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A Review: Application of Cold Plasma in Food Processing Industry

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Nowadays, demand for minimally processed food has increased globally very rapidly. However, the food preservation and the period of storage is a key challenge in front of the food processing industry.So to overcome this problem,recently widely used cold plasma technology which is an alternative method for heat treatment. It is a novel, non-heat transferable, nature-friendly, and money-saving technology which does not change the organoleptic characteristics of food and enhances the microbiological quality of food.It helps to preserve the natural aroma and flavour. Cold plasma technology is agrowingtechnique and it has significant potential to decrease the undesirable effects on nutritional as well as quality characteristics of food. The review evaluates the recent status of this technique in the food processing sector. As this is a grow ingmethod which is utilized in several food processing sectors they are listed below. Cold plasma technology shows promising results primarily in shelf life extension as well as in microbial inactivation.

Keywords: Cold plasma; allergens; microbial decontamination; dairy industry etc.

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1. INTRODUCTION

In 1926, Irving Langmuir coined the term "Plasma" to characterize this state of matter, saying that near the electrodes and there are sheaths comprising extremely small amount of electrons, the ionized gas carries ions and electrons in roughly identical amounts, resulting in a very small space charge." It is termed as plasma. to characterize this area with a balance of ions, electrons [5]. A state of matter consist of a sizable number of electrically charged or ionized at omsor molecules according to a later expansion of the term. Due to its characteristics, including its irregular shape and volume and ability to form filaments or beams in the presence of magnetic fields, plasma is considered as a unique state of matter. It can exhibit a wide range of states, from complete thermal equilibrium to extreme no equilibrium, depending on the mode of creation used. Stars and lightning are examples of natural phenomena that contain plasma. Plasma can also be created artificially to make incandescent, blazing brilliant lightsand further things. The cold plasma technique research fields are expanding quickly and have received a lot of attention. Cold plasma is primarily studied in biomedical fields [47]. It is a unique technology making use of reactive gases, In order to destroy spoiling microorganisms on meat and meat products poultry, fruits and vegetables [9]. Food producers are more conscious about food preservation and food safety and consumers have become the most crucial part of it. Other than heat treatment recently, non-heat transferable techniques like the cold plasma technique has been used extensively. [25, 27, 97, 118]. Fruit juices, food wrapping, instruments, sterilization, and biofilm management have all been improved by microbial decontamination and sterilization using cold plasma [31, 92, 119,]. Pesticides, dyes, and other chemical toxins have also been demonstrated to degrade due to applications in the food sector and wastewater therapy facilities [65, 66]. This technology is widely researched for cancer therapy and wound healing applications in addition to medical device and package sterilization [39]. Moreover, as consumers are more conscious about healthy habits. There is a requirement for untreated food to be enhanced. However, issues like inadequate safety for microbes can lead to foodborne illnesses. Consequently, the pursuit of alternate sterilizing methods is needed. The advantage of non-thermal treatment is that it helps to maintain the natural odour, taste helps to promote food safety from a microbiological perspective without destroying its quality. It has been observed that in heat treatment quality of food is not maintained properly. These benefits have a growing curiosity about alternative methods of food sector. This technology is a substitute for new-generation techniques. Technologies [51,61]. This non-thermal technology called has been utilized in the food processing sector. It isa very important preservation technique of meat products bonding. It is widely applicable in various fields. Plasma is an ionized gas that comprises of numerous things like electrons, free radicals, ions etc. Plasma has a net neutral charge so it can be in ground or excited states. It is brought about under many pressures and temperatures by energizing a neutral gas. It is further grouped into Thermal and non-thermal plasma. This non thermal technology sterilizing technique using ionized gas [29,30]. The foundation of plasma technology lies in the partial ionization of positively and negatively charged ions, free radicals, electrons, photons, and gas-containing molecules. Plasma can interact with bacterial cells and inhibit microbes, spores and viruses [60, 62]. The utilization of this technique for microbe inactivation has been recognized as beneficial since it is eco-friendly, does not include harmful materials, and doesn't lead to production of long-lasting hazardous substances and its method is aseptic [113]. It is employed in food safety, surface treatment, and decontamination of apparatus, it is also used for cleaning purposes [49]. It has been stated that this technique can be utilized to sanitize food surfaces, water, air while processing materials without harming living tissues. Cold plasma is split into two parts. Depending upon the pressure of working environment.

