Application of cold plasma in food processing industry:A review

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 organolepticcharacteristics of food and enhances the microbiological quality of food.It helps to preserve the natural aroma and flavour. Cold plasma technology is agrowing technique 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 growingmethodwhich 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.*

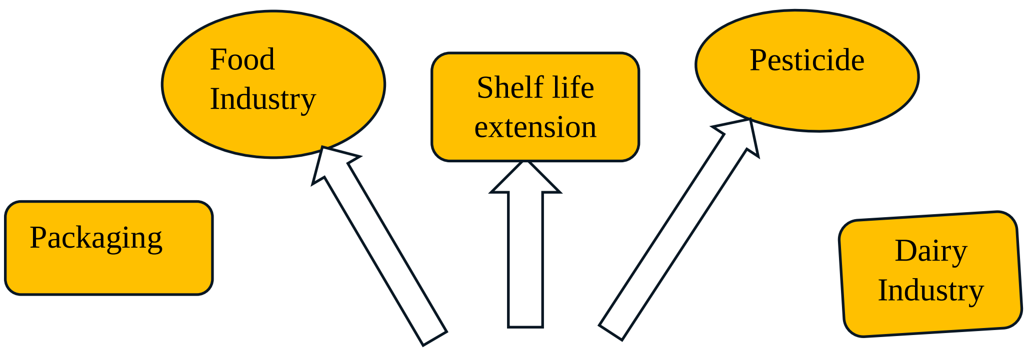
1. Introduction

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(Langmuir I,1928). Astate of matter consistof a sizable number of electrically charged or ionized atomsor 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(Kogelschatz*et al.,*2007; Rossi F*et al.,*2006). It is a unique technology making use of reactive gases, In order to destroy spoiling microorganisms on meat and meat products poultry, fruits andvegetables(Banu*et al.,*2012).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 techniqueslikethe cold plasma technique has been used extensively.(Ekezie*et al.,*2017; Sonawane and Patil 2020; Zhao*et al.,*2019).Fruit juices,food wrapping, instruments, sterilization, and biofilm management have all been improved by microbial decontamination and sterilization using cold plasma(Gadri *et al.,*2000; Shi *et al., 2011; Ziuzina et al,2015).*Pesticides, dyes, and other chemical toxins have also been demonstrated to degrade due to applications in the food sector and wastewater therapy facilities(Misra *et al*., 2014; Sarangapani *et al.,* 2016).This technologyis widely researched for cancer therapy and wound healing applications in addition to medical device and package sterilization(Isbary *et al.,* 2013).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 microbescan 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,tastehelps 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(C. M.G. Charoux *et al.*, 2021; Cl´ementine M.G;Charoux *et al.*, 2020; P. Y. Lee*et al.*, 2016; Mir *et al.*, 2020). This non-thermal technology called has been utilized in the food processing sector. It isa very importantpreservation technique of meat products bonding. It is widely applicable in various fields. Plasma is an ionized gas that comprises ofnumerous 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 nonthermal technology sterilizing technique using ionized gas(Fernandez *et al.*,2013).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 (Mendes-Oliveirab*et al.*,2019;Misra *et al.*,2021).The utilization of this technique for microbe inactivation has been recognized as beneficial since it iseco-friendly, does not include harmful materials, and doesn't lead to production of long-lasting hazardous substances and its method is aseptic(Yang *et al.*,2009).It is employed in food safety,surface treatment, and decontaminationof apparatus, it is also used for cleaning purposes(Lacombe *et al.* 2015).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 (Niemira *et al.*,2012). The capability ofthis technique relieson a number of factors but is largely related to the reality that different plasmas and the methods used to induce them have unique properties.For instance,the capability of the technology process depends largely on the kind of processing gas used, which also affects the character andreactive species created in the discharge and efficacy of treatment process. Similarly, the active species produced is impacted by frequency and input voltage, which islarger values correlate with raise high in energy density (Guo *et al.*,2015).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 (Patil *et al.*, 2014).



