NOVEL APPLICATION OF COLD PLASMA TECHNOLOGY IN FOOD PROCESSING

A SEMINAR REPORT

submitted by

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in partial fulfilment of the requirements for the award of the Degree

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Food Technology

Department of Food Technology

TKM Institute of Technology

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DECLARATION

I undersigned hereby declare that the seminar report on “Novel Application of Cold Plasma Technology in Food Processing” submitted for partial fulfilment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Dr. Rahul Krishna B, Assistant Professor of Department of Food Technology. This submission represents my ideas in my own words and where ideas or words of others have been included; I had adequately and accurately cited and referenced the original sources. I also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

KOLLAM
24/08/2024

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CERTIFICATE

This is to certify that the report entitled "**NOVEL APPLICATION OF COLDPLASMA TECHNOLOGY IN FOOD PROCESSING**" submitted by **ANUPAMA V** to the APJ Abdul Kalam Technological University in partial fulfilment of the requirements for the award of degree of Bachelor of Technology in Food Technology is a bonafide record of the seminar work carried out by them under my guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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"It is not possible to prepare a seminar report without the assistance and encouragement of other people. This one is certainly no exception."

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ABSTRACT

Plasma is a state of matter analogous to gas in which a certain portion of the particles are ionized. It has recently showed its potential as a sanitizing tool and is frequently utilized in the processing of industrial products. This is mainly due to innovative technologies which easily yield non thermal plasmas (NTPs) at normal atmospheric pressure. Cold atmospheric plasma has budding in the food manufacturing segment to incapacitate microorganisms, thereby improving food safety. The food business faces a problem in providing safe food with minimal processing as demand for fresh produce grows. It is critical that foods are provided without any microbial contamination as many products are eaten raw. As a result, there is much attention in novel ways of preserving food and extinguishing micro-organisms without affecting its quality. One such emerging technology that has shown promise is the use of cold atmospheric plasma (CAP) treatment. Currently, an intermingling of cold plasma with other promising approaches, for example nanotechnology applications, with nanofiber, nanoemulsion, nanoparticles, and nanoencapsulation, and developing nonthermal technologies, including pulsed electric field (PEF), pulsed light (PL), and ultrasound, are gaining augmented attention. In addition to its many advantages, cold plasma is a low-cost method that can be an alternative to heat-based techniques used for the processing of food products.

Keywords: *Plasma, non-thermal plasma, food safety, food processing, sanitizing tool*

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	**percent**
&	-	And
±	-	Plus or minus sign
^{o}	-	degree
GHz	-	Giga hertz
^{o}C	-	Degree Celsius
g	-	gram
mm	-	millimetre
mg	-	milligram
ml	-	millilitre
Min	-	minute

ABBREVATIONS

ACP	-	Acyl Carrier Protein
CAP	-	Cold Atmospheric Plasma
CP	-	Cold Plasma
HHP	-	High Hydrostatic Pressure
LTP	-	Low Temperature Plasma
NTP	-	Non – thermal technology
MD	-	Maltodextrin
PEF	-	Pulse Electric Field
pH	-	Percentage of H^{+} ions
UV	-	Ultra violet

CHAPTER 1
INTRODUCTION

Food items that are premium grade, long-lasting, safe for consumption, and highly nourishing are now given priority by consumers. Food safety is one of the foremost concerns facing the food sectors, regulatory organizations, and consumers. The main problem with food processing is the microorganisms because of the negative effects they have on public health and the economy. To eradicate the many microbes, thermal methods like pasteurization, sterilization, and autoclaving are employed. Despite the fact that all of these methods are effective and advantageous, they have certain downsides, such as decreased food functionality, altered sensory aspects, and nutritional loss. Edible coating is one of the easiest ways to preserve fruits and vegetables, but it works only with whole product, and canning has been done for years[1].

To get over these thermal processing drawbacks, new cold processing technologies also known as non-thermal technologies such as Ozone, Ultraviolet, Pulse Electric Field (PEF), High Hydrostatic Pressure (HHP), Irradiation, Ultrasound, etc, are introduