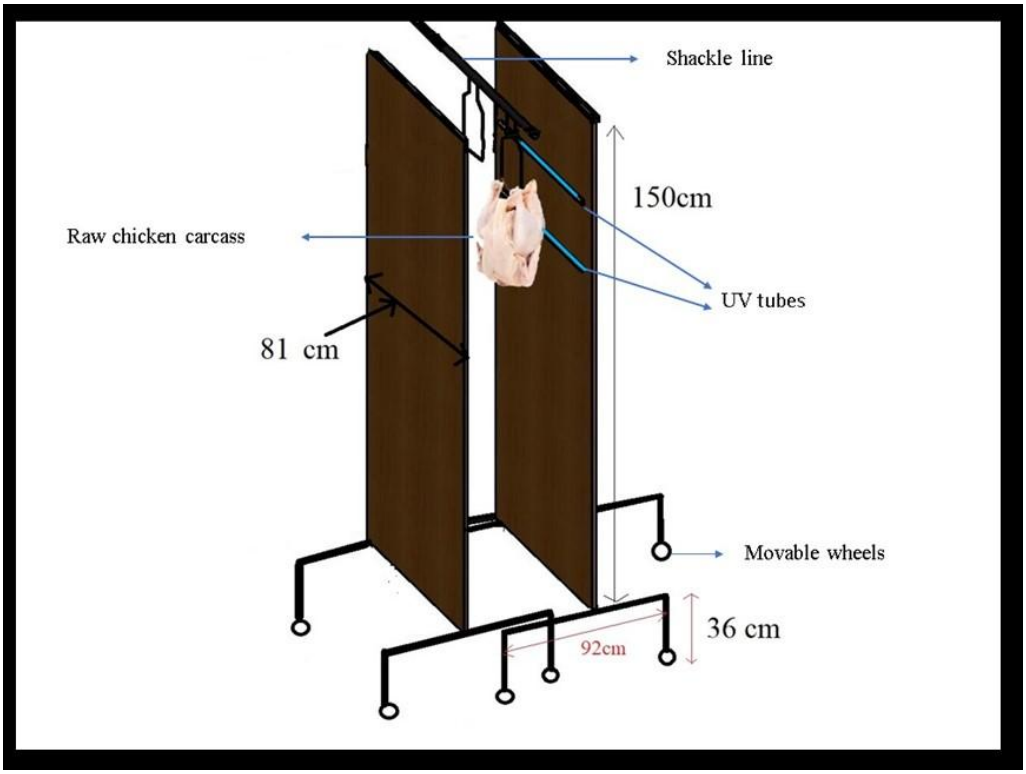

Fig. 1. Ultraviolet-C (UV-C) chamber prototype device

Table 1. Standardizing the dose of UV-C light and sodium hypochlorite by microbial and sensory evaluation

Sr. No	Parameters	Groups (n=6/groups)							Level of significance
		Carcass Side	C	UV-I	UV-II	UV-III	UV-IV	CL	
			Control	Exposure Times in Second/Distance in cm				Chlorine	
				30 sec / 10 cm 233.86mJ/cm^2	30 / 15 cm 103.93mJ/cm^2	60 sec/15 cm 207.87mJ/cm^2	120 sec/15 cm 415.75mJ/cm^2	50 ppm /60 Second	
Microbial count (log_{10} cfu/cm^2)									
1.	Total Viable	Ventral	6.26^{a} ±0.100	5.982^{ab} ±0.011	5.978^{ab} ±0.135	5.847^{b} ±0.099	5.31^{c} ±0.211	5.185^{c} ±0.083	*
	Count	Dorsal	6.4^{a} ±0.096	5.988^{b} ±0.160	5.982^{b} ±0.055	5.942^{b} ±0.074	5.23^{c} ±0.191	5.163^{c} ±0.156	
2.	*Staphylococcus* spp.	Ventral	4.578^{a} ±0.125	4.207^{ab} ±0.273	4.003^{b} ±0.140	3.535^{c} ±0.062	3.47^{c} ±0.08	3.418^{c} ±0.096	*
		Dorsal	4.415^{a} ±0.197	4.39^{a} ±0.232	4.088^{a} ±0.087	3.48^{b} ±0.047	3.555^{b} ±0.05	3.51^{b} ±0.100	*
3.	*E. Coli*	Ventral	4.233^{a} ±0.360	3.533^{bc} ±0.209	3.805^{ab} ±0.281	3.045^{cd} ±0.234	2.86^{d} ±0.100	2.838^{d} ±0.084	*
		Dorsal	4.483^{a}±0.295	3.425^{bc} ±0.341	3.798^{b} ±0.192	2.853^{cd} ±0.078	2.738^{d}±0.084	2.838^{cd} ±0.084	*
Sensory Analysis									
1	*Odour*	Whole Carcass	7.818a±0.011	7.967a±0.010	7.837a±0.021	7.777a±0.096	5.907b±0.150	7.822a±0.009	*