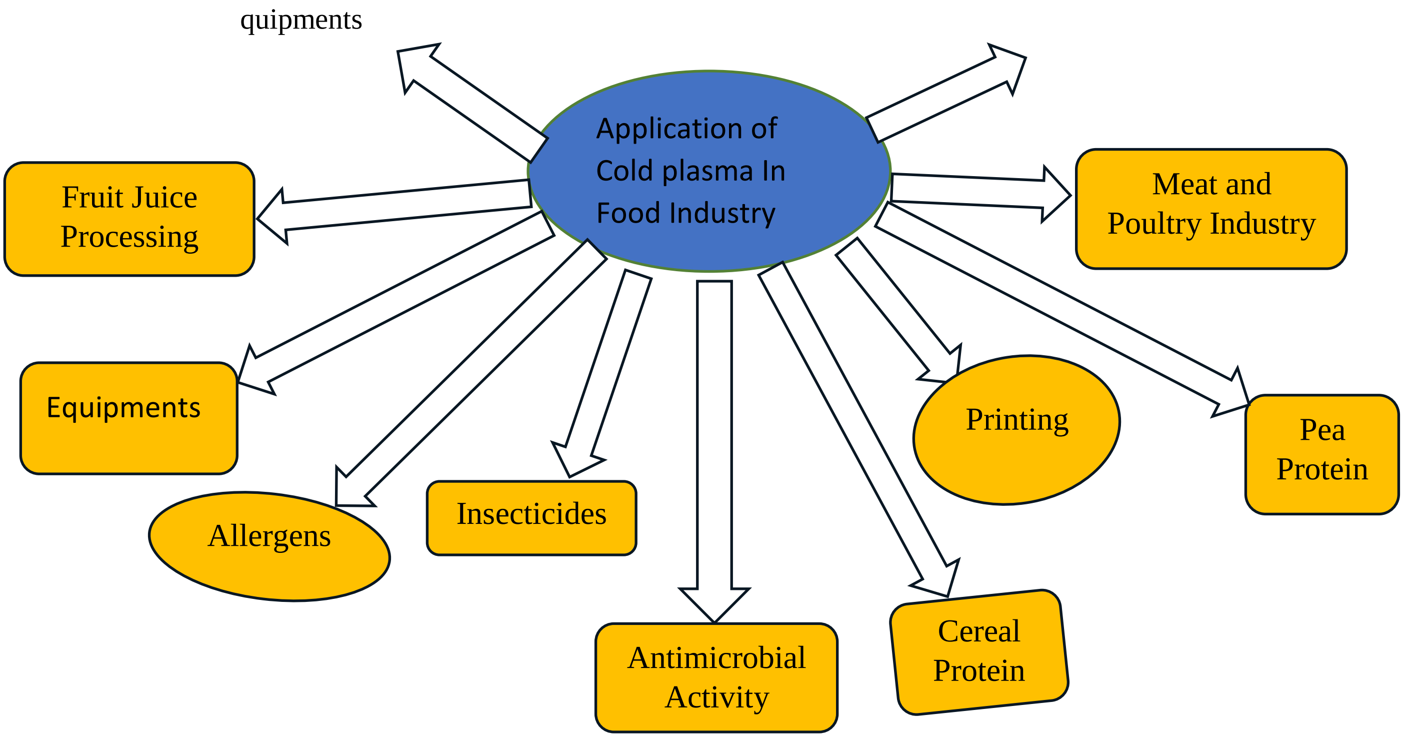


Figure 1:Applicationof cold plasma in the food industry

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 studywas 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 plasmaspread, 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 nonpathogenic microorganisms. By the late 1990s, as technology has advanced into fields including biomedicine, the environment, aircraft, and agriculture (Laroussi M,1996).

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(Dobeic,2018). 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(Thirumdas *et al.*,2017).

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(Lacombe*et al.*,2015).It was demonstrated that CP treatment could improve the firmness of fresh-cut apples after immediate treatment and even after storing them for 6h(Tappi *et al.* 2014).

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(Fernandez *etal*.,2013).For utilization of less processed food,foodwhich is not stored properly should be free of bacteria. While undergoing antibacterial treatment, its properties should not vary(Lu*et al.*,2014). 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(Misra *et al*., 2012). 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 intothe cell leading to rupture of DNA and intracellular proteins with oxidative or nitrosative species takes place.There is a significant diversity of reactive speciesare produced, therefore plasma discharge and these reactive species are what have antimicrobial properties. Manydeactivationswere seen in this nonthermal technique of decontaminationinvestigations in the cell envelope, with gram-positive bacteria being reported to be more rebellious as compared to the gram-negative bacteria(Ermolaeva *et al.*,2011;Liao*et al.*,2021). When microwave-induced, this non thermal technology wasgiven to *E. coli* O157:H7 on lettuce 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,andascorbic acid concentration.Antioxidant activity was also noted (Song *et al.*,2015).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(Wong et *al.*,2020).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(Donegan*et al.*,2013).

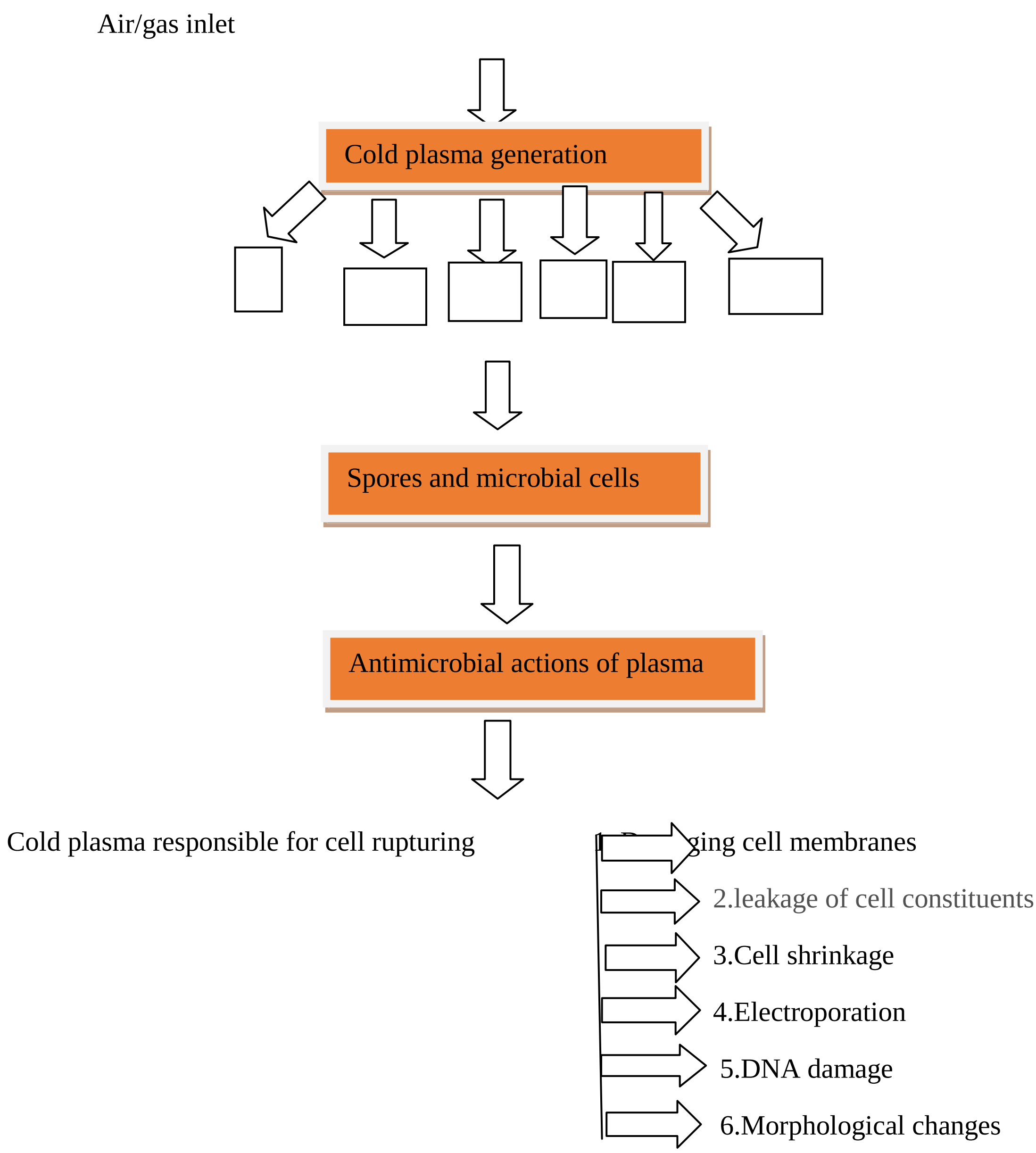

Air/gas inlet
Cold plasma generation
Spores and microbial cells
Antimicrobial actions of plasma
Cold plasma responsible for cell rupturing
ging cell membranes
2.leakage of cell constituents
3.Cell shrinkage
4.Electroporation
5.DNA damage
6.Morphological changes

