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Review

LED induced non-thermal preservation of muscle foods: A systematic review

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ABSTRACT

LED technology has emerged as a promising non-thermal preservation method for highly perishable muscle foods like meat and fish. Muscle foods are most susceptible to spoilage due to their high moisture content and nutrient density, which create an ideal environment for microbial growth, chemical oxidation, and enzymatic activity, which negatively alter their quality. LED treatment offers an effective solution by significantly reducing microbial loads and extending shelf life without adversely affecting sensory and nutritional properties. Specific wavelengths of LED light induce microbial inactivation through mechanisms like DNA damage, lipid oxidation, and protein alteration. Studies have shown that LED treatment can preserve the fresh-like quality of muscle foods by mitigating common spoilage processes. The advantages of LED technology include its non-thermal nature, ability to integrate with other preservation methods, and controllability in terms of intensity and wavelength. This enables for tailored applications based on food type and spoilage risks. As consumer demand grows for safe, chemical-free food options, LED technology addresses this need while enhancing food safety and quality. Further research is encouraged to optimize LED applications in various muscle food preservation contexts. With its exceptional ability to produce DNA damage in bacteria, inactivate enzymes, and malfunction biological activities, LED could serve as an inexpensive processing intervention to safeguard the quality of meat and seafood products. This review underscores the potential of LED technology as a promising alternative to traditional preservation methods for decontamination of muscle food.

1. Introduction

Foods are organic and inorganic compounds of plant or animal origin which contains macro and micro nutrients (Vigar et al., 2019). Meat ranks as one of the healthiest and most energizing often consumed food item, people use as energy for their daily activities (Hussain et al., 2018). Foods undergo spoilage due to microbial, chemical, or physical hazards. Various physicochemical, sensorial and microbial activities are susceptible to spoilage (Amit et al., 2017). Meat proteins are susceptible to enzymatic and microbial degradation. The high moisture content of meat creates an ideal environment for bacterial growth, particularly psychrophilic bacteria that thrive at refrigeration temperatures (Rahman et al., 2023). Fats in meat can undergo oxidation, resulting in rancidity and unpleasant flavors (Dave and Ghaly, 2011). Furthermore, the presence of minerals and vitamins can contribute to the growth of spoilage microorganisms (Karanth et al., 2023).

Fish is abundant in proteins, but it also contains higher levels of unsaturated fats (Hosomi et al., 2012). These unsaturated fats are prone to oxidation, leading to the development of disagreeable flavors and odors commonly associated with fish spoilage (Shahidi and Hossain, 2022). Fish also contains trimethylamine oxide (TMAO), which, when influenced by microbial action, converts into trimethylamine (TMA)—the culprit behind the characteristic "fishy" odour (Wang et al., 2023). The high moisture content of fish makes it vulnerable to bacterial and enzymatic degradation, with psychrotrophic bacteria thriving even at lower temperatures (Ghaly, 2010).

Meat and fish have higher nutrient and water content, which results in the loss of many physiological and sensory properties due to the growth of microorganisms and increased enzymatic spoiling activity (Gill, 1983; Addis, 2015). Fish and meat processing, breeding, harvesting, pre and post-slaughtering techniques, and handling operations all contributed to its proliferation (Comi, 2017) which further results in changes in colour, an off flavor and odour, the development of slime, and black, white, or green discoloration.

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Numerous preservation techniques (see Fig. 1) are employed globally to prevent the loss of meat and fish due to spoilage. Meat and fish are preserved using physical, chemical, and biological techniques. Canning, smoking, dehydration, cooling, freezing, ozonisation, irradiation, high pressure processing, and other modern packaging technologies are examples of physical techniques that are also categorized as thermal and non-thermal methods. Meat and fish are also preserved chemically through curing, biologically through pickling and fermentation, and naturally antimicrobially through the use of bacteriocins (Chellaiah et al., 2020; Dave and Ghaly, 2011; Rahman et al., 2017; Zhou et al., 2010).

All these different thermal preservation techniques have an impact on the sensory and nutritional quality of meat and fish. There are numerous restrictions on the heat preservation of meat and fish (Mathavi et al., 2013;Sofos, 2008). Consumers are growing more knowledgeable about eating safe and chemical-free food. The situation around the acceptability of preservation techniques is changing due to changes in consumer demand and awareness, evolving legal and regulatory compliances, and industrial interest in providing chemical-free foods. Therefore, effective preservation techniques must be developed in order to safely produce and preserve the food (Braiek & Smaoui, 2021; Hyun and Lee, 2020; Thirumdas et al., 2014). Non-thermal food processing techniques have an insignificant effect on the nutritional and sensorial qualities of foods, and increases shelf stability by killing microorganisms. Non-thermal processes additionally address industry issues by value added products, new market openings and added safety edges (Morris et al., 2007).

Light-emanating diode, ordinarily called a LED is a semiconductor diode that discharges indistinguishable narrow-spectrum of light when electrically biased the forward way of the p-n junction, as in the normal LED circuit (Singh, 2009). Light waves of electromagnetic spectrum have been used to disinfect the different organisms. Light-emitting diodes (LED) creating monochromatic light have been used in food industries. Each wavelength causes effect on physicochemical and microbial quality of food. The primary qualities of LED lights, and its mechanism of activity in food is to broaden time span of shelf life and improve properties (Finardi et al., 2021).

Therefore LED will be upcoming non chemical preservation method used for preservation of meat and fish products. This review highlighted about the reasons of muscle food spoilage, effect of non-thermal processing on muscle food, properties of LEDs, principle of decontamination of muscle food by LEDs and advantages of LED non thermal method.

2. Mechanism of microbial inactivation by light emitting diode

Depending on its type and wavelength, LED light as a physical and non-thermal approach has a variety of mechanisms of action on live cells that target a particular cellular component and result in some biological consequences shown in Fig. 2. The main biological effect of LED light exposure in microbes is DNA damage. Due to the intense LED light, biomolecules including proteins and lipids faced various biological defects. Reactive oxygen species (ROS), which LED light produces, are thought to primarily target proteins and lipids, which has an indirect impact (Kebbi et al., 2020).

2.1. DNA damage

It is important to note that LED radiations further generate cyclobutane–pyrimidine dimers (CPDs). The predominant by-products that have had the most damaging effects on microbial cells are CPDs. Additionally, 6–4 photo products are produced, which have mutagenic and fatal effect. DNA is also impacted by photoreactions that result in the production of singlet oxygen (Kebbi et al., 2020; Rastogi et al., 2010).

2.2. Lipid oxidation

Microbial cell contains large amount of iron which produces high amount of Reactive Oxygen Species (ROS). The fatty acids in the cell membrane are oxidized by these reactive oxygen species, rupturing the bacterial cell membrane (Kebbi et al., 2020; Martysiak-Żurowska et al., 2017).