*a, b, c means with different superscripts in a row differ significantly $^{*}p<0.05$ * = Significant at 5 %*

Table 2. Results of microbial, sensory and physicochemical analysis of raw chicken carcasses treated with UV-C Light (415.75 mJ/cm^2) and sodium hypochlorite solution (50 ppm) during storage

Sampling Time in Hours		**0**	**24**	**48.**	**72**
Temperature (^{0}C)		**-**	**4.07±0.173**	**3.73±0.189**	**3.87±0.377**
A) Microbial count (log cfu/cm^2)					
TVC	**UV-C**	4.33±0.105	4.93±0.169	5.54±0.050	6.17±0.020
	CH	5.30±0.16	5.66±0.123	5.80±0.054	6.55±0.124
Level of significance		**	**	**	*
***Pseudomonas* spp.**	**UV-C**	-	-	-	-
	CH	-	-	1.033±0.008	1.32±0.005
Level of significance		-	-	-	-
B) Sensory parameter					
Odour	**UV-C**	5.740±0.173	5.573±0.180	5.375±0.115	4.742±0.221
	CH	7.822±0.009	7.395±0.271	6.847±0.320	4.110±0.043
Level of significance		**	**	**	*
C) Physicochemical parameters					
Hours		**0**	**24**	**48.**	**72**
Temperature (^{0}C)		**-**	**4.07±0.173**	**3.73±0.189**	**3.87±0.377**
pH	**UV-C**	5.97±0.115	5.94±0.051	5.85±0.066	5.85±0.031
	CH	5.61±0.115	5.70±0.088	5.59±0.119	5.35±0.080
Level of significance		*	*	NS	**
	UV-C	0.383±0.010	0.520±0.021	0.630±0.010	0.777±0.010
TBA (MDA / kg)	**CH**	0.363±0.016	0.490±0.017	0.515±0.093	0.700±0.019
Level of significance		NS	NS	NS	**
Tyrosine (mg/g)	**UV-C**	0.169±0.009	0.308±0.021	0.358±0.031	0.523±0.023
	CH	0.167±0.017	0.297±0.041	0.314±0.041	0.519±0.025
Level of significance		NS	NS	NS	NS
Peroxide value	**UV-C**	1.378±0.021	1.453±0.029	1.555±0.020	1.821±0.063
(meq/ kg)	**CH**	1.14±0.057	1.257±0.053	1.329±0.023	1.449±0.028
Level of significance		**	**	**	**

***= 1% Level of significance *=5% Level of significance*

4. CONCLUSION

The results of this investigation lead us to the conclusion that raw chicken carcasses' surface microflora can be effectively reduced by UV-C light (207.87 and 415.75 mJ/cm^2). In comparison to sodium hypochlorite (50 ppm) treatment, UV-C light (415.75 mJ/cm^2) was found effective at extending the shelf life of chicken with little to no impact on the TBA, tyrosine, and pH values of raw chicken sample However, it was discovered that the UV-C light (415.75 mJ/cm^2) and sodium hypochlorite (50 ppm) groups were on par with one another in reaching a 3-day shelf life for refrigeration storage (0–4ºC). It is concluded that surface disinfection of raw chicken carcasses using UV-C light technology at a dosage of 415.75 mJ/cm^2 may be beneficial.