1) Low-pressure pressure plasma

The most important principle of low-pressure plasma is that it can be created at low pressure perhaps in the vacuum also.

2) Atmospheric plasma

In this technique, a cold plasma system runs at radio frequency. The device generates ionization with the help of rapid electrical stimulations at frequent period of time and by varying the system's gas operation power levels and voltages [17]. The capability of this technique relies on a number of factors but is largely related to the reality that different plasmas and the methods used to induce them have unique

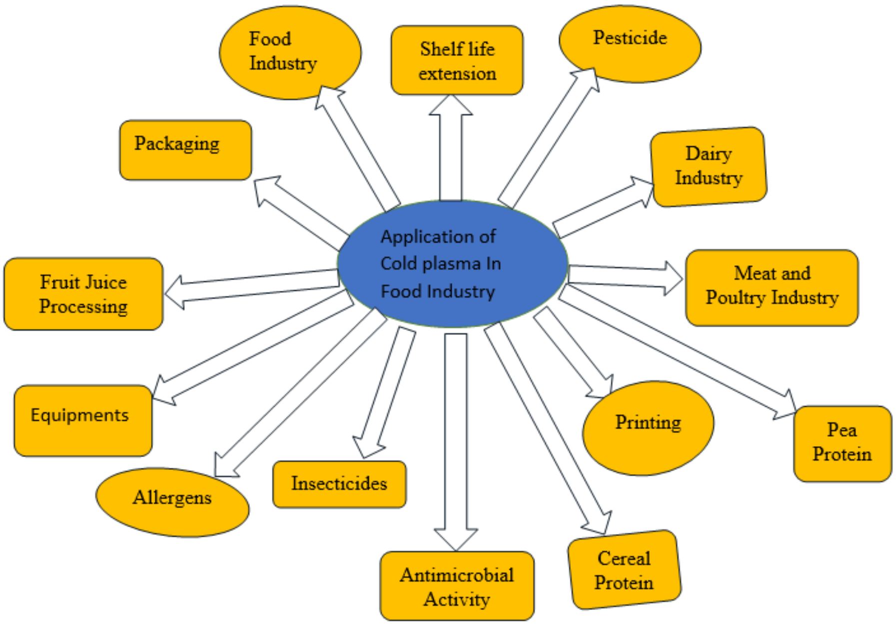

Fig. 1. Application of cold plasma in the food industry

properties. For instance, the capability of the technology process depends largely on the kind of processing gas used, which also affects the character and reactive species created in the discharge and efficacy of treatment process. Similarly, the active species produced is impacted by frequency and input voltage, which is larger values correlate with raise high in energy density [33]. The mode of exposure is a further process variable that influences CP efficiency, with direct contact being preferred over indirect or distant exposure for process enhancement due to the latter's reduced heat transmission to the matrix assuming of self-quenching characteristics of the charged particle as well as the capacity to reassemble prior to achieving the sample [78].

2. HISTORY OF COLD PLASMA

English scientist Sir William Crookes recognized plasmas in 1879. Dr. Irving Langmuir described the word plasma to the ionized gas in1929.Ozone was created by the Siemens Company in the late 1850s using plasma discharge, and it served as a contaminant-removing agent. Harmful pollutants found in water. However, very small study was done on the interaction between biological cells and plasma. Although little cause-and-effect research was done, plasmas were mostly used as a secondary agent to show biological sterilization during the 1960s and 1980s.Scientists did not make significant advancements in cold plasma technology until the mid-1990s. As word of plasma spread, creative scientists noticed and started investigating and working on it. However, by 1997, teams from multiple disciplines had established proof of concept studies to show that plasma could be used as a decontaminant or sterilizing agent, as well as to investigate the effects of plasmas on pathogenic and non pathogenic microorganisms. By the late 1990s, as technology has advanced into fields including biomedicine, the environment, aircraft, and agriculture [51].