2.3. Protein alteration

The LED light dosages also change proteins. The doses of LED light have a negative impact on enzymes. As a result of enzyme deactivation,

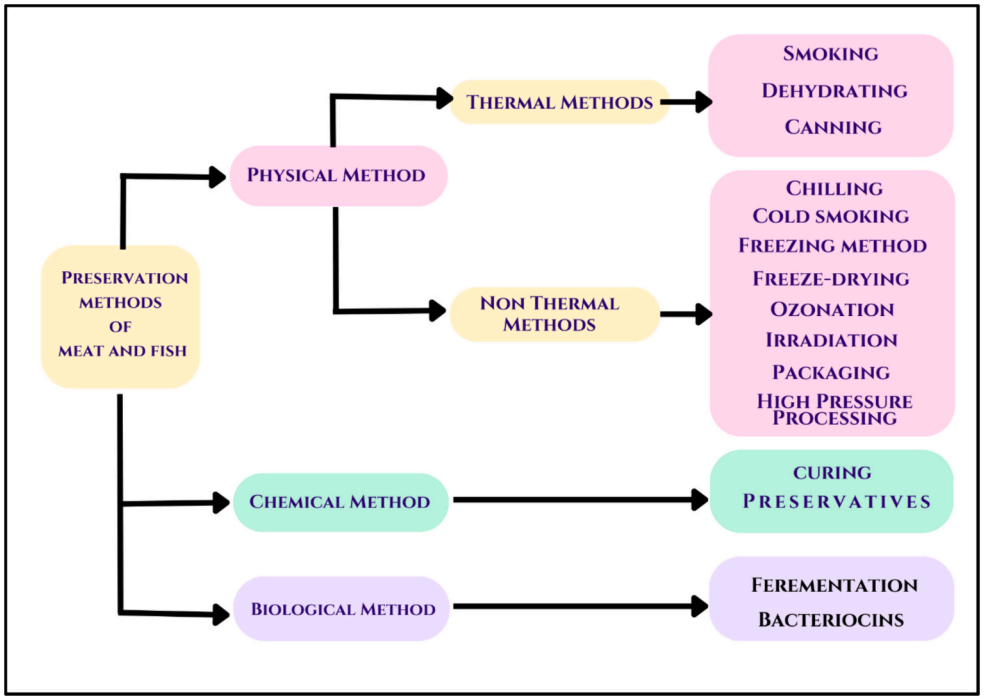


Fig. 1. Various preservation methods of meat and fish.

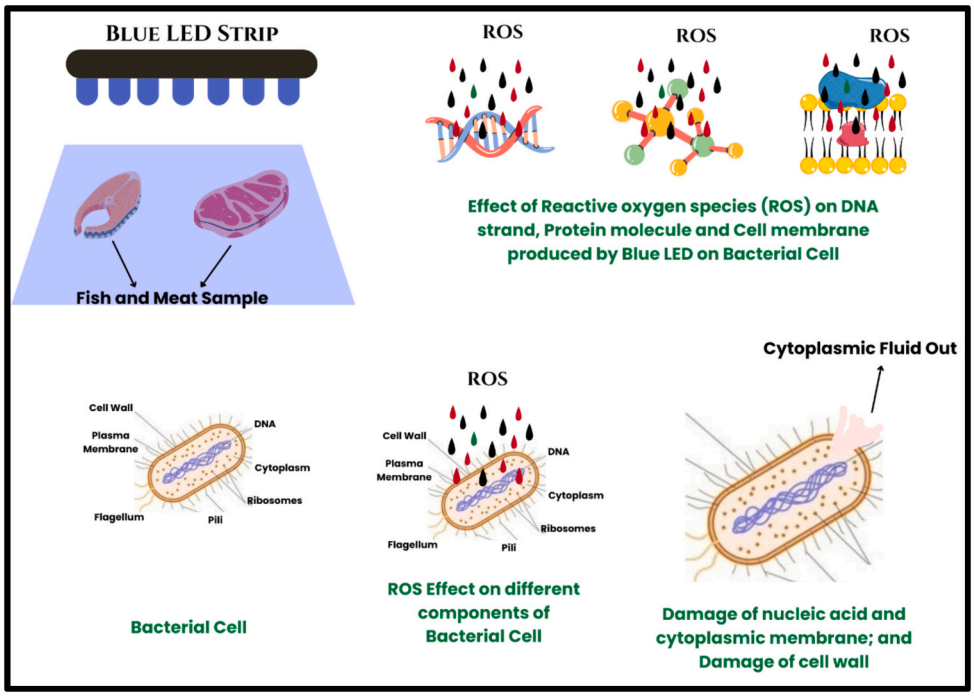


Fig. 2. Mechanism of microbial inactivation by light emitting diode.

cellular processes become dysfunctional (Kebbi et al., 2020; Kim et al., 2022; Pigeot-Rémy et al., 2012).

3. Meat spoilage mechanism

Meat is basically defined as the flesh of animals used as food. Meat has undergone certain chemical and biochemical changes following death of an animal which is a post-mortem aspects. Spoilage of meat is happened due to physical, chemical and biological agents shown in Fig. 3 (Soladoye et al., 2024). Composition of meat such as Fat, protein, minerals, carbohydrate and water are favourable for microbial degradation of meat (Heinz and Hautzinger, 2007). Spoilage of meat caused degradation of physic-chemical qualities like different nutritive qualities, sensorial qualities i.e. flavor, odour, colour, texture (Addis, 2015). Different types of aerobic and Anaerobic spoilages of meat by bacteria and also by aerobic spoilage by molds are happened (Gill, 1983). The most important change that occurs in post-mortem muscle is the development of rigor mortis, means stiffening of muscles after death. The stiffening is due to formation of irreversible actomysine cross bridges (Dave and Ghaly, 2011). Different types of microbes are present

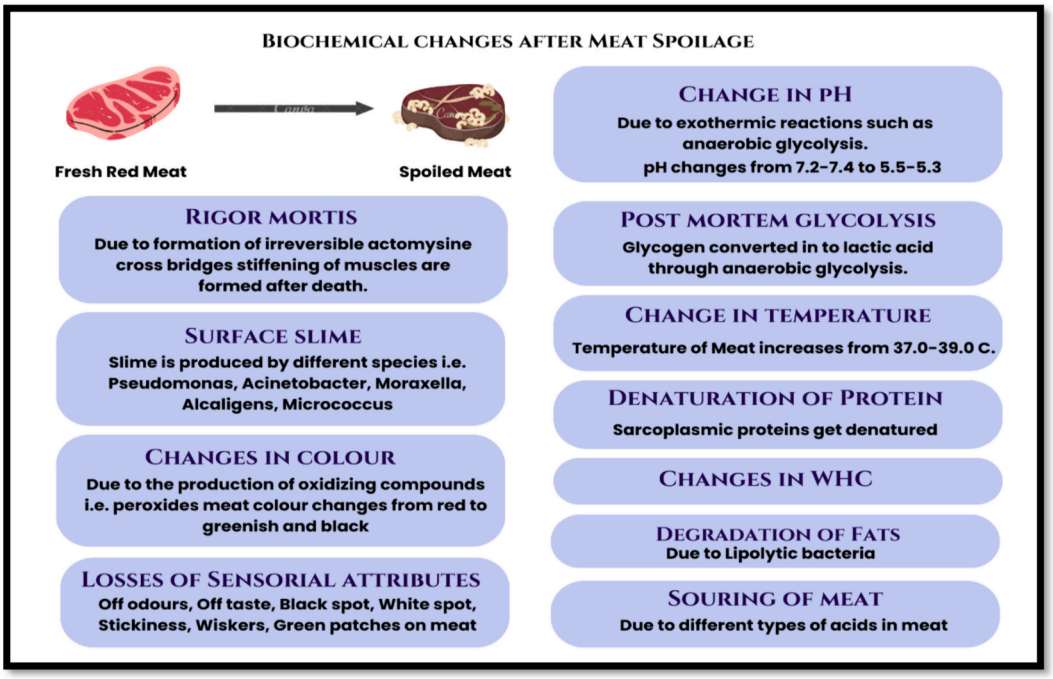


Fig. 3. Biochemical changes occur in meat spoilage.