Figure 2: Antimicrobial action of cold plasma

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(Tiozzo *et al.*,2011). 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(Korachi *et al*., 2015).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(Ali *et al.*,2014).Cold plasma breaks downthe genetic material and inhibits many of the genetic processes;as a result, cells kills**(**Bermudez-Aguirre D and ed.Cambridge,2020).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(Thirumdas*et al.*,2015).It leads to caused structural alterations in active sites to prevent binding and catalysis(Rodacka*et al.*,2010). It also alters the formation and content of amino acids(Bubler*et al.*,2017; Khani*et al.*,2017).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(Segat *et al.*,2015).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(Segat *et al.*,2015).Inhibition of *Escherichia coli*was treated at low temperatures by plasma technology in unprocessed milk comprisingmany fat ratios ofmilk(Yong*et al.*,2015).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(Gurol*et al.*,2012).

Table1: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*

7. Meat and poultry industry

It states thatcold plasma is efficientagainst micro-organisms presentin meat and meat products(Bae*et al.*,2015;Gavahian*et al.*,2019;Puligundla and Mok,2016).Deactivation of *Campylobacter jejuni* in chicken ham utilizing the atmospheric-pressure plasma techniqueaccomplishedat radio frequency and using argon gas(Kim*et al.*,2013). 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(Ulbin-Figlewicz*et al.*,2015). From some studies, it has been observed that was effectively able to spoil the bacteriaon chicken meat(Noriega *et al.,* 2011). Studies states that thedestroying *Listeria innocua* in ready-to-eat meat by up to 1.6 ± 0.5 log cfu/g is possible based upon constitution of the charged species(Rød *et al.*, 2012). ROS and RNS created through the disintegration of gaseous molecules take place during plasma generation(Conrads and Schmidt, 2000; Han *et al.*, 2016).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(Cullen *et al.*, 2014; Han *et al.*, 2016).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(Sensenig *et al.*, 2011). 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(Yong *et al.*, 2014).

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 *campylobacter jejuni*
2.	Ready-to-eat meat	*Listeria innocua*	Destroying *Listeria innocua* in ready-to-eat meat by up to 1.6 ± 0.5 log cfu/g

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(Pankaj *et al.*, 2014). This technique is also responsible for providing the sealing properties of polymer foils(Heise*et al.*,2004).By using A deposition barrier which 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(Ekezie*et al.*,2017).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(Joerger *et al.,* 2009; Popelka *et al.*,2012). 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(Karam *et al.*, 2016; Clarke *et al.*,2017).

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.Ancestralasepsisapproaches 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(Yepez*et al.,*2020). 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(Katsigiannis*et al.*,2020). 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(Alkawareek *et al.*,2012). 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.(Niemira *et al.*,2008; Niemira *et al.*,2012a).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(Pan and Zhang,2020; Leipold*et al.*,2010). 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(Katsigiannis*et al.*,2020).

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(Ohta 2016). 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 insecticides.For this reason, recent Cold plasma related articles have been published andshown that this novel technique can be believed to be aneffective way to preserve food goods by reducing insecticidal effects(Paul and Mahendran2020; Ratish*et al.*,2018; Sarangapani *et al.,* 2016). It has been found that after brown rice was exposed to CP at 200 V for 24 hours,*T. castaneum* was eliminated(Paul and Mahendran,2020).To enhancegrafting 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(zhang *et al.*,2014).

11. Allergen or enzyme degradation approach

Food allergies are increasing quickly worldwide basis(Nwaru *et al.*,2014).Food allergies are the result of an immunoglobin-mediated response to antigens,most often proteins(Meinlschmidt *et al.*,2016).Due to their leasteffects on food quality indicators,Nonthermal therapies have newly been explored in order to reduce food allergenicity(Huang *et al.*,2014; Shriver and Yang 2011). 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(Shriver*et al.*,2011).Fish, crustaceans and molluscsare the most crucial food products that trigger allergic reactions in those who consume seafood(Gavahian and Khaneghah2020;Kamath*et al.*,2013). 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(Ekezie*et al.*,2019).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. 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(Ekezie*et al.*,2019). Additionally, it has 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 thehistidine decarboxylaseresponsible for seafood contamination.According to the mentionedstatement of recent studies, it may have commercial uses for minimizing the allergenicity or enzyme activity of seafood items(Misra*et al.*,2016;Pan*et al.*,2019; Umair *et al.*, 2021). 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(Bußler *et al.*,2015).

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(Shi *et al.*,2011).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(Shi *et al.*, 2011). *Citrobacter freundii* was likewise reduced by 5 logs in apple juice after 480 seconds(Surowsky *et al*., 2014). 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(Almeida *et al.*,2015).

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(Ziuzina*et al.*,2014).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)(Misra*et al.*,2016).Impacts of this non thermaltechnique 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(Tappi *et al.*,2014).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 (Surowsky *et al.*,2013).

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(Donohue*et al.*,2006). The nonthermal plasma treatment-induced mortality of *Myzus persicae*, *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(Bures*et al.*,2006). 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(Abd El-Aziz *et al.*,2014; Mahendran*et al.*,2016).

15. Result 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(Misra*et al.*,2015).Wheat flour can undergo a cold plasma treatment that changes the proteins to the point where it impacts the functionality of the flour(Bahrami *et al.*,2016).According to research done on zein films exposed to cold plasma treatment, the disordered and -helical conformations were impacted(Pankaj*et al.*,2014). 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(Dong*et al.*,2017).

16. Result of cold plasma treatment on pea protein

It helps to enhance the functional characteristics of food materials(Thirumdas *et al.*,2017; Sarangapani*et al.*,2018).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(Bußler*et al.*,2015).

17. Advantages of cold plasma technology

17.1. 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(Niemira*et al.*,2012;Pankaj *et al.*, 2014).

17.2. It helped to deactivate the microorganisms in a relatively short period(Niemira*et al.*,2012; Pankaj *et al.*,2014).

17.3. The procedure also makes it possible. Fast sterilization without exposing the finished items to residues like food packaging, plastic bottles, and caps(Niemira*et al.*,2012; Pankaj *et al.*, 2014).

18.Future prospects

18.1. Evaluating the capability of this nonthermal techniqueon various food products processing as it is cost-effective as well as an environmentally friendly technique.