3. RESOURCES OF COLD PLASMA CREATION

This nonthermal technique is used to produce various energy such as Electricity, heat and electromagnetic waves like radio and microwaves. Dielectric barrier discharges (DBD), corona glow discharges, atmospheric glow discharges, high voltage pulsed discharges, gliding arc discharges, plasma jets, radio frequency (RF) discharges, inductively coupled plasma (ICP)and microwave-induced plasma (MIP) are examples of the requirements that can be used to accomplish and induce cold plasma. Due to factors including their easy creation and widespread commercial availability, DBD and plasma jets are the plasma sources that are most frequently employed in food research [102].

4. APPLICATIONS OF COLD PLASMA TECHNOLOGY IN FOOD PROCESSING SECTOR

4.1 Prevention of Fruit Tenderness by Cold Plasma Technique

Fruit firmness can enhance the life span of fruits. It helps formaintaining morphology of fruit. Additionally, CP demonstrated outstanding fruit-softening suppression abilities, which may be applicable to both enzyme inactivation as well as fruit surface sterilization [49]. It was demonstrated that CP treatment could improve the firmness of fresh-cut apples after immediate treatment and even after storing them for 6h [101].

5. ANTIMICROBIAL ACTIVITY

It has been observed that consuming raw, partially processed or unprocessed food is considered as microbiologically unsafe. To minimize the risk of microbes, cold plasma technology proved to be an effective non-thermal technology [30,39]. For utilization of less processed food, food which is not stored properly should be free of bacteria. While undergoing antibacterial treatment, its properties should not vary [56]. In multiple species, the effectiveness of CP is closely connected with the thickness ofbacterial cell wall. Cold plasma technology is utilized successively in the decontamination of micro-organisms etc. The mode of act of this technique contrast according to the technique utilizedto which type of micro-organismsare associated with [56,64]. It is believed that cold plasma attacks the cell wall, DNA, and membrane among other internal structures. Intracellular proteins, and peptidoglycan structure in the gram-positive bacteria can be broken by plasma species and that leads to membrane lipid peroxidation in gram-negative bacteria. This interference leads to the rupturing of the cell wall and as a result, puncture of cellular constituents, involving proteins, potassium, and nucleic acids. Once the cell wall is ruptured, reactive species can sneak into the cell leading to rupture of DNA and intracellular proteins with oxidative or nitrosative species takes place. There is a significant diversity of reactive species are produced, therefore plasma discharge and these reactive species are what have antimicrobial properties. Many deactivations were seen in this nonthermal technique of decontamination investigations in the cell envelope, with gram-positive bacteria being reported to be more rebellious as compared to the gram-negative bacteria [28, 55]. When microwave-induced, this non thermal technology wasgiven to *E. coli* O157:H7 on lettuce

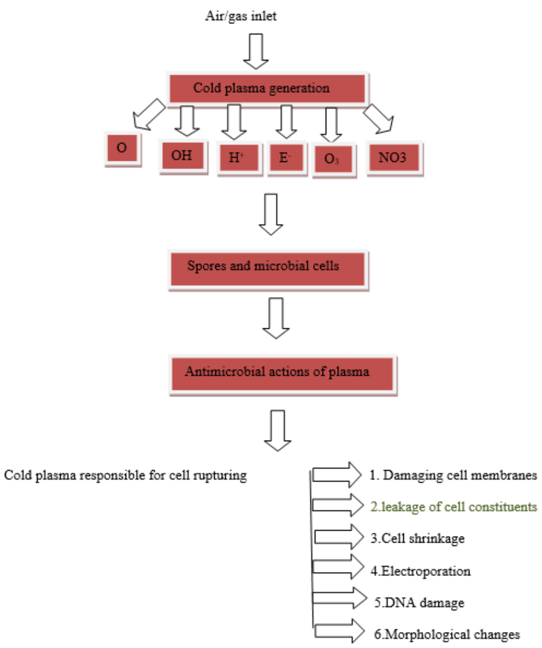

Fig. 2: Antimicrobial action of cold plasma

surprisingly, roughly about 90% deactivation were carried out and this result was noted. There were no significant changes to organoleptic and quality characteristics like colour, weight reduction, and ascorbic acid concentration. Antioxidant activity was also noted [96]. Cold plasma is used on polypropylene films coated with carboxymethyl cellulose and containing essential oils. Additionally, PP treated with plasma had bumpy surfaces and a decreased contact angle, both of which suggested improved surface hydrophilicity [108]. Cold plasma technology iscost-effective, sterilizes cleaning substances, inhibits microbial activity that could be harmful to human health and harmless to the nature because it is made under vacuum and at room temperature [21].