on meat like *Pseudomonas*, *Leuconostoc*, *Enterobacteriaceae*, *Clostridium tetani*, *Carnobacterium*, *Brochothrix thermosphacta* and many other microbes (Zhu et al., 2022). Surface slime is the defect produced by different bacteria such as *Pseudomonas*, *Moraxella*, *Acinetobacter*, *Alcaligens*, *Streptococcus*, *Micrococcus*, *Leuconostoc*, and *Bacillus* in aerobic condition (Ercolini et al., 2006). Glycogen is converted in to lactic acid through anaerobic glycolysis so decrease in pH due to lactic acid formation is accompanied. The pH changes from 7.2 to 7.4 to 5.5–5.3 so the souring of the meat happened (Gill, 1983). Colour is the sensorial attribute used to assess the quality of meat. Fresh meat is exist in red colour. Due to the formation of oxidizing compounds, e.g., peroxides, or of hydrogen sulfide by different bacteria convert the red colour of meat to green, brown, or grey (Seideman et al., 1984). Fat is oxidized and degraded by the lipolytic bacteria such as *Pseudomonas* and *Achromobacter* or by yeasts (Gill, 1983). Different qualities of meat i.e. water holding capacity (WHC) and colour are affected by the denaturation of sarcoplasmic proteins (Marino et al., 2014). Sensorial attributes such as taste and odour are highly affected by microbial spoilage. Stickiness, whiskers, black spot, white spot, and green patches are formed due to different types of molds in aerobic conditions (Soladoye et al., 2024; Addis, 2015; Gill, 1983).

4. Fish spoilage mechanism

Fish spoilage is a process that reduces the fish's quality and affects the flavor, taste and appearance of the fish. Fish decaying is caused by the breakdown of biomolecules such proteins, amino acids and lipids in the fish. A fish can therefore become spoiled either by chemical or biological degradation (Lakshmanan, 2000; Comi, 2017).

Protein, lipids, amino acids and other substances are broken down chemically whereas microorganisms are responsible for biological degradation. Fish decaying can also be carried about by enzymatic and mechanical damage in addition to bacterial and chemical deterioration. Fish decaying is facilitated by a number of reasons, including excessive moisture level, protein and fat content, improper handling, etc. (Ahmad et al., 2021; Pedrosa-Menabrito and Regenstein, 1988; Raa et al., 1982).

Bacterial contamination and chemical oxidation (proteins and lipids) are the usual causes of fish deterioration. The microorganisms involved in fish spoilage refers to the specific spoilage organisms (SSOs) produces a large number of undesired metabolites and give fish an undesirable flavor and odour (Khuntia, 2009; Ghaly, 2010).

Fish spoilage is generally of three types namely autolysis, bacterial spoilage and chemical spoilage shown in Fig. 4 (Supriya, 2022). Autolysis refers to enzymatic degradation that results in the cell damage of fish and release of an autolytic enzyme, which degrades the cell components like proteins, fats etc. and thereby change the flavor of fish. The changes in the flavor of fish can be due to the conversion of ATP to hypoxanthine and the decomposition of fish. Conversion of ATP to hypoxanthine adds a bitter taste to fish. We can estimate the degree of freshness by knowing the hypoxanthine content. The action of digestive enzymes in the fish gut leads to belly bursting of the fish hence causes fish spoilage. Autolysis can change the appearance and flavor of the fish by two ways. First is black spot formation which cause black spot formation in shrimps by showing some enzymatic action on the amino acids. The black spot occurs due to the formation of melanin pigment, which results in poor appearance. Second by producing a foul smell by the action of proteinase enzyme on the muscle proteins into amino acids and formation of compounds like ammonia, carbon dioxide, amines, fatty acids etc. Thus, the production of secondary metabolites produces indole, skatole, etc., results in the release of a foul smell from a fish (Mukundan et al., 1986; Khuntia, 2009; Datta, 2013; Callow, 1925).

Spoilage of fish is carried out by different types of organisms such as *Pseudomonas* (*P. putida*, *P. fluorescens*, and *P. fragi*) and *Shewanella* (*S. putrefaciens*, *S. proteamaculans*, and *S. baltica*). Also, other bacteria from different genus like *Aeromonas*, *Bacillus*, *Brochothrix*, *Carnobacterium*, *Escherichia*, *Enterobacter*, *Listeria*, *Micrococcus*, *Moraxella*, *Proteus*, *Psychrobacter*, and *Vibrio* were reported for the spoilage of fish (Gram and Huss, 1996; Chen et al., 2020; Novoslavskij et al., 2015; Odeyemi et al., 2020). A fish acquires a load of microorganisms on its exterior and in its gills. When a fish dies, the bacteria that are already present in the fish attack the flesh and produce undesired byproducts. The type of water from which a fish was caught determines the microbial growth in that fish. The following are the ways that bacteria can cause fish spoilage such as Odorous trimethylamine is produced when odourless trimethylamine oxide is reduced by the action of bacterial enzymes. Degradation of amino acids to primary amines can result in food poisoning when amino acids are broken down into primary amines. i.e. Histamine – Histidine and Glutamic acid-arginine and degradation of

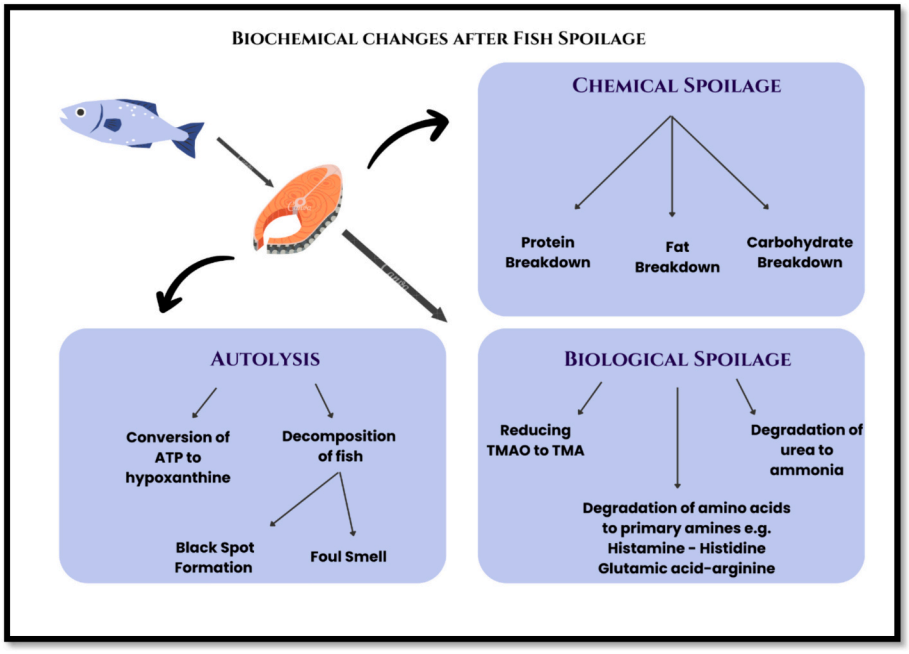


Fig. 4. Biochemical changes occur in fish spoilage.

urea to ammonia can produce unpleasant odour is also produced by the breakdown of urea to ammonia (Khuntia, 2009; Ghaly, 2010; Datta, 2013).

Chemical deterioration is favored by high temperature. Chemical deterioration is frequently brought on by oxidative rancidity. Proteolytic enzymes from microbes break down proteins into amino acids, amines, ammonia, and hydrogen sulfide. The action of fermentative bacteria causes the breakdown of carbohydrates into acids, alcohols, and gases. Lipolytic bacteria break down fats into fatty acids and glycerol (Pedrosa-Menabrito and Regenstein, 1988; Khuntia, 2009; Nazir and Magar, 1963; Datta, 2013).

5. Preservation of meat and fish quality by application of LED

Fish and meat are particularly prone to deterioration due to the mechanism covered in preceding sections. It has also been proposed that LEDs increase food shelf life by preventing lipid oxidation, inactivating enzymes, and inhibiting Gram positive and Gram negative microbes (Table 1) (Hyun and Lee, 2020; D'Souza et al., 2015).