18.2. enhancing the storage life of food products is a globally faced challenge and cold plasma technology will show positive effects on it.

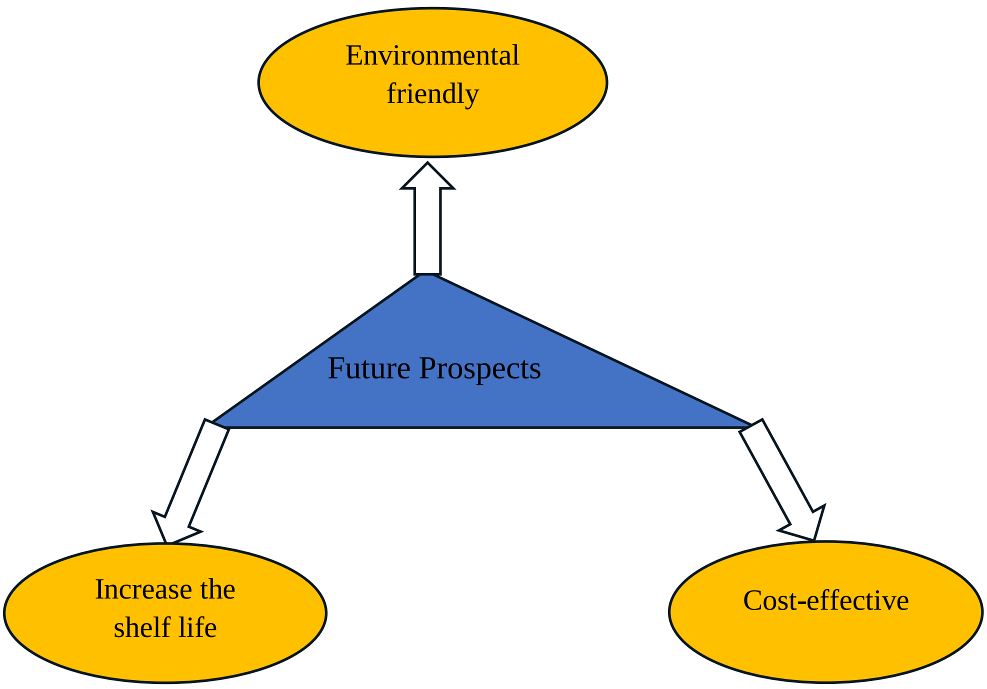


Figure.3: Future Prospects

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.

References

Abd El-Aziz MF, Mahmoud EA, Elaragi GM. 2014. Non thermal plasma for control of the Indian meal moth, Plodia interpunctella (Lepidoptera: Pyralidae). *Journal Of Stored Products Research*.Effect of cold plasma on mortality of Tribolium castaneum on refined wheat flour. *Proceeding of the international conference on control atmosphere.* Fumigation Stored Product;25(3), 251-270.

Ali A, Kim Y H, Lee J Y, Lee S, Uhm H S, Cho G, Park B J and Choi E H (2014) Inactivation of Propionibacterium acnes and its biofilm by nonthermal plasma. *Journal of current applied physics*;14,142–148.

Alkawareek, M. Y., Gorman, S. P., Graham, W. G., & Gilmore, B. F. (2014). Potential cellular targets and antibacterial efficacy of atmospheric pressure non-thermal plasma. *International Journal of Antimicrobial Agents*, 43(2),154-160.

Alkawareekmy, Algwari QT, Laverty G, Gorman SP, Graham WG, O'Connell D, Gilmore BF. 2012. Eradication of pseudomonas aeruginosa biofilms by atmospheric pressure non-thermal plasma. *Journal of plos one;*5 (1), 2008-4978.

Almazan-Almazan, M. C., Paredes, J. I., Perez-Mendoza, M., Domingo-Garcia, M., Lopez-Garzon, F. J., Martinez-Alonso, A., and Tascon, J. M. (2005). Effects of oxygen and carbon dioxide plasmas on the surface of poly(ethylene terphthalate).*Journal of Colloid Interface of Science;*14 142–148.

Almeida, F.D.L., Cavalcante, R.S., Cullen, P.J., Frias, J.M., Bourke, P., Fernandes, F.A., et al., 2015. Effects of atmospheric cold plasma and ozone on prebiotic orange juice.Journalofinnovative food science and emerging technology;32, 127 135.

Bae, S. C., Park, S. Y., Choe, W., and Ha, S. do (2015). Inactivation of murine norovirus-1 and hepatitis A virus on fresh meats by atmospheric pressure plasma jets.*Journal of food research international*;76, 342–347.

Bahrami, N., Bayliss, D., Chope, G., Penson, S., Perehinec, T., and Fisk, I. D. (2016). Cold plasma: A new technology to modify wheat flour functionality. *Journal of food chemistry*;1–15.

Banu, M. S. (2012). Cold Plasma as a Novel Food Processing Technology. International *journal of emerging trends in engineering and developments*;10 (3), 235–242.

Bermudez-AguirreD and ed.Cambridge(2020). *Book- Advances in cold plasma applications for food safety and preservation*;pp.49, 91.

Bubler S, Ehlbeck J and Schluter O K (2017) Pre-drying treatment of plant related tissues using plasma processed air: impact on enzyme activity and quality attributes of cut apple and potato. *The Journal of innovative food science and emerging technologies*;167, 166-174.

Bures BL, Donohue KV, Roe RM, Bourham MA. 2006. Nonchemical dielectric barrier discharge treatment as a method of insect control. *Journal of IEEE transaction on plasma science,*17(1), 2–62.

Bußler, S., Steins, V., Ehlbeck, J and Schlüter, O. (2015). Impact of thermal treatment versus cold atmospheric plasma processing on the techno-functional protein properties from Pisum sativum 'Salamanca'. *Journal of innovative food science and emerging technology*; 167, 166-174.

Bußler, S., Steins, V., Ehlbeck, J., and Schlüter, O. (2015). Impact of thermal treatment versus cold 629 atmospheric plasma processing on the techno-functional protein properties from Pisum sativum 630 'Salamanca' *Journal of food engineering*; 167, 166-174.

Charoux, C. M. G., Patange, A., Lamba, S., O'Donnell, C. P., Tiwari, B. K., and Scannell, A. G. M. (2021). Applications of nonthermal plasma technology on safety and quality of dried food ingredients. *Journal of Applied Microbiology*;10, 17297.

Chen, H. H., Chen, Y. K., and Chang, H. C. (2012). Evaluation of physicochemical properties of plasma reated brown rice. *Journal of food chemistry*;150, 112382.