6. DAIRY INDUSTRY

Milk is a wholesome food that can be eaten up every day. Although, a significant issue is that,if spoiled milk is drinkregularly it can show adverse effects on health and can lead to critical health issues [104]. Coldplasma technique is a recent technology in the dairy sector. Making use of cold plasma technique at less temperatures and maintaining anappropriate temperature in the course of application make it an effective technique [48]. The components and procedure used to create the plasma depends upon the charged particles found in cold plasma, which include positive and negative ions, excited and nonexcited molecules, electrons, and radiations.On the other hand, various acts are recorded byusing Cold Plasma that comes from various sources. Numerous investigations havebeendocumentedon cell ruptures when exposed to the cold plasmaand theduration influencing the degree of the phenomenon [2]. Cold plasma breaks downthe genetic material and inhibits many of the genetic processes;as a result, cells kills [10]. Reactive nitrogen species (RNS) and ROS are produced when CP is applied. It is known that the oxidation process used by free radicals, or plasma reactive species, renders enzymes inactive [101]. It leads to caused structural alterations in active sites to prevent binding and catalysis [83]. It also alters the formation and content of amino acids [11, 45]. For milk processing heat transfertechniques such as pasteurization as well as high temperature therapy are mandatory to avoid utilization of unprocessed milk.Although, this thermal process can lead to make alterations in the physicochemical attributes of milk [89]. Effects of Sliced cheese contaminated with facultative anaerobic bacteria*Listeria monocytogenes*. Initially, concentration of microorganisms was higher, but as soon as cold plasma technology was applied microbial load was decreased remarkably [89]. Inhibition of *Escherichia coli*was treated at low temperatures by plasma technology in unprocessed milk comprisingmany fat ratios of milk [114]. This nonthermal technique is widely used as a sterilization technique for inactivation of microorganisms in milk. More studies need to be done to show the positive effects of this technology on the milk [34].

7. MEAT AND POULTRY INDUSTRY

It states thatcold plasma is efficientagainst micro-organisms presentin meat and meat products [7, 31, 80]. Deactivation of *Campylobacter jejuni* in chicken ham utilizing the atmospheric-pressure plasma techniqueaccomplishedat radio frequency and using argon gas [46]. It has been observed that a minimizing up to 3 log and 1.5 log CFU/cm2 after 6 and 10 min of therapy.Impact of cold plasma employing argon, nitrogen, and helium gases on the deactivation of microbes on meat surface, meat quality, and PH value. Following a 10-minute nonthermal treatment with argon and helium, the amount of bacteria that grow at low temperatures decreased by 2 and 3 log CFU/cm2, respectively, as did the total amount of bacteria. Hence,no communicationwasnoticedonbacteria when thenitrogen treatment is given.From the studies, it has been concluded that the Cold Plasma techniquedoesn’t showadverse effects on the quality, colour and pH of meat [106]. From some studies, it has been observed that was effectively able to spoil the bacteriaon chicken meat [71]. Studies states that thedestroying *Listeriainnocua* in ready-to-eat meat by up to 1.6 ± 0.5 log cfu/g is possible based upon constitution of the charged species [84]. ROS and RNS created through the disintegration of gaseous molecules take place during plasma generation [18, 35]. Different microbicidal mechanisms are used by the ROS in APCP to affect both Gram-positive and Gram-negative bacteria. The thick cell wall of gram-positive bacteria is made of peptidoglycan. When Listeria monocytogenes and Staphylococcus aureus are treated with APCP,as a result, cell shrinkageand cell wall ruptures take place [20]. It has been noted that intracellular DNA damage caused by ROS created by DBD plasma can pass across the cell membrane and induces the cell lysis [9].