5.1. Effects of LED on microbial stability

5.1.1. Effects of LED on bacterial stability

Every year, a number of foodborne outbreaks have been linked to chicken, fish, and their products (Sheng and Wang, 2020). The application of LED for the preservation of muscle food has received a lot of attention, with several studies claiming that LED therapy greatly decreased the microbial load on fish and muscle food (Monteiro et al., 2024, 2023; Russo et al., 2024; Wang et al., 2023). Fresh meat treated with 253 nm LED light shows 2 log reduction of bacteria at radiation dose of 150 mW s/cm^2. Further increases in dose level to 500 mW s/cm^2 reduced the bacteria level one additional log cycle (Stermer et al., 1987). Hassan et al. (2015) studied the impact of ultraviolet irradiation processing on quality of fresh beef meat during cold storage. As per his outcome the fresh beef meat treated with 254 nm LED light shows significant reduction in organism. The shelf life of treated sample was increased by 20 days at cold storage condition.

Kim et al. (2002) was reported the effect of UV irradiation on chicken meat. Effects of UV light were studied on different spoilage organisms such as *Listeria monocytogenes*, *Escherichia coli* O157:H7, and *Salmonella Typhimurium*. All these organisms *Listeria monocytogenes*, *Escherichia coli* O157:H7, and *Salmonella Typhimurium* significantly decreased by 5.77, 5.03 and 5.02 log cfu/g of samples with treatment of UV radiation respectively. Another study of broiler breast fillets were subjected to LED lights with treated dose of 1000 μW/cm^2 at a wavelength of 254 nm for 5 min to determine its potential to reduce *Listeria monocytogenes* count. Two log reduction in L. *monocytogenes* was observed with all 4 strains on LEDs treated breast fillets as compared with the non-treated breast fillets. Raw breast fillets treated with 254 nm LEDs at a slaughter plant shown significantly reduction in L. *monocytogenes* (Lyon et al., 2007). Chun et al. (2010) explored into the way UV-C radiation affected the inactivation of injected microorganisms and the quality of chicken breasts during storage. In this investigation, several bacteria including *Salmonella enterica*, *Listeria monocytogenes*, and *Campylobacter jejuni* were found to be present in chicken breast samples. Then, multiple 254 nm LED wave dosages were applied to this sample. *C. jejuni*, *L. monocytogenes*, and *S. typhimurium* initial populations all had declines of 1.26, 1.29, and 1.19 log CFU/g, respectively.

The susceptibility of *Campylobacter* to high intensity near ultraviolet/visible light was investigated by Haughton et al. in 2012. When exposed to 395 nm LED lights at a distance of 2 cm, *Campylobacter jejuni* and *Campylobacter coli* were reduced by 3.91 log CFU/ml and 1.11 log CFU/ml, respectively. According to Lázaro et al. (2014), UV light has an impact on chicken that has been vaccinated against *Salmonella*. Chicken samples were exposed to UV light at diverse intensities (0.62, 1.13, and 1.95 mW/cm2) and at varying durations (30, 60, and 90 s). The UV-treated material demonstrated a 0.60 log cfu/g log decrease for 90 S. The findings showed that 90S and 1.95 mW/cm2 were the ideal UV-C exposure period and light intensity, respectively. Cichoski et al. (2015) investigated the oxidative and microbiological profiles of chicken drumsticks treated with ultraviolet-c radiation. In this study, the authors found that the lifespan of chicken drumstick treated with UV-C LED was improved by three days. The amount of mesophilic aerobic bacteria, psychrotrophic bacteria and molds and yeasts was better reduced. Different viruses are common cause of foodborne disease. A few viral infections have been perceived to represent an enormous proportion of foodborne sicknesses such as human norovirus (HNoV) and hepatitis An infection (HAV) said by Jenns et al. (2022).

The research conducted by Sommers et al. (2016) reported that the *Escherichia coli* treated with 254 nm LED light shown 0.6 log cfu/g reduction with alteration in quality of ground chicken meat. Food Borne illness is associated with *Listeria monocytogenes* through chicken meat. Treating chicken meat to reduce the growth of *Listeria monocytogenes* is important as per said by Rothrock et al. (2017). Yang et al. (2017a, 2017b) studied the effect of UV-C light on *Listeria monocytogenes* on chicken breast. The treatment effectively reduced count of *Listeria monocytogenes* on chicken breast sample by 1.58 log CFU/g with energy dose 2400 mWs/cm^2. *Escherichia coli* is major concern in all food processing industries due to its pathogenic potential to cause food borne infections among people said by Yang et al. (2017a, 2017b). McLeod et al. (2017) assessed effect of UV LED (254 nm) on microbial and sensorial quality of chicken fillet. Effect of LED on many organisms shown in given table which results average reductions from 1.1 to 2.8 log cfu/cm^2. LED light at 405 ± 5 nm was evaluated for antimicrobial effects against *Salmonella Enteritidis* on the outer layer of cooked chicken. Three types of LED-illuminated *S. Enteritidis* were studied in cooked chicken at doses of 1.58–3.80 kJ/cm2 (for 20–48 h) under storage conditions of 4, 10 and 20 °C. *Salmonella* populations on illuminated cooked chicken decreased from 0.8 to 0.9 log CFU/cm2 at 3.80 kJ/cm2. It brings new knowledge about the use of LED lights for chicken conservation (Kim et al., 2017).

Philip et al. (2020) evaluated the surface pasteurization of fresh chicken meat using UV-C LEDs. According to its baseline results, the number of aerobic mesophiles present on the outer layer of fresh chicken meat was 3.31 ± 0.11 and 3.80 ± 0.35 log CFU cm-2 for skin-on and skinless chicken meat tests, individually. The initial aerobic mesophilic counts were reduced to 3.07 ± 0.22 and 1.87 ± 0.98 log CFU cm −2 resulting in a log reduction in bacteria of 0.24 and 1.93, respectively. Calle et al. (2021) explains the reduction of *Salmonella* on chicken breast. For chicken breasts treated with 50 % irradiation, the bacterial colonization association was assessed at 6.21 ± 0.16 Log CFU/cm2. Salmonella reduced 1.02 Log CFU/cm2, which is very significant. The application of LED-UV-based light technology to decontaminate chicken breasts was investigated by Soro et al., in 2021. Chicken breast fillets were exposed to LEDs with different light lengths such as: 255, 280, 300 and 365 nm. The fluency rates of certain LEDs are 0.003 W/cm2 for 255 nm, 0.068 W/cm2 for 280 nm, 0.049 W/cm2 for 300 nm, and 0.043 W/cm2 for 365 nm. Different bacteria such as pseudomonas and lactic acid bacteria showed a decrease of 2 log CFU/g after exposure to LED light, which is a remarkably high level. Swanson et al., 2022 evaluated UV decontamination and predicted bacterial spoilage of vacuum-packed chicken breasts. In this study, vacuum packed meat was treated with a 254 nm LED. Significant reductions in total gut bacteria (TEC) and total live bacteria (TVC) were observed. Treatment of these LEDs showed a reduction of 0.87 log CFU/g and 0.63 log CFU/g in total intestinal bacteria (TEC) and total viable counts (TVC), respectively. Thus, the storage time of the treated samples increased by 3 days compared to the untreated control samples.

Molina et al., 2014 investigated the effect of ultraviolet light on the microbial quality of sea bass fillets (*Dicentrarchus labrax*). During his research, fillets were treated with UV light at doses of 7.9 kJ/m2 and 15.8 kJ/m2 at 254 nm, respectively. Total viable counts (TVCs) were

Table 1
Effect of LEDs on physicochemical, sensorial and microbial stability.