Clarke, D., Tyuftin, A.A., Cruz-Romero, M.C., Bolton, D., Fanning, S., Pankaj, S.K., Bueno-Ferrer, C., Cullen, P.J., Kerry, J.P., 2017. Surface attachment of active antimicrobial coatings onto conventional plastic-based laminates and performance assessment of these materials on the storage life of vacuum packaged beef sub-primals. *Journal of food microbiology;*75, 83–91.

Conrads, H. and Schmidt, M. (2000) Plasma generation and plasma sources. *Journal of plasma sources science and technology*;9, 441-454.

Cullen, P. J., Misra, N. N., Han, L., Bourke, P., Keener, K., O'Donnell, C., Moiseev, T., Mosnier, J. P., and Milosavljevic, V. (2014) Inducing a dielectric barrier discharge plasma within a package. *IEEE Transaction on Plamsa Science*. 42, 2368-2369.

Cullen, P. J., J. Lalor, L. Scally, D. Boehm, V. Milosavljevic, P. Bourke, and K. Keener. 2018. Translation of plasma technology from the lab to the food industry. *Journal of plasmaprocesses and polymer*s;82(2):450-458.

Donegan, M., Milosavljevi´c, V. and Dowling, D. P. (2013). Activation of PET using an RF atmospheric plasma system. *Journal of plasma chemistry and plasma processing*;33(5), 941–957.

Dong, S., Gao, A., Xu, H., and Chen, Y. (2017). Effects of dielectric barrier discharges (DBD) cold plasma treatment on physicochemical and structural properties of zein powders. *Journal of food and bioprocess techn*ology;110:197–202.

Donohue KV, Bures BL, Bourham MA, Roe RM. 2006. Mode of action of a novel nonchemical method of insect control: atmospheric pressure plasma discharge.*Journal of economic entomology*;0(3), 213-219.

Ekezie, F. G. C., Sun, D. W. and Cheng, J. H. (2017). A review on recent advances in cold plasma technology for the food industry: Current applications and future trends. *Journal of trends in food Science and technology*;69, 46–58.

Ekezie, F. G. C., Sun, D. W. and Cheng, J. H. (2019). Altering the IgE binding capacity of king prawn (Litopenaeus Vannamei) tropomyosin through conformational changes induced by cold argon-plasma jet. *Journal of food chemistry*;276, 147–156.

Ekezie, F. G. C., Sun, D. W. and Cheng, J. H. (2019). Altering the IgE binding capacity of king prawn (Litopenaeus Vannamei) tropomyosin through conformational changes induced by cold argon-plasma jet. *Journal of food chemistry*;276, 147–156.

Ekezie, F. G. C., Sun, D. W., and Cheng, J. H. (2017). A review on recent advances in cold plasma technology for the food industry: Current applications and future trends.*Journal of trends in food science and technology;*69, 46–58.

Ermolaeva, S. A., Varfolomeev, A. F., Chernukha, M. Y., Yurov, D. S., Vasiliev, M. M., Kaminskaya, A. A., et al. (2011);60(1), 75–83.*Journal of medical microbiology;*

Fernandez, ´ A., Noriega, E. and Thompson, A. (2013). Inactivation of Salmonella enterica serovar Typhimurium on fresh produce by cold atmospheric gas plasma technology.*Journal ofFood Microbiology;*33(1), 24–29.

Fernandez, ´ A., Noriega, E. and Thompson, A. (2013). Inactivation of *Salmonella enterica serovar Typhimurium* on fresh produce by cold atmospheric gas plasma technology.*Journal offood microbiology;*33(1), 24–29.

Gadri, R.B., Roth, J.R., Montie, T.C., Kelly-Wintenberg, K., Tsai, P.P.Y., Helfritch, D.J., et al., 2000. Sterilization and plasma processing of room temperature surfaces with a one atmosphere uniform glow discharge plasma (OAUGDP).*Internationaljournal of Surface coatings technology*; 131 (1 3), 528 541.

Gavahian, M. and Khaneghah, A. M. (2020).Cold plasma as a tool for the elimination of food contaminants: Recent advances and future trends.*Journal of critical reviews in food science and nutrition*;76, 342–347.

Guo, J., Huang, K.and Wang, J. (2015). Bactericidal effect of various non-thermal plasma agents and 669 the influence of experimental conditions in microbial inactivation: *A review. food control*;50:482-490.

Gurol, C., Ekinci, F. Y., Aslan, N., and Korachi, M. (2012). Low temperature plasma for decontamination of E. coli in milk.International*journal of food microbiology*;157(1), 1–5.

Gurol, C., Ekinci, F. Y., Aslan, N., and Korachi, M. (2012). Low temperature plasma for decontamination of E. coli in milk.*International journal of food microbiology*; 157(1), 1–5.

Han, L., Patil, S., Boehm, D., Milosavljevic, V., Cullen, P. J., and Bourke, P. (2016) Mechanisms of inactivation by high voltage atmospheric cold plasma differ for *Escherichia coli* and *Staphylococcus aureus*. *Journal of applied and environmental microbiology;*82, 450-458.

Heise, M., Neff, W., Franken, O., Muranyi, P., and Wunderlich, J. (2004). Sterilization of polymer foils with dielectric barrier discharges at atmospheric pressure. *Journal of Plasmas and polymers*,9(1), 23-33.

Huang, M., Zhuang, H., Zhao, J., Wang, J., Yan, W., and Zhang, J. (2020). Differences in cellular damage induced by dielectric barrier discharge plasma between Salmonella Typhimurium and Staphylococcus aureus. *Journal of bioelectrochemistry;*132, 107445.

Isbary, G., Stolz, W., Shimizu, T., Monetti, R., Bunk, W., Schmidt, H.U., et al., 2013. Cold atmospheric argon plasma treatment may accelerate wound healing in chronic wounds: results of an open retrospective randomized controlled study in vivo. *Journal of* clinical plasma Medicine;1 (2), 25–30.

Jo K., Lee J., Lim Y., Hwang J., Jung S. Curing of meat batter by indirect treatment of atmospheric pressure cold plasma.*Korean journal of agriculture science,2018*;338, 127826.

Joerger, M.C., 2009. Antimicrobial activity of chitosan attached to ethylene copolymer films.*International journal of packagingtechnology and science;*22, 125–138.