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AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. USDA GAIN. (United States Department of Agriculture Global Agricultural Information Network) India's Poultry Market - A Snapshot of 2020-21; 2021.
2. BAHS (Basic Animal Husbandry Statistics), BAHS (Basic Animal Husbandry Statistics) Department of Animal Husbandry, Dairying and Fisheries, Government of India; 2019. Available:https://dahd.nic.in/sites/default/filess/BAHS%20%28Basic%20Animal%20Husbandry%20Statistics-2019%29_0.pdf (2019)
3. Waghamare RN, Popalghat HK, Londhe SV, Deshmukh VV, Khobe VV. An online survey of consumers of Maharashtra concerning the expected change in the meat and meat product business Journal of Animal Research. 2021;11(1):137-141. Available:https://doi.org/10.30954/2277-940X.01.2021.18
4. Capita R, Alonso-Calleja C, Garcia-Fernandez MC, Moreno B. Trisodium phosphate (TSP) treatment for decontamination of poultry. Food Science and Technology International. 2002;8(1): 11-24 Available:https://doi.org/10.1106/10820130 2023118
5. Castañeda-Gulla K, Sattlegger E, Mutukumira AN. Persistent contamination of Salmonella, Campylobacter, Escherichia coli and Staphylococcus aureus at a broiler farm in New Zealand. Canadian Journal of Microbiology. 2020;66(3):171-185. Available:https://doi/10.1139/cjm-2019-0280.
6. Phillip AJ, Nikanjam N, Nowak E, Mutukumira AN. Surface pasteurisation of fresh chicken meat using UV-C technology. Engineering in Agriculture, Environment and Food. 2020;13(4): 121-128. Available:https://doi.org/10.37221/eaef.13.4_121
7. Petracc M, Fletche DL. Broiler skin and meat color changes during storage. Poultry Science. 2002;81(10):1589-1597. Available:https://doi.org/10.1093/ps/81.10.1589
8. Gould GW. New processing technologies: An overview. Proceedings of the Nutrition Society 2001;60(4):463-474.
9. Lynch S. Pulsed Electric Fields (PEF): Technology, role in food science and emerging applications. USA: Nova Science Publishers Inc; 2016.
10. Gunter Ward DM, Patras A, Bhullar SM, Kilonzo Nthenge A, Pokharel B, Sasges M. Efficacy of ultraviolet (UV - C) light in reducing foodborne pathogens and model viruses in skim milk. Journal of Food Processing and Preservation. 2018;42(2): e13485. Available:https://doi.org/10.1111/jfpp.13485
11. Koutchma T. Advances in Ultraviolet light Technology for Non-thermal Processing of Liquid Foods. Food and Bioprocess Technology: An International Journal. 2009;2(2):138-155. Available: https://doi.org/10.1007/s11947-008-0178-3