Sr. no.	Food product		Organism	Gram stain	Treated LED wavelength	LED intensity	Effect on microbial quality	Effect on physicochemical and sensorial quality	Reference
1	Fresh meat	–	Total plate count		253 nm	150 mW s/cm^2	2 log CFU/cm^2	No significant differences for odour and appearance	Stermer et al., 1987
2	Fresh beef meat		Total plate count		254 nm	38.2 W·s/cm^2	3 log CFU/cm^2	Moisture content, collagen content, WHC and cooking loss were decreased. Lipid oxidation was increased.	Hassan et al., 2015
3	Beef	Diced Beef	*Listeria monocytogenes*	Gram positive	255 nm	0.6 mJ/cm^2	7.2 log cfu/g	–	McSharry et al., 2022
			Salmonella Typhimurium	Gram negative	265/285 nm	10 mJ/cm2	7.4 log cfu/g		
4	Chicken	–	*Listeria monocytogenes,*	Gram positive	254 nm	500 mW/cm^2	5.77 log cfu/g	–	Kim et al., 2002
			Escherichia coli	Gram negative			5.03 log cfu/g		
			Salmonella Typhimurium	Gram negative			5.02 log cfu/g		
5	Chicken	Broiler breast fillets	*Listeria monocytogenes*	Gram positive	254 nm	1000 μW/cm^2	2 log CFU/cm^2	No impact on colour value	Lyon et al., 2007
6	Chicken	Chicken breasts	*Campylobacter jejuni*	Gram negative	254 nm	0.5 W/cm^2	1.26 log CFU/g	pH, TBARS and hunter colour values were not changed significantly.	Chun et al., 2010
			Listeria monocytogenes	Gram positive	254 nm	0.5 W/cm^2	1.29 log CFU/g		
			Salmonella Typhimurium	Gram negative	254 nm	0.5 W/cm^2	1.19 log CFU/g		
7	Chicken	Raw chicken	*Campylobacter jejuni*	Gram negative	395 ± 5 nm	0.018 W/cm^2	1.45 log cfu/g	Did not affect the colour. Weight of the sample reduced significantly.	Haughton et al., 2012
			Total viable counts		395 ± 5 nm	0.018 W/cm^2	2.17 log cfu/g		
			Enterobacteriaceae	Gram negative	395 ± 5 nm	0.018 W/cm^2	1.23 log cfu/g		
8	Chicken	Chicken drumsticks	Psychrotrophics count		254 nm	0.22 W/cm^2	0.75 log CFU/cm^2	Fatty acid content was significantly changed. Reduction in PUFA. Higher the values of conjugated dienes (CD). Not accelerate the initiation stage of lipid oxidation. No significant changes in peroxide values. TBARS were not changed.	Cichoski et al., 2015
			Total aerobics mesophilic count		254 nm	0.22 W/cm^2	5.85 log cfu/cm2		
9	Chicken	–	*Salmonella* spp.	Gram negative	254 nm	1.95 mW/cm^2	0.60 log cfu/g	Concentration of biogenic amines was increased. pH and TBAR were stable. L* and a* instrumental colour value were slightly changed.	Lázaro et al., 2014
10	Chicken	Chicken breast	Hepatitis A		260 nm	3600 mW s/cm^2	1.17 log cfu/g	Acceptable by consumer. L* value is decreased. pH value was stable. TBAR value was increased.	Park and Ha, 2014
			Murine norovirus-1		260 nm	3600 mW s/cm^2	1.23 log cfu/g		
11	Chicken	Ground chicken meat	*Escherichia coli*	Gram negative	254 nm	2 mW/cm^2	0.6 log cfu/g	–	Sommers et al., 2016
12	Chicken	Chicken breast	*Listeria monocytogenes*	Gram positive	260 nm	2400 mW s/cm^2	1.58 log cfu/g	L* value is decreased but colour was not changed significantly. pH value not changed. TBAR slightly increased. Sensorial values not changed significantly.	Yang et al., 2017a, 2017b
13	Chicken	Skinless chicken breast fillets	*S. aureus*	Gram positive	254 nm	10 mW/cm^2	2.2 log CFU/cm^2	Colour stability was not affected	McLeod et al., 2017
			S. enteritidis	Gram negative	254 nm	10 mW/cm^2	1.6–2.4 log CFU/cm^2	Protein denaturation was not happened.	
			Pseudomonas spp.	Gram negative	254 nm	10 mW/cm^2	2.0–2.7 log CFU/cm^2	Significant off odour and off flavor were observed.	
			C. divergens	Gram positive	254 nm	10 mW/cm^2	1.9–2.8 log CFU/cm^2	Lipid oxidation doesn't adversely affect.	
			E. coli	Gram negative	254 nm	10 mW/cm^2	1.7–2.8 log CFU/cm^2		
			B. thermospacta	Gram positive	254 nm	10 mW/cm^2	1.7–2.7 log CFU/cm^2		

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Table 1 (*continued*)

Sr. no.	Food product		Organism	Gram stain	Treated LED wavelength	LED intensity	Effect on microbial quality	Effect on physicochemical and sensorial quality	Reference
			L. monocytogenes	Gram positive	254 nm	10 mW/cm^2	1.5–1.8 log CFU/cm^2		
14	Chicken	Cooked chicken	*Salmonella Enteritidis*	Gram negative	405 ± 5-nm	3.80 kJ/cm^2	0.8 log CFU/cm^2	–	Kim et al., 2017
15	Chicken	Skin-on chicken breast Fillet; Wskinless chicken breast fillet	*Salmonella* spp.; *Staphylococcus aureus*; *Listeria monocytogenes*		254 nm	50 mJ/cm^2	0.24 log CFU/cm^2	Significant effect skin-on chicken breast fillet; no effect on skinless chicken breast fillet; no impact on lipid oxidation. No impact on appearance and texture of chicken. Off-odour on the chicken samples is detected.	Philip et al., 2020
16	Chicken	Skinless chicken breast	*Salmonella enterica*	Gram negative	250–280 nm	2 mW/cm^2	1.02 log CFU/cm^2	–	Calle et al., 2021
17	Chicken	Chicken breast fillets	*Pseudomonas* bacteria	Gram negative	280 nm 300 nm 365 nm	0.003 W/cm^2 0.068 W/cm^2 0.049 W/cm^2	2 log CFU/g	Colour, texture and pH did not change significantly	Soro et al., 2021
			Lactic acid bacteria	Gram positive	280 nm 300 nm 365 nm	0.003 W/cm^2 0.068 W/cm^2 0.049 W/cm^2	2 log CFU/g		
18	Chicken	Vacuum packed chicken breasts	Total viable (TVC)		254 nm	0.291 W/cm^2	0.87 log CFU/g	Very minor changes were observed. pH did not change significantly	Swanson et al., 2022
			Total Enterobaceriaceae counts (TEC)	Gram negative	254 nm	0.291 W/cm^2	0.63 log CFU/g		
19	Chicken	Chicken skin	*Salmonella Enteritidis*	Gram negative	254 nm and Lactic acid (0.5–2.0 %)	1000 ± 50 μW/cm^2	3.35–6.41 log CFU/cm^2	Minor quality changes in colour and texture	Byun et al., 2022
20	Fish	Sea bass fillets	Total viable count (TVC)		254 nm	7.9 kJ/m^2	2.4 log cfu/g	Sarcoplasmic (SPP) and myofibrillar protein (MFP) content was increased. pH and TBARS values were increased. Sensorial value was slightly changed. Water holding capacity was decreased.	Molina et al., 2014
			Total viable count (TVC)		254 nm	15.8 kJ/m^2	2.6 log cfu/g		
21	Fish	Raw salmon fillets	*Listeria monocytogenes*	Gram positive	254 nm	10. W/cm^2	0.79 log CFU/g	Odour and colour were affected.	Mikš-Krajnik et al., 2017
			Total viable count		254 nm	10 W/cm^2	0.59 log CFU/g		
22	Fish	Fresh salmon surface	*Listeria monocytogenes*	Gram positive	405 nm	LED (16 ± 2 mW/cm^2) for 8 h at 4 and 12 °C	0.4 log CFU/cm^2	Not cause any unfavourable decolourization.	Li et al., 2018
			Salmonella spp.	Gram negative	405 nm	LED (16 ± 2 mW/cm^2) for 8 h at 4 and 12 °C	0.5 log CFU/cm^2		
23	Fish	Raw tuna fillets	*Salmonella Typhimurium*	Gram negative	275 nm	0.5 mW/cm^2	1.31 log CFU/cm^2	Water holding capacity (WHO), pH, colour, texture were not significantly changed.	Fan et al., 2021
			E. coli	Gram negative	275 nm	0.5 mW/cm^2	1.77 log CFU/cm^2		
			Listeria monocytogenes	Gram positive	275 nm	0.5 mW/cm^2	1.86 log CFU/cm^2		
24	Fish	Raw salmon	*Pseudomonas* spp.	Gram negative	254 nm	127.2 mJ/cm^2	0.9 log CFU/g	Significant colour changes and increases in lipid oxidation were observed	Pedrós-Garrido et al., 2018