Kamath, S. D., Rahman, A. M. A., Komoda, T. and Lopata, A. L. (2013). Impact of heat processing on the detection of the major shellfish allergen tropomyosin in crustaceans and molluscs using specific monoclonal antibodies. *Journal of foodchemistry;*141 (4), 4031–4039.

Karam, L., Casetta, M., Chihib, N., Bentiss, F., Maschke, U., Jama, C., 2016. Optimization of cold nitrogen plasma surface modification process for setting up antimicrobial low density polyethylene films. *Journal of taiwan institute of chemical engineers*;64, 299–305.

Katsigiannis, A. S., Bayliss, D. L. and Walsh, J. L. (2020). Cold plasma decontamination of stainless steel food processing surfaces assessed using an industrial disinfection protocol. *Journal offood control*;4(1), 50–59.

Khani M R, Shokri B and Khajeh K (2017) Studying the performance of dielectric barrier discharge and gliding arc plasma reactors in tomato peroxidase inactivation.*Journal of food Engineering;*197 107–112.

Kim, J. S., Lee, E. J., Cho, E. A. and Kim, Y. J. (2013). Inactivation of *Campylobacter jejuni* using radio-frequency atmospheric pressure plasma on agar plates and chicken hams. *KoreanJournal of food science of animal resources*;33(3), 317–324.

Kogelschatz U. Twenty years of Hakone symposia: From basic plasma chemistry to billion dollar markets. Plasma Processes and Polymers. 2007; 4: Pg no-15 and Rossi F, Kylian O, Hasiwa M. Decontamination of surfaces by low pressure plasma discharges.*Reviewjournal of plasma processes and polymers.2006;*4: 678-681; 71:13–24.

Korachi, M., Ozen, F., Aslan, N., Vannini, L., Guerzoni, M. E., Gottardi, D., et al. (2015). Biochemical changes to milk following treatment by a novel, cold atmospheric plasma system. *International dairy journal;*42, 64–69.

Lacombe A, Niemira BA, Gurtler JB, Fan X, Sites J, et al. 2015. Atmospheric cold plasma inactivation of aerobic microorganisms on blueberries and effects on quality attributes.*Journal offood microbiology*;46, 479–484.

Langmuir I. Oscillations in ionized gases. *Journalof proceedings of the national academy of sciences* 1928;18, 2246-2253;1928; 14: 628.

LaroussiM.(1996).*Journal of AIEEE Transaction on plasmascience;*7:113902.

Leipold, F., Kusano, Y., Hansen, F. and Jacobsen, T. (2010). Decontamination of a rotating cutting tool during operation by means of atmospheric pressure plasmas.*Journal offood control*;21(8).

Lee H., Yong H.I., Kim H.J., Choe W., Yoo S.J., Jang E.J., Jo C., Jayasena D.D., Kim H.J., Y. Evaluation of the microbiological safety, quality changes, and genotoxicity of chicken breast treated with flexible thin-layer dielectric barrier discharge plasma. International journal of Food Science and Biotechnology,2016; 25(4):1189-1195.

Li S., Chen S., Han F., Xv Y., Sun H., Ma Z., *et al*., Wu W. Development and optimization of cold plasma pretreatment for drying on corn kernels. Journal of food science,2019;114, 60–66.

Liao, X., Liu, D., Chen, S., Ye, X. and Ding, T. (2021). Degradation of antibiotic resistance contaminants in wastewater by atmospheric cold plasma: Kinetics and mechanisms. Environmental Technology. *Journal of environmental technology*.42(1), 58–71.

Los A., Ziuzina D., Akkermans S., Boehm D., Cullen P.J., Van Impe J., Bourke P. Improving microbiological safety and quality characteristics of wheat and barley by high voltage atmospheric cold plasma closed processing. *Journal offood research international,2018;*8(6), 207.

Lu, H., Patil, S., Keener, K. M., Cullen, P. J., & Bourke, P.(2014). Bacterial inactivation by high-voltage atmospheric cold plasma: Influence of process parameters and effects on cell leakage and DNA. *Journal of applied microbiology;*116(4), 784–794.

Mahendran R. 2016. Effect of cold plasma on mortality of Tribolium castaneum on refined wheat flour. *International conference on controlled atmosphere and fumigation in stored products;*80:93–103.

Meinlschmidt, P., Ueberham, E., Lehmann, J., Reineke, K., Schlüter, O., Schweiggert-Weisz, U and Eisner,P. (2016). The effects of pulsed ultraviolet light, cold atmospheric pressure plasma, and gamma-irradiation on the immunoreactivity of soy protein isolate. *Journal of innovative food science and emerging technologies;*38:374–83.

Mendes-Oliveira, G., Jensen, J. L., Keener, K. M. and Campanella, O. H. (2019). Modeling the inactivation of Bacillus subtilis spores during cold plasma sterilization.*Journal OF Innovative Food Science and Emerging Technologies;*52, 334–342.

Mir, S. A., Siddiqui, M. W., Dar, B. N., Shah, M. A., Wani, M. H., Roohinejad, S., et al. (2020). Promising applications of cold plasma for microbial safety, chemical decontamination and quality enhancement in fruits. *Journal of Applied Microbiology*;129(3), 474–485.

Misra N, Pankaj S, Segat A, Ishikawa K. 2016. Cold plasma interactions with enzymes in foods and model systems.*Journal oftrends food science and technology*;55, 39–47.

Misra, N. N., Kaur, S., Tiwari, B. K., Kaur, A., Singh, N., and Cullen, P. J. (2015). Atmospheric pressure cold plasma (ACP) treatment of wheat flour. *Journal of food hydrocolloids*;44, 115-121;

Misra, N., Pankaj, S., Segat, A., and Ishikawa, K. (2016). Cold plasma interactions with enzymes in foods and model systems. *Journal of trends in food science and technology*;125, 131 138.

Misra, N., Pankaj, S., Walsh, T., O'Regan, F., Bourke, P., Cullen, P., 2014a. In-package nonthermal plasma degradation of pesticides on fresh produce. *Journal of hazardous materials*;7, 3045–3054.

Misra, N.N., Pankaj, S.K., Segat, A., Ishikawa, K., 2016. Cold plasma interactions with enzymes in foods and model systems. *Journal of trendsfood science and technology;*125, 131 138.

Morales- de la Peña, M., Salvia- Trujillo, L., Rojas- Graü, M. A., & Martín- Belloso, O.(2017). Effects of high intensity pulsed electric fields or thermal pasteurization and refrigerated storage on antioxidant compounds of fruit juice- milk beverages. part I:phenolic acids and flavonoids.*Journal of food processing and preservation;*41, 1-10.