Table 1. Effects of cold plasma on the micro-organisms of the dairy products

Sr.No.	Food product	Micro-organisms involved	After Cold Plasma treatment
1.	Sliced cheese	*Listeria monocytogenes*	Microbial load decreases.
2.	Raw milk	*Escherichia coli*	Caused a 0.3 log CFU/g depletion in the *Escherichia coli*

Table 2. Effects of cold plasma on the micro-organisms of the meat and poultry industry

Sr. No.	Food product	Micro-organisms involved	After CP treatment
1.	Chicken ham	*Campylobacter jejuni*	Inactivation of *campylobacterjejuni*
2.	Ready-to-eat meat	*Listeria innocua*	Destroying *Listeriainnocua* in ready-to-eat meat by up to 1.6 ± 0.5 log cfu/g

Spoilage by the micro-organisms is avoided because the pasteurized food is delivered to the customers through the sealed package long shelf life of the reactive species especially the ozone and the hydrogen peroxide created in the airtight packaging, pasteurizes the microbes consistently after exposure to the cold plasma [113].

8. PACKAGING

Cold plasma technique is used for the surface therapy of packaging materials to enhance surface operationalization. Etching or rinsing,accumulation etc. Surface operationalization putting adding definite functional groups to the surface of the packaging material in order to improve mechanical qualitiesas well as antimicrobial capabilities [77]. This technique is also responsible for providing the sealing properties of polymer foils [36]. By using A deposition barrierwhich is composed of multiple layers, the Cold plasma technique can be utilized to accumulateSurface coatings applied to polymers. As a result, there may be less oxygen and carbon dioxide absorption into food packaging materials [24]. Researchers were also able to coat food packaging materials with additional antimicrobial agents like triclosan, silver, chitosan, and chlorhexidine, which effectively enhanced the packaging material's resistance micro-organisms [40, 81]. Studies showed that 300 W of cold nitrogen plasma treatment was used to apply commercially available antimicrobial substances like Auranta FV and Nisin, to polyethylene packaging. These substances provided selected antibacterial activity against yeast, and mold. As a result, addition of these materials to the packaging film enhanced the storage span of the foods [42, 17].

9. ROLE OF COLD PLASMA TECHNOLOGY IN SANITATION AND DECONTAMINATION

9.1 Food Processing Equipment

Contact between food products and unsanitary surfaces can lead to sources of impurities in the food processing industry. Ancestral asepsis approaches are not that effective in eliminating microorganisms from food processing surfaces. As aresult, it has been noted that the cold plasma approach may be used to disinfect processing equipment against micro-organisms [111]. Additionally, the rough, sponge-like surfaces of stainless steel and aluminium surfaces make it simpler for microorganisms to adhere to them. Microorganisms like *L. monocytogenes are* present inproducts through coming in touch with contaminated food-processing surfaces [43]. Gliding arc plasma serves as the foundation for this AC plasma jet apparatus. Between two shaped electrodes, a 1 cm gap creates an ionizing potential.Producing a plasma arc inside a Teflon sheath. The feed gas, which is dry air at 60 psi, pushes the plasma arc toward the outside, where it expands and cools. The apparatus utilized in this investigation has been adjusted to accommodate changes in the electrical pulse frequency. Previous research has shown that altering the pulse frequency can have a major effect on the ability of bacteria to endureand which is treated with cold plasma [3,4]. At this, power usage varied between around 522, 549 W.Components left in this investigation were the distance (5 or 7.5 cm) and exposure period (5, 10, or 15 s) from the plasma jet emitter head. These separations were selected so that the biofilms would be situated in the "active" plasma (5 cm) or "quenched" plasma