significantly reduced by 2.4 and 2.6 log cfu/g with UV doses of 7.9 kJ/m2 and 15.8 kJ/m2, respectively. Mikš-Krajnik et al. (2017) studied the effect of combined LED and ultrasonic treatment on raw salmon fillets. Efficacy was assessed against different microorganisms such as *Listeria monocytogenes* and Total viable counts (TVC). As a result, *L. monocytogenes* was reduced by 0.79 log CFU/g while the total viable cell count decreased by 0.59 log CFU/g. The antibacterial effect of 405 nm light-emitting diodes on the outer layer of ready-to-eat fresh salmon (RTE) was evaluated against *Listeria monocytogenes* and *Salmonella* spp. Both *L. monocytogenes* or *Salmonella* spp. were cultured on the surface of freshly cut salmon and then illuminated with 405 nm (16 ± 2 mW/cm2) LEDs for 8 h at 4 and 12 °C. Both *L monocytogenes* and *Salmonella* cells

were essentially ($P < 0.05$) reduced by 0.4 and 0.5 log CFU/cm2 in 8 h compared with unlightened cells at 4 °C to 12 °C (Li et al., 2018).

Another study on the impact of LEDs on the microbiological safety and quality characteristics of raw tuna fillets (Fan et al., 2021) showed a high concentration of *Salmonella typhimurium* (gram negative), *E. coli* and *Listeria monocytogenes* were significantly reduced. Raw tuna inoculated with a mixture containing these organisms treated with a 275 nm LED showed a 1.31 log CFU/cm2, 1.77 log CFU/cm2 and 1.86 log CFU/cm2 reduction in *Salmonella typhimurium* (gram negative), *E coli* and *Listeria monocytogenes*.

Byun et al. (2022) explored the effectiveness of UV-C treatment in reducing *Salmonella Enteritidis* biofilms on various surfaces on chicken skin. The method used for UV-C treatment in the study involved the use of a UV-C lamp emitting radiation at 253.7 for 5 or 10 min for food contact surfaces or chicken skin, and the samples were flipped to expose both sides. The UV-C lamp was turned on 30 min before the experiment for stabilization of UV-C emission. The results of the UV-C treatment showed that it was effective in reducing *Salmonella Enteritidis* biofilms on stainless steel with 3 log CFU/cm2 reduction. Chicken skin was around 1 log CFU/cm2 during the same treatment time. The study also indicated that significant differences in the survived population of *Salmonella Enteritidis* biofilms were observed.

In another study done by McSharry et al. (2022) investigated Inactivation of *Listeria monocytogenes* and *Salmonella Typhimurium* in beef broth and on diced beef using an ultraviolet light emitting diode (UV-LED) system. Specific UV-LED wavelengths, including 255 nm, 265 nm, and 285 nm, were employed either individually or in combination to assess their effectiveness in microbial decontamination. The findings revealed that significant reductions in the target bacteria were achieved after 2 min of UV-LED treatment, with almost complete elimination observed after 60 min for all individual and combined wavelengths tested. Notably, 255 nm and 265/285 nm combination were identified as the most effective single UV treatment, and significant reductions in L. *monocytogenes*, TVCm, and TEC were achieved. These results demonstrate the potential of UV-LED technologies for the decontamination of beef products, highlighting their application in enhancing food safety practices within the meat industry.

Pedrós-Garrido et al. (2018) were studied Efficacy of ultraviolet light (UV-C) and pulsed light (PL) for the microbiological decontamination of raw salmon (*Salmo salar*) and food contact surface materials. Raw salmon pieces were treated with UV-C with 254 nm UV-C light. Pseudomonas spp. were treated by the UV-C light. Optimization of treatment conditions for ultraviolet light (UV-C) was carried out on raw salmon, obtaining inactivation levels of 0.9 log CFU/g.

5.1.2. Effects of LED on viral stability

Ultraviolet (UV) light has been shown to effectively inactivate a range of foodborne viruses, including human norovirus (HuNoV), hepatitis A virus (HAV), and surrogates like murine norovirus (MNV-1) and MS2 bacteriophage, by damaging their genetic material (DNA or RNA) and altering viral proteins, which renders them non-infectious. Studies have demonstrated the efficacy of UV light on various food products, including fruits, vegetables, meat products, and liquid foods, highlighting its potential for enhancing food safety. The effectiveness of UV treatment can vary based on factors such as the type of virus, the specific food matrix, and the presence of organic matter, which can shield viruses from UV exposure. Overall, UV light represents a promising technology for reducing the risk of foodborne viral infections while maintaining the quality of food products (Gomez-Lopez et al., 2021).

Park and Ha (2014) investigated the effectiveness of Ultraviolet C (UV-C) radiation in inactivating foodborne viruses, specifically hepatitis A virus (HAV) and murine norovirus-1 (MNV-1), on the surfaces of fresh chicken breasts. The materials used included experimentally contaminated chicken breast samples and UV-C radiation equipment emitting at 260 nm. The method involved exposing the chicken samples to varying doses of UV-C radiation (60–3600 mWs/cm^2) and subsequently measuring the viral titers to assess inactivation. The results indicated that UV-C radiation significantly reduced the viral counts, with over 1 log reduction observed at higher doses, specifically 3600 mWs/cm^2. The study concluded that UV-C radiation is an effective decontamination technique for reducing foodborne viruses on chicken surfaces, although higher doses may adversely affect the physicochemical and sensory qualities of the meat.

5.1.3. Effects of LED on fungi stability

Begum et al. (2009) investigated the effect of UVC light (254 nm) on food spoilage fungi, specifically *Aspergillus flavus*, *Aspergillus niger*, *Penicillium corylophilum*, and *Eurotium rubrum*, using various exposure techniques on moist surfaces (agar), dry surfaces (membrane filter), and in liquid (aqueous Tween 80). UVC irradiation effectively inactivated the spores of these fungi, with varying efficacy depending on the exposure method, achieving significant reductions in fungal survival after 1 to 3 min of exposure at a dose of 4644 J/m^2/min. The findings suggest that UVC light can be a viable method for controlling fungal contamination in food products, particularly in the baking industry where these fungi are common spoilage agents.