Muranyi, P., Wunderlich, J., and Heise, M. (2007). Sterilization efficiency of a cascaded dielectric barrier discharge. *Journal of applied microbiology*;103(5), 1535–1544.

Muranyi, P., Wunderlich, J.and Heise, M. (2008). Influence of relative gas humidity on the inactivation efficiency of a low temperature gas plasma.*Journal of applied microbiology*;104, 1659–1666.

Niemira BA, Sites J. 2008. Cold plasma inactivates Salmonella Stanley and Escherichia coli O157:H7 inoculated on golden delicious apples. *Journal of Food Protection*;Niemira BA. 2012a. Cold plasma decontamination of foods. *Annul review of food science and technology,2012;*71(7), 1357–1365.

Niemira, B. A. (2012). Cold plasma decontamination of foods. *Annual review of food science and technology*;3(1), 125–142.

Noriega, E., Shama, G., Laca, A., Díaz, M., and Kong, M. G. (2011). Cold atmospheric gas plasma disinfection of chicken meat and chicken skin contaminated with *Listeria innocua.* Food microbiology;28(7), 1293–1300.

Nwaru BI, Hickstein L, Panesar S, Muraro A, Werfel T, et al. 2014.*The epidemiology of food allergy in Europe: a systematic review and meta-analysis*;69 (8):992–1007.

Ohta,T. ed. NN Misra, O Schluter, PJ Cullen, 2016. Plasma in agriculture. In Cold Plasma in Food and Agriculture: *Plasmonics Fundamentals and Applications;*67 (2), 646 648.

Pan, Y., Cheng, J., & Sun, D. (2019). Cold plasma-mediated treatments for shelf life extension of fresh produce: A review of recent research developments.*Journal of comprehensive reviews in food science and food safety*;18(5), 1312–1326.

Pan, Y., Zhang, Y., Cheng, J. H., & Sun, D. W. (2020). Inactivation of Listeria Monocytogenes at various growth temperatures by ultrasound pretreatment and cold plasma.*Journal of Lebensmittel-Wissenschaft und -Technologie;118*, 108635.

Pankaj, S. K., Bueno-Ferrer, C., Misra, N. N., Milosavljević, V., O'Donnell, C. P., Bourke, P., Keener, K. M. and Cullen, P. J. (2014). Applications of cold plasma technology in food packaging.*Journal of trends Infood science and technology*;35(1).

Pankaj, S. K., Bueno-Ferrer, C., Misra, N. N., O'Neill, L., Tiwari, B. K., Bourke, P., andCullen, P. J. (2014). Physicochemical characterization of plasma-treated sodium caseinate film. *Journal of food research international*;35(1), 5-17.

Patil, S., Moiseev, T., Misra, N., Cullen, P., Mosnier, J., Keener, K.and Bourke, P. (2014). Influence of high voltage atmospheric cold plasma process parameters and role of relative humidity on inactivation of Bacillus atrophaeus spores inside a sealed package.*Journal of Hospital Infection;*125:131-138.

Paul, A.and R, M. (2020).Mortality of Tribolium castaneum and quality changes in Oryza sativa by indirect exposure to Non-Thermal Plasma.*International journal of frontiers in advanced materials research*;2(2), 26–40.

Puligundla, P., & Mok, C. (2016). Non-thermal plasmas (NTPs) for inactivation of viruses in abiotic environment. *Research Journal of Biotechnology*, 11(6), 91–96.

Popelka, A., Nova´k, I., Lehocky´, M., Choda´k, I., Sedliacik, J., Gajtanska, M., Sedliacikova´, M., Vesel, A., Junkar, I., Kleinova´, A., 2012. Anti-bacterial treatment of polyethylene by cold plasma for medical purposes. Molecules.*Journal of open access molecules ISSN 1420* -3049;17, 762–785.

Ratish Ramanan, K., Sarumathi, R., and Mahendran, R. (2018). Influence of cold plasma on mortality rate of different life stages of Tribolium castaneum on refined wheat flour. *Journal of stored products research*;77, 126–134.

Rodacka A, Serafin E and Puchala M (2010). Efficiency of superoxide anions in the inactivation of selected dehydrogenases.*Journal ofradiation physics, radiation chemistry and radiation processing;*ted dehydrogenases.(79)960–965.

Rød S.K., Hansen F., Leipold F., Knøchel S. Cold atmospheric pressure plasma treatment of ready-to-eat meat: Inactivation of Listeria innocua and changes in product quality. *Journal of* food microbiology. 2012;30(1):233-238.

Sarangapani, C., Devi, Y., Thirundas, R., Annapure, U. S., and Deshmukh, R. R. (2015). Effect of low pressure plasma on physico-chemical properties of parboiled rice. LWT- *Journal of foodscience and technology*;3(1):452-460.

Sarangapani, C., Misra, N. N., Milosavljevic, V., Bourke, P., O’Regan, F., & Cullen, P. J. (2016). Pesticide degradation in water using atmospheric air cold plasma.*Journal of Water Process Engineering*;9, 225–232.

Sarangapani C, Patange A, Bourke P, Keener K and Cullen P J (2018) Recent advances in the application of cold plasma technology in foods.*Annual review of food science and technology*;9:609–29.

Segat A, Misra N N, Cullen P J and Innocente N (2015) Atmospheric pressure cold plasma (ACP) treatment of whey protein isolate model solution.Journal of innovative food science and emerging technologies;(29)247–254.

Selcuk M., Oksuz L., Basaran P. Decontamination of grains and legumes infected with Aspergillus spp. and Penicillum spp. by cold plasma treatment. *Journal of bioresourcetechnology*.2008;99(11):5104-5109.

Sensening, R., Kalghatgi, S., Cerchar, E., Fridman, G., Shereshevsky, A., Torabi, B., Arjunan, K. P., Podolsky, E., Fridman, A., and Friedman, G. (2011) Nonthermal plasma induces apoptosis in melanoma cells via production of intracellular reactive oxygen species. *Journal of annals of biomedical engineering*;39, 674-687.

Shi, X.-M., Zhang, G.-J., Wu, X.-L., Li, Y.-X., Ma, Y., Shao, X.-J., 2011. Effect of low-temperature plasma on microorganism inactivation and quality of freshly squeezed orange juice. *Journal of plasma science*; 39 (7), 1591 1597.