12. Oğuz R, Güler C. 21.Yüzyılda niçin klorlama. TSK Koruyucu Hekimlik Bülteni. 20043(8):186-195.
13. Semi, MFB. UV-light treatment of fruit in a rotating drum. (Bachelor of Engineering), Massey University, New Zealand; 2016.
14. BAM (Bacteriological Analytical Manual), 8th edition publication by FDA, U.S; 1998.
15. ISO 6888-2 International Standards Office :(Reaffirmed at 2012) Indian standard methods for detection of Bacteria responsible for food poisoning part- 8 horizontal method for enumeration of Coagulase-positive Staphylococcus (Staphylococcus aureus and other species) section- 2, Technique using rabbit plasma fibrinogen agar medium; 1999.
16. ISO. 16649-2:2001 International Organization for Standardization. Microbiology of food and animal feeding stuffs—horizontal method for the enumeration of beta-glucuronidase-positive *Escherichia coli*—part 2 colony-count technique at 44 degrees C using bromo-4-chloro-3-indolyl beta-D-glucuronide, ISO16649-2:2001, International Organization for Standardization, Geneva; 2001.
Available:www.iso.org (accessed 2018)
17. ISO. 11059 2009. Milk and milk products. Method for the enumeration of *Pseudomonas spp*. ISO Norm 11059: 2009 (IDF/RM 225: 2009).
18. Strange ED, Benedict RC, Smith JL and CE. Swift. Evaluation of rapid tests for monitoring alterations in meat quality during storage: I. Intact meat. Journal of Food Protection, 1977;40(12):843-847.
Available:https://doi.org/10.4315/0362-028X-40.12.843
19. Sallam KI, Ishioroshi M, Samejima K. Antioxidant and antimicrobial effects of garlic in chicken sausage.LWT-Food Science and Technology. 2004;37(8):849-855.
Available:https://doi.org/10.1016/j.lwt.2004.04.001
20. Keeton JT. Effect of fat and NaCl/phosphate levels on the chemical and sensory properties of pork patties. Journal of Food Science.1983;41:878–881.
Available:https://doi.org/10.1111/j.1365-2621.1983.tb14921
21. Lázaro CA, Júnior CC, Monteiro MLG, B Costa-Lima BRC, Mano SB, Franco RM. Effects of ultraviolet light on biogenic amines and other quality indicators of chicken meat during refrigerated storage. Poultry Science. 2014;93(9):2304-2313,
Available:https://doi.org/10.3382/ps.2013-03642
22. Isohanni PMI, Lyhs U. Use of ultraviolet irradiation to reduce Campylobacter jejuni on broiler meat. Poultry Science. 2009; 88(3):661-668.
Available:https://doi.org/10.3382/ps.2008-00259
23. Haughton PN, Lyng JG, Cronin DA, Morgan DJ, Fanning S, Whyte P. Efficacy of UV light treatment for the microbiological decontamination of chicken, associated packaging, and contact surfaces. Journal of Food Protection. 2011;74(4):565-572.
Available:https://doi.org/10.4315/0362-028X.JFP-10-356
24. Gayán EI, Álvarez Condón S. Inactivation of bacterial spores by UV-C light. Innovative Food Science and Emerging Technologies. 2013;19:140-145.
Available:
https://doi.org/10.1016/j.ifset.2013.04.007
25. Maharjan S, Rayamajhe B, Chhetri VS. Microbial quality of poultry meat in an ISO 22000:2005 certified poultry processing plant of Kathmandu valley. Food Contamination. 20196(8).
Available:https://doi.org/10.1186/s40550-019-0078-5
26. Liu NQ, Zh X, Zeng B, Yang M, Liang P, Hu, Zhou J. Influences of pulsed light-UV treatment on the storage period of dry-cured meat and shelf life prediction by ASLT method. Journal of Food Science and Technology, 2019;56(4):1744-1756.
Available:https://doi/10.1007/s13197-019-03603-1
27. Shen L, Xing Z, Zou J, Li Z, Wu X, Zhang Y, Zhou W. Black TiO2 nanobelts/g-C3N4 nanosheets laminated heterojunctions with efficient visible-light-driven photocatalytic performance. Scientific Reports. 2017;7(1): 1-11.
Available:https://doi.org/10.1038/srep41978
28. Sommers CH, Cooke PH, Fan X, Sites JE. Ultraviolet light (254 nm) inactivation of Listeria monocytogenes on frankfurters that contain potassium lactate and sodium diacetate. Journal of Food Science. 2009;74(3):M114-M119.
Available:https://doi.org/10.1111/j.1750-3841.2009.01081