Belloli et al. (2022) studied the effectiveness of UV-C LED systems in inactivating fungal conidia, specifically targeting food-spoilage fungi such as *Hyphopichia burtonii*, *Penicillium brevicompactum*, and *Aspergillus brasiliensis*. Fungal conidia were applied to polyethylene terephthalate lids and exposed to two distinct UV-C LED light intensities for up to 800 s. Results indicated that *A. brasiliensis* exhibited the highest resistance to UV-C LED irradiation, while *H. burtonii* and *P. brevicompactum* were effectively inactivated within 5 s under optimal conditions.

5.2. Effects of LED on sensorial stability

One of the key determinants of muscle foods is sensory quality because it has been shown in numerous products that changes in sensory attributes happen well in advance of any health risk to the consumer, and that sensory attributes severely reduce the shelf life of the majority of food products (Giménez et al., 2012). Therefore, it's significant to assess the way LED affects the meat and fish's sensory qualities. Meat treated with LED lights results showed no significant differences in organoleptic scores for odour and appearance at the end of the storage period of 2 months (Stermer et al., 1987). Lyon et al. (2007) studied the raw breast fillets treated with LEDs at wavelength 254 nm shown no significant negative effect on meat colour (L, a, b values). Haughton et al. (2012) investigated that there were no effect of LED treatment on colour value of raw chicken. In another outcomes reported by Cichoski et al. (2015) stated that there was no significant difference seen in Peroxide values (PV) so the rancid odour was not seen during the storage period.

Effect of UV-C (260 nm) light on sensorial quality of chicken breast was studied by Park and Ha (2014). As per them, the chicken samples treated with UV-C (260 nm) darken and gets darker red and yellow colour. The values given by hunter colour lab the L* value is decreased and the values of a* and b* were significantly improved. So treatment was effect on the colour quality of chicken. In this study the sensorial score assessed by nine point hedonic scale was gradually decreased by increased light doses. Chicken sample treated with less energy (60–1200 mWs/cm2) shown satisfactory consumer acceptance of chicken sample. Yang et al. (2017a, 2017b) assessed the sensorial attributes of chicken treated with UV-C light (260 nm) by 7 point hedonic scale. Different sensorial attributes like texture, appearance, colour and the overall acceptability were gradually decreased by increasing dose of UV-C light. But there was no significant difference found between the sample treated at 600 mWs/cm^2, 1200 mWs/cm^2, and 1800 mWs/cm^2. So the sample treated with less dose couldn't effect on sensorial properties of chicken breast. Volatile organic compounds from chicken which showed an expansion in concentration because of openness to UV LED light. Volatile compounds like dimethyltri-sulfide, pentane, heptane,

propanoic corrosive, 2-pentanone, 1-pentanol and hexanal were seen after the UV treatment. The significant fatty aldehyde hexanal is a regular unpredictable optional lipid oxidation item. Many delivered volatile intensifies answerable for off-odour. Chicken presented to UV light can foster off-flavors brought about by the retention of ozone and oxides of nitrogen, or as a result of photochemical effect for the lipid parts of the chicken fillet (McLeod et al., 2017).

The current outcomes showed the difference between colour values of non-enlighten and enlightened salmon which shown insignificant indicating that LED illumination for 8 h wouldn't create any ominous decolourization of RTE fresh salmon (Li et al., 2018). Fresh untreated and chicken treated at 254 nm (50 mJ/cm2) skinless and skin-on chicken bosom samples were assessed for sensorial traits like appearance, odour, and texture. Chicken sample treated with LED light has shown no effect on appearance and texture throughout the storage time but off-odour on the chicken sample is noticed (Philip et al., 2020). Soro et al. (2021) reported that there is no significant changes in colour of chicken fillets were observed after the exposure of LED lights. During this analysis there is no impact of LED light exposure on textural quality of chicken. This treatment may not impact on texture of tender chicken sample.

As per the said reports by the Swanson et al. (2022) not all the colour characteristics were affected. The outcomes shown that the lightness of the LED treated chicken sample was slightly lower as compared to lightness of control sample. Fish fillet sample treated with 254 nm UV light didn't change springiness, cohesiveness and resilience as per reported by Molina et al. (2014). Gumminess and chewiness values were slightly decreased during the storage period. Treatment of UV light didn't significantly effect on the appearance and hunter colour value of the sea bass fillets. As per the investigation carried out by Mikš-Krajnik et al. (2017), Sensory parameters like odour and colour were affected by the combined treatment of LED and Ultrasound. The result noted by the Fan et al., 2021 shown that there very minor changes seen in L*, a* and b* values of fish finger fillet.

According to the study done by Byun et al. (2022), the colour and texture of chicken skin were evaluated after combination treatment of Lactic Acid with UV-C for 10 min. The results showed that there were no changes in the quality of chicken skin by UV-C treatment for 10 min. However, the a* value of chicken skin was significantly decreased when combination treatment by LA with 10 min UV-C was applied. The overall colour difference of chicken skin treated with 1 % LA was between 0.5 and 1.5. The hardness of chicken skin was significantly decreased by combination treatment with 2 % Lactic Acid with UV-C. Comprehensively, these results indicate that combination treatment by Lactic Acid with UV-C can affect overall colour change and hardness mainly due to PAA and LA.

The effect of UV-C treatments on the colour and lipid oxidation of raw salmon was evaluated in the study. The results showed that UV-C treatments caused detectable colour changes and increases in lipid oxidation in the salmon samples. The highest energy treatments resulted in the development of detectable sensory changes in the salmon, with samples being perceived as paler and having a strong rancid odour. Lipid oxidation in salmon samples exposed to UV-C was also evaluated for each distance and treatment time. Significantly higher values with respect to controls were observed for 60 s at 26 cm, 45 s at 16 cm, and 5 s at 6 cm treatments. Generally, no significant differences were found between treatment distances, except for 26 and 16 cm at 45 s, and between 16 and 6 cm at 5 s. Overall, the study suggests that while UV-C treatments can effectively reduce microbial counts in raw salmon, they can also cause undesirable changes in colour and lipid oxidation, particularly at higher energy doses.

5.3. *Effects of LED on physicochemical stability*

Muscle foods are an excellent source of high-nutrient proteins (Alasalvar et al., 2010). Fish proteins have a variety of functional characteristics that can be significantly impacted by LED treatment Therefore, it is critical to assess how LED affects fish proteins. It's becoming widely acknowledged that meat and fish are excellent sources of unsaturated fatty acids. LED-produced reactive species do not significantly affect the oxidation of lipids, but in particular, give an off flavor or odour. Consequently, the lipid profile of meat and fish products is known to be unaffected by LEDs. Therefore, in order to preserve the quality, a treatment needs to be used. The acceptance of meat and fish products seems to be influenced by colour, which is considered an important characteristic (Alasalvar et al., 2010). Therefore, in order to satisfy varying market demands, it is fundamental to assess and quantify the exterior features, particularly on the product's colour (Hong et al., 2014). According to Skjold et al. (2020), one key quality factor influencing fish acceptance is pH. Hence, any significant pH shift is linked to meat and fish deterioration, which impairs textural and sensory properties.

McLeod et al. (2017) stated that effect of LED with 254 nm has no significant effect on colour of chicken fillet but as per Philip et al. (2020) evaluated the outcome of the colour estimations showed that chicken samples treated with 254 nm fundamentally affected colour values of skin-on chicken bosom filet. It shown that treatment somewhat affected the b* value. Meat and fish are being recognized as a high-quality fat source that is high in unsaturated fatty acids. McLeod et al. (2017) stated that lipid oxidation doesn't adversely affect the odour and flavor of the chicken filet at the applied UV dosages. The progressions of the lipid peroxidation in both UV-treated and untreated skin-on and skinless chicken bosom were not huge so there is no progressions seen in lipid oxidation of chicken samples (Philip et al., 2020). As per the outcome stated by Hassan et al. (2015), moisture content, collagen content and the amount of fat was decreased while pH value and the rate of lipid oxidation was increased. Some other physical parameters like cooking loss and water holding capacity were decreased.