(7.5 cm) zones. They are associated with regions where the majority of gas molecules are absolutely ionized, near to the electrodes and within the plasma plume, or further away from the electrodes and outside the plasma plume, This is referring to the region where the highly reactive plasma species have undergone recombination before reaching the target. [69, 70]. In the course of processing meat products, knives and cutting instruments are crucial points of pathogen contamination. DBDs are one of the cold plasma sources that are mostly utilized for infectious agent deactivation because they provide homogeneous therapy over big surface regions.Cold plasma is used to decontaminate the meat-slicing equipment significant reduction in microbiological contamination was observed following the use of a direct-mode DBD on the surface of an industrial rotating trimming apparatus [75, 51]. Using this non thermal technique in decontamination of microorganisms such as *L. monocytogenes* and *S. typhimurium* helps to decrease the microbial load.These experiments showed that Cold plasma is efficient at lowering the microbial load on stainless steel or other material surfaces that might be in near interaction with food products.Hence this technology can be successfully utilized for sanitation of equipments [43,68].

10. REMOVAL OF INSECTS AND IDENTIFICATION OF INSECTICIDES

In order to adequately feed the world's population, contemporary agriculture mostly uses agrochemicals such as fumigants and pesticides [115]. Insecticides are often utilized in contemporary agriculture to control insect infestation and minimize crop reduction by removing insects. Nevertheless,their utilization could be toxic to health as well as to the ecosystem. Hence,other techniques can also be adopted to decrease the use of insect cides.For this reason, recent Cold plasma related articles have been published and shown that this novel technique can be believed to be aneffective way to preserve food goods by reducing insecticidal effects [79, 82, 85]. It has been found that after brown rice was exposed to CP at 200 V for 24 hours,*T.castaneum* was eliminated [79]. enhance grafting polymerization, molecularly imprinted membranes (MIM) were created with cold plasma.With respect to this,in Pampus argenteus fish samples, five pyrethroid insecticide residues were observed fenvalerate, deltamethrin, cypermethrin, cyfluthrin, and bifenthrin. So it can be concluded that this technique has different strategies for getting rid of insects and identifying insecticides in foods [115].

11. ALLERGEN OR ENZYME DEGRADATION APPROACH

Food allergies are increasing quickly worldwide basis [74]. Food allergies are the result of an immunoglobin-mediated response to antigens,most often proteins [59]. Due to their leasteffects on food quality indicators, Nonthermal therapies have newly been explored in order to reduce food allergenicity [38, 93, 110,]. Shrimp tropomyosin was treated with direct plasma treatment for 5 minutes and as a result allergenicity of shrimp tropomyosin was reduced by up to 76%. In addition, the author noted that cold plasma therapy decreased IgE binding to tropomyosin and shrimp extract [92,93], crustaceans and molluscsare the most crucial food products that trigger allergic reactions in those who consume seafood [32, 42]. Tropomyosin is an important allergen present in shellfish. Scientists are looking for methods to reduce the allergenicity of seafood among them,such method is heat treatment. Although, owing due Because tropomyosin is heat-stable, basic heat treatment does not diminish allergenicity to an adequate degree [26]. Allergic reaction of tropomysin in fresh king prawnstreated with cold argon plasma jet. IgE- and IgG-binding capability were decreased by 17.6% and 26.87%, respectively, after 15 minutes of plasma treatment. After more than 9 minutes of treatment, surface hydrophobicity and total free sulfhydryl group levels were also changed [16,116]. This is linked to changes in amino acids in the IgE-binding area, which affects the antibody binding capacity of tropomyosin's ability with changes in its alpha-helix and beta-sheet structures [26]. Additionally, it shas the capacity of preserving the primary food quality while deactivating enzymes and ensuring enzymatic stability. So,it is important to concentrate on how Cold Plasma affects the histidine decarboxylase responsible for seafood contamination. According to the mentioned statement of recent studies, it may have commercial uses for minimizing the allergenicity or enzyme activity of seafood items [62, 75, 107]. It has been investigated the potential of eliminating numerous allergens by using cold plasma, including a-casein, b-lactoglobulin, a-lactalbumin, b-conglycinin, tropomyosin, glycinin, conglycinin etc. Studies states that theresult of this non thermal method on the main allergens in soy protein isolate, b-conglycinin (Gly m5) and glycinin (Gly m6).It has been noted that protein bands in the (SDS-PAGE) were removed and formation of insoluble aggregates during the cold plasma treatment takes place. The scientists found that 10 minutes of this non thermal treatment completely minimized the immunoreactivity of soy protein isolates.The loss in protein bands in SDS-PAGE was caused by a reduction in protein solubility, which was followed by the development of combined or the creation of new proteins by the cross-linking of free amino acids. In the past, it was stated that a cold plasma treatment might make protein less soluble [14].