Shriver, S.K. 2011. Effect of selected nonthermal processing methods on the allergen reactivity of Atlantic white shrimp. *Critical reviews in food science and nutrition;*Pg no-2.

Silva B., Silva J., Moecke E., Scussel V. Effect of Cold Plasma treatment on fungi inactivation and germination of maize grains (Zea mays L.). *IOSR-JAVS.*2020;119, 564-570.

Smuda, M. and Glomb, M. A. (2013). Maillard degradation pathways of vitamin C. *Angewandte chemie international edition*;52, 4887-4891.

Song, A. Y., Oh, Y. J., Kim, J. E., Song, K. B., Oh, D. H.and Min, S. C. (2015). Cold plasma treatment for microbial safety and preservation of fresh lettuce.*International journal offood science and biotechnology*;84, 268–275.

Sonawane, S. K., T, M.and Patil, S. (2020). Non-thermal plasma: An advanced technology of the food industry. *International journal of food science and technology*;26(8).

Suhem K., Matan N., Nisoa M., Matan N. Inhibition of Aspergillus flavus on agar media and brown rice cereal bars using cold atmospheric plasma treatment. *International journal of food microbiology*. 2013;52, 4887-4891.

Surowsky B, Fischer A, Schlueter O, Knorr D. 2013. Cold plasma effects on enzyme activity in a model food system.*Journal ofinnovative food science and emerging technology.*,19, 146-152.

Surowsky, B., Fro¨hling, A., Gottschalk, N., Schlu¨ter, O., Knorr, D., 2014. Impact of cold plasma on Citrobacter freundii in apple juice: inactivation kinetics and mechanisms. *International journal offood microbiology*;7(2), 82-108

Tappi S, Berardinelli A, Ragni L, Dalla Rosa M, Guarnieri A, Rocculi P. 2014. Atmospheric gas plasma treatment of fresh-cut apples.*Journal oF innovative food science and emerging technology*;21:114–22.

Thirumdas R, Sarangapani C and Annapure U S (2015) Cold plasma: a novel non-thermal technology for food processing. *Journal of food biophysics;*(10) 1–11.

Thirumdas, R., Kadam, D. and Annapure, U. S. (2017). Cold plasma: An alternative technology for the starch modification.*Journal of food biophysics*;12(1), 129-139.

Tiozzo, B., Mari, S., Magaudda, P., Arzenton, V., Capozza, D., Neresini, F., *et al.* (2011). Development and evaluation of a risk-communication campaign on salmonellosis.*Journal offood control*;22(1), 109–117.

Tolouie H., Mohammadifar M.A., Ghomi H., Yaghoubi A.S., Hashemi M. The impact of atmospheric cold plasma treatment on inactivation of lipase and lipoxygenase of wheat germs. *Journal of innovative food science and emerging technology*,2018;61(1), 2-30.

Ulbin-Figlewicz, N., Brychcy, E., and Jarmoluk, A. (2015). Effect of low-pressure cold plasma on surface microflora of meat and quality attributes. *Journal of food science andtechnology*;52(2), 1228–1232.

Umair, M., Jabbar, S., Ayub, Z., Muhammad Aadil, R., Abid, M., Zhang, J., *et al.* (2021). Recent advances in plasma technology: Influence of atmospheric cold plasma on spore inactivation. *Food reviews international;*8(11):593.

Wang J.M., Zhuang H., Lawrence K., Zhang J.H. Disinfection of chicken fillets in packages with atmospheric cold plasma: effects of treatment voltage and time.*Journal of appliedmicrobiology*,2018;83, 1–8.

Wong, L. W., Hou, C. Y., Hsieh, C. C., Chang, C. K., Wu, Y. S. and Hsieh, C. W. (2020). Preparation of antimicrobial active packaging film by capacitively coupled plasma treatment.*Journal of lebensmittel-wissenschaft and -technologie;*36(8), 807-844.

Yang, L., Chen, J. and Gao, J. (2009). Low temperature argon plasma sterilization effect on Pseudomonas aeruginosa and its mechanisms. *Journal of Electrostatics*;67(4), 646–651.

Yang, L., Chen, J. and Gao, J. (2009). Low temperature argon plasma sterilization effect on Pseudomonas aeruginosa and its mechanisms.*Journal of electrostatics*;67(4), 646–651.

Yepez, X.v., Misra, N. N. and Keener, K. M.(2020).Nonthermal plasma technology. *Food engineering series*;85(4), 1203–1212.

Yong, H. I., Kim, H. J., Park, S., Alahakoon, A. U., Kim, K., Choe, W., *et al.* (2015). Evaluation of pathogen inactivation on sliced cheese induced by encapsulated atmospheric pressure dielectric barrier discharge plasma. *Journal of food microbiology;*(46)46–50.

Yong, H. I., Kim, H. J., Park, S., Alahakoon, A. U., Kim, K., Choe, W., et al. (2015). Evaluation of pathogen inactivation on sliced cheese induced by encapsulated atmospheric pressure dielectric barrier discharge plasma. *Journal of foodmicrobiology*;(46)46–50.

Yong, H. I., Park, J., Kim, H. J., Jung, S., Park, S., Lee, H. J., Choe, W., and Jo. C. (2017b) An innovative curing process with plasma-treated water for production of loin ham and for its quality and safery. *Journal of plasmaprocesses and polymers;*123, 151–156.

Yusupov, M., Bogaerts, A., Huygh, S., Snoeckx, R., van Duin, A. C. T., and Neyts, E. C. (2013) Plasma-induced destruction of bacterial cell wall components: A reactive molecular dynamics simulation. *Journal of physical Chemistry C;*117, 5993-5998.

Zhang, R., Guo, X., Shi, X., Sun, A., Wang, L., Xiao, 2014).Highly permselective membrane surface modification by cold plasma-induced grafting polymerization of molecularly imprinted polymer for recognition of pyrethroid insecticides in fish. *Journal of analytical chemistry*;86(23), 11705–11713.

Zhao, Y. M., de Alba, M., Sun, D. W., and Tiwari, B. (2019). Principles and recent applications of novel non-thermal processing technologies for the fish industry—a review. *Journal of critical reviews in food sciences and nutrition*;59(5), 728–742.

Ziuzina D, Patil S, Cullen P, Keener K, Bourke P. 2014. Atmospheric cold plasma inactivation of Escherichia coli,Salmonella enterica,serovar Typhimurium and Listeria monocytogenes inoculated on fresh produce. *Journal offood microbiology*;6 (3-4):397–412.