29. Kim T, Silva JL, Chen TC. Effects of UV irradiation on selected pathogens in peptone water and on stainless steel and chicken meat. Journal of Food Protection. 2002;65(7):1142-5.
Available:https://doi/10.4315/0362-028x-65.7.1142
30. McLeod A, Hovde Liland K, Haugen JE, Sørheim O, Myhrer KS, Holck AL. Chicken fillets subjected to UV-C and pulsed UV light: Reduction of pathogenic and spoilage bacteria and changes in sensory quality. Journal of Food Safety. 2018;8(1):e12421.
Available:https://doi.org/10.1111/jfs.12421
31. Stermer RA, Lasater-Smith M, Brasington CF. Ultraviolet radiation—an effective bactericide for fresh meat. Journal of Food Protection. 1987;50(2):108-111.
Available:https://doi.org/10.4315/0362-028X-50.2.108
32. Wallner-Pendleton EA, Sumner SS, Froning GW, Stetson LE. The use of ultraviolet radiation to reduce *Salmonella* and psychotropics bacterial contamination on poultry carcasses. Poultry Science. 1994;73(8):1327-1333.
Available:https://doi.org/10.3382/ps.0731327
33. Lyon SA, Fletcher DL, Berrang ME. Germicidal ultraviolet light to lower numbers of *Listeria monocytogenes* on broiler breast fillets. Poultry Science. 2007;86(5):964-967.
Available:https://doi.org/10.1093/ps/86.5.964
34. Isohanni PMI, Lyhs U. Use of ultraviolet irradiation to *reduce Campylobacter jejuni* on broiler meat. Poultry Science. 2009; 88(3):661-668.
Available: https://doi.org/10.3382/ps.2008-00259
35. Rouger A, Tresse O, Zagorec M. Bacterial contaminants of poultry meat: sources, species, and dynamics. Microorganisms. 2017;*5*(3):50.
Available:http://dx.doi.org/10.3390/microorganisms5030050
36. Kozačinski L, Hadžiosmanovi M, Zdole N. Microbiological quality poultry meat on the Croatian market. Veterinarski arhiv. 2006; 76(4):305-313
Available:https://vetarhiv.vef.unizg.hr/papers/2006-76-4-4
37. Park SY, Lee NY, Kim SH, Cho JI, Lee HJ, Ha SD. Effect of ultraviolet radiation on the reduction of major food spoilage molds and sensory quality of the surface of dried filefish (*Stephanolepis cirrhifer*) fillets. Food Research International. 2014;62: 1108-111.
Available:https://doi/10.1016/j.foodres.2014.05.060
38. Bintsis T, Litopoulou Tzanetaki E, Robinson KR. Existing and potential applications of ultraviolet light in the food industry–a critical review. Journal of the Science of Food and Agriculture. 2000; 80(6):637-645.
Available:https://doi.org/10.1002/(SICI)1097-0010(20000501)80:6<637::AID-JSFA603>3. 0.CO;2-1.
39. Chun HH, Kim JY, Lee BD, Yu DJ, Song KB. Effect of UV-C irradiation on the inactivation of inoculated pathogens and quality of chicken breasts during storage. Food Control. 2010;21(3):276-280.
Available:https://doi.org/10.1016/j.foodcont.2009.06.006
40. Reitznerová A, Šuleková M, Nagy J, Marcinčák S, Semjon B, Čertík M, Klempová T. Lipid peroxidation process in meat and meat products: A comparison study of malondialdehyde determination between modified 2-thiobarbituric acid spectrophotometric method and reverse-phase high-performance liquid chromatography. Molecules. 2017;22(11): 1988.
Available:https://doi.org/10.3390/molecules22111988.
41. Gao Y, Zhuang H, Yeh HY, Bowker B, Zhang J. Effect of rosemary extract on microbial growth, pH, color and lipid oxidation in cold plasma-processed ground chicken patties. Food Science and Emerging Technologies. 2019;57:1021-68
Available:https://doi.org/10.1016/j.ifset.2019.05.007
42. Gayán E, Álvarez I, Condón S. Inactivation of bacterial spores by UV-C light. Innovative Food Science & Emerging Technologies. 2013;19:140-145.
Available:https://doi.org/10.1016/j.ifset.2013.04.007
43. ISO 18593. Horizontal methods for sampling techniques from surfaces using contact plates and swabs. In: Microbiology of Food and Animal Feeding Stuffs. (ISO 18593:2018). British Standards Institution, London. 2018;14.
Available:https://www.iso.org/standard/64950.htm

44. Domínguez R, Pateiro M, Gagaoua M, Barba FJ, Zhang W, Lorenzo JM. A comprehensive review on lipid oxidation in meat and meat products. Antioxidants. 2019;8(10):429. Available:https://doi.org/10.3390/antiox8100429
45. Paskeviciute E, Buchovec I, Luksiene Z. High-power pulsed light for decontamination of chicken from food pathogens: A study on antimicrobial efficiency and organoleptic properties. Journal of Food Safety. 2011;31(1):61-68. Available:https://doi.org/10.1111/j.1745-4565.2010.00267
46. Biswas P, Cho SR, Kim JW, Baek SD, Myoung JM. Improved UV response of ZnO nanotubes by resonant coupling of anchored plasmonic silver nanoparticles. Nanotechnology, 2017;28(22):225502. DOI:https://doi.org/10.1088/1361-6528/aa6ce0

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