12. FRUIT JUICE PROCESSING

The food processing industry appears to have promising prospects for the implementation of cold plasma. It offers an exclusivequiescent for processing thermosensitive items due to its nonthermal characteristics. Fruit juices are among the thermal-sensitive goods after thermal processing lose their functional, and nutritive value [92.Microorganisms such as *Staphylococcus aureus*, *Candida albicans*, and *Escherichia coli* diminished by more than 5 log/mL in freshly squeezed orange juice after applying this nonthermal technique for 12, 8, and 25 seconds, respectively [92]. *Citrobacter freundii* was likewise reduced by 5 logs in apple juice after 480 seconds [99]. The quality of fruit juices was also evaluated by other studies. After being treated to cold plasma, no changes were noted for color, PH, antioxidant activity, phenolic content ,[6].

13. SHELF LIFE EXTENSION

Increasingthe storage span of products is a worldwide challenge to ensure food safeness and lower the waste is storage span expansion. It has been observed that the samples were treated to packaged plasma technology for 10, 60, and 120 seconds respectively. As a result, microbes such as *Salmonella*, and *Escherichia coli*were significantly reduced. Also,*L. monocytogenes* on cherry tomatoes were negligible [90,117]. Mechanism of plasma interactions with enzymeslinked tochemical changes that resulted in decreased enzyme activity to species that are reactive with plasma, primarily hydroxyl radicals (OH), superoxide anion radicals (O2), hydroperoxy radicals (HOO), and nitric oxide (NO) [65]. Impacts of this non thermal technique on the stability of fresh-cut melon in course of the controlled storage were observed.A decrease in POD and (PME) residual activity has been noted in relation to treatment duration [100]. This was brought on by the tissue's decreased metabolic activity, which was caused by the prevention of enzymatic browning, alterations in the amino acid side chain and a reduction in the number of α-helix formation in different enzymes [98,99].

14. PLASMA AS A PESTICIDE

The hunt for alternatives, particularly ones that leave no residuals at the time of consumption, has been prompted by the unfavorablenature and health effects of their greater use as well as the possibility of insect rebellious. Plasma technology considered as an effective technique for pest management of stored grain crops is [23]. The nonthermal plasma treatment-induced mortality of *Myzuspersicae*, *Planococcus citri* and Ped*iculus humanus.* On a range of substrates, involving living plant material. After 24 hours of treatment, green peach aphid populations exposed to plasma for 120 seconds experienced an 87% mortality rate,but human body louse populations exposed to plasma for 60 seconds experienced a 95% mortality rate [12,67]. Plasma treatment is one of the best against *Plodia interpunctella* and *Tribolium castaneum*.The substantial increases in lipid peroxide levels were indicative of the oxidizing effects of the plasma therapy and decrease in glutathione and protein constituents that the Plodia interpunctella larvae showed, indicating their sensitivity to the therapy [1, 57].

15. RESULTS OF COLD PLASMA TREATMENT ON CEREAL PROTEIN

Stout and weak wheat flour proteins have been observed to exhibit changes such as reduction in -β-sheets antiparallel -β-sheets. However, when the cold plasma technique wasapplied as a result, it gain in a-helix and β -turns were observed [62,63]. Wheat flour can undergo a cold plasma treatment that changes the proteins to the point where it impacts the functionality of the flour [8]. According to research done on zein films exposed to cold plasma treatment, the disordered and -helical conformations were impacted [77]. The concentration of Zein powder exposed to cold plasmashown to alter its secondary structure and have more free sulfhydryl (SH) groups than before. A prolongation of the treatment period may strengthen certain of the functional characteristics of zein films [22].

16. RESULT OF COLD PLASMA TREATMENT ON PEA PROTEIN

It helps to enhance the functional characteristics of food materials [102, 86, 87]. When pea protein isolate is treated with cold plasma treatment it leads to some structural as well as compositional modifications. These alterations have been experimentally linked to capabilities like the ability of protein-rich pea flour to bind water and fat, and they are related to changes in surface hydrophobicity. Protein solubility was seen to be impacted by it [13,14].

17. ADVANTAGES OF COLD PLASMA TECHNOLOGY

1. This nonthermal technology is doesn't create toxic waste and therefore it is an environment-friendly technique.It can enable disinfection at low temperatures while consuming little energy and cost-effective process [70, 76].
2. It helped to deactivate the microorganisms in a relatively short period [70, 76].
3. The procedure also makes it possible. Fast sterilization without exposing the finished items to residues like food packaging, plastic bottles, and caps [7, 76].

18. FUTURE PROSPECTS

1. Evaluating the capability of this nonthermal techniqueon various food products processing as it is cost-effective as well as an environmentally friendly technique.
2. Enhancing the storage life of food products is a globally faced challenge and cold plasma technology will show positive effects on it.

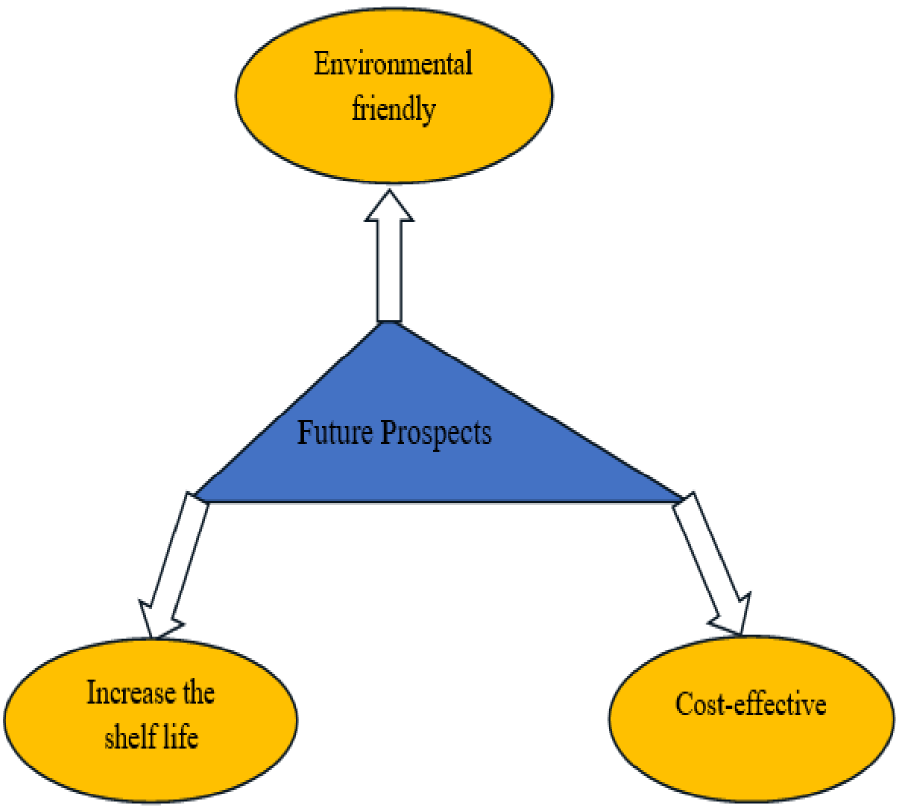

Fig. 3. Future prospects

19. CONCLUSION

Cold plasma technology is novel, non-heat transferable, money saving and environment-friendly method. It is extensively utilized in the food processing sector. As it is an ultra-fast sterilization and preservation technique. The rapid growth of microorganisms is a most difficult thing in front of food processing industry so this technique is very crucial in the deactivation of microbes.In order to increase the storage span and offer high-quality food products. It also helps to prevent physicochemical changes to increase the microbiological quality of food.Therefore, from above mentioned applications in various sectors of the food processing sector, it can be successfully concluded that the efficacy of thistechnique in the food processing sector is highly appreciable and it is one of the most promising technologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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