As per the Haughton et al. (2012) investigation the weight of the treated raw chicken sample was reduced significantly with treatment of LED lights. Lázaro et al. (2014) studied the effect of UV light on different quality characteristics i.e. Biogenic Amines, Lipid oxidation and pH. Biogenic amines are decarboxylated products of Amino Acids. Biogenic amines are very much important for many functional role in body. Slight increase in concentration of biogenic amines such as tyramine, cadaverine, and putrescine in chicken was found. pH and TBARS values were slightly changed with treatment UV-C light treatment. Lightness and a* instrumental colour value of the sample were slightly changed whereas b* value was stable. Effect of UV-C LED lights on different physicochemical qualities were observed and noted by Cichoski et al. (2015). Fatty acid content in sample treated with 254 nm LED lights were significantly changed. The amount of polyunsaturated fatty acids were reduced in chicken drumstick treated with LEDs during the storage period. The highest value of conjugated dienes (CD) was seen in chicken treated with UV-LED which subsequently did not accelerate the initiation stage of lipid oxidation. Thiobarbituric acid reactive substances (TBARS) values of the LED treated chicken drumstick were not changed. Protein oxidation level also not affected by the treatment LED waves. In another case suggested by Park and Ha (2014) shown lipid degradation which subsequently increases the value of thiobarbituric acid reactive substance (TBARS). There is no change was seen in pH values of chicken. Denaturation of protein is a breakdown of a complex of protein molecules that happens at a temperature higher than 65 °C. During the LED treatment only a minor elevation of temperature was seen so there has no effect of LED treatment on protein denaturation (McLeod et al., 2017).

Effect of different doses of UV-C light on physicochemical quality of chicken breast was assessed by Yang et al. (2017a, 2017b). Sample was slightly darker red and yellow. L* value is less and a* and b* values were slightly changed but the difference was not significant. A gradual increase in value of TBARS was seen with increase in UV-C light dose. There was no change in pH was found in treated chicken breast sample.

The pH of the treated chicken fillets sample was noted by Soro et al. (2021) which shown slight changes in pH after LED treatment. In another study of Swanson et al. (2022) concluded that pH of the LED treated sample was no differ significantly and the values of pH change during the storage period of vacuum packed and LED treated chicken sample. Effect of UV-C irradiation on physicochemical qualities of chicken breast was analyzed by Swanson et al. (2022). During this study they came to know that treatment LED waves on chicken breasts leads to very minor changes in pH values. So for the stability of pH will be achieved by LED treatment with any meat poultry and fish products are possible. Results indicated by the authors also strongly said that there is no effect of LED treatment on the thiobarbituric acid reactive substances (TBARS) values of the treated chicken breast during the storage period. The hunter colour values are also not affected by the LED treatment as per Swanson et al. (2022).

The significant change in fish fillets treated by UV light was noted by Molina et al. (2014). As per his reported outcome, microbial inhibition increase in the value of pH was observed. Sarcoplasmic protein (SPP) and myofibrillar protein (MFP) content was increased but not changed significantly. WHC of the fish fillet was decreased due to increase in pH and smaller change in protein structure. TBARS value was increased with treatment in fish fillet. Another result noted by the Fan et al. (2021) shown that there is no remarkable changes in pH and water holding values of LED treated tuna fish fillet.

6. Limitations of LED technology in meat and fish preservation

LED (Light Emitting Diode) Technology has several limitations when applied to the preservation of meat and fish. These constraints highlight the need for thorough research, development, and consideration of alternative methods.

6.1. Limited light penetration

One major challenge lies in the limited depth of penetration of LED light. Meat and fish, especially those with dense or thick structures, may not receive uniform exposure throughout their entire volume. As a result, certain areas may become pockets where microorganisms can thrive, potentially leading to incomplete preservation (Hyun and Lee, 2020).

6.2. Wavelength selection and effectiveness

The effectiveness of LED technology for meat and fish preservation depends on specific wavelengths of light. It is crucial to carefully tailor the choice of wavelengths to match the characteristics of the food products. Not all wavelengths may be equally effective in inhibiting microbial growth or preventing spoilage for different types of meat and fish (Finardi et al., 2021).

6.3. Surface treatment versus volume preservation

LED technology may be better suited for surface treatment rather than preserving the entire volume of meat and fish. Given the varied shapes and sizes of these food products, ensuring consistent exposure to LED light across all surfaces can be a challenge. Shadows or shielded areas may compromise the overall preservation process, necessitating alternative preservation strategies (Hyun and Lee, 2020).

6.4. Temperature sensitivity

The heat generated by LEDs during operation poses a concern for effective preservation. Proper temperature management is critical to maintaining the quality and safety of preserved meat and fish. Failure to control the heat produced by LEDs could result in temperature fluctuations that negatively impact the preservation process (Poonia et al., 2022).

6.5. Research and development efforts

If LED technology is still in the research and development stage for meat and fish preservation, uncertainties and limitations may exist that require further exploration and resolution. While LEDs hold promise for a range of applications, including food preservation, their specific limitations in the context of preserving meat and fish underline the need for continued research and the exploration of alternative preservation methods (Soro et al., 2023).

7. Conclusion

Meat and fish are among the foods that are necessary for a healthy diet because they are high in different nutrients. However, spoilage can occur due to microbial, chemical or physical hazards. Meat and fish have higher water and nutrients, leading to loss of physiological and sensory properties due to microorganism growth and increased enzymatic spoiling activity. Bacterial contamination and chemical oxidation are common causes of fish deterioration, with specific spoilage organisms producing undesired metabolites that affect the flavor and odour of the fish. Thermal preservation techniques often impact the quality of the meat and fish. The need from consumers for safe, chemical-free food is also rising. Light-emitting diodes (LEDs) as a non-thermal preservation method can used for the storage stability of meat and fish. This novel non-thermal method address industry issues, market openings, and added safety features. The properties of light-emitting diodes (LEDs) include high efficiency, controllability of intensity, small size, fast response time, dimming capability, design flexibility, ability to work well in a wide range of temperatures, longevity and environmentally safe operation. One of the main biological effects of UV light emitted by LEDs on microbes is DNA damage. UV light produces reactive oxygen species (ROS) that primarily target proteins and lipids, causing biological defects. DNA damage is further generated through the formation of cyclobutane-pyrimidine dimers (CPDs) and 6–4 photo products, which have mutagenic and fatal effects. LED-induced decontamination has been shown to inhibit the growth of various microorganisms such as *Listeria monocytogenes*, *Escherichia coli* O157:H7, and *Salmonella Typhimurium* in meat. Additionally, UV light dosages alter proteins, leading to enzyme deactivation and dysfunction in cellular processes. Overall, the mechanism of microbial inactivation by LEDs involves DNA damage, lipid oxidation, and protein alteration. Outcome of various studies show no significant changes in sensory attributes of meat and fish products, including sensorial stability, colour, odour, appearance, lightness, pH, fatty acid content, moisture, collagen, fat content, lipid oxidation, protein denaturation, or TBARS values. Hence these review article findings suggest that LED-based non-thermal preservation methods have a minimal impact on the sensorial and physicochemical quality of meat and fish. Additionally, LEDs have benefits and can be used with other non-thermal technologies by optimizing conditions for improved microbial destruction and nutrient retention. Further research and studies may be needed to fully assess the effectiveness and feasibility of LED-based preservation methods in various applications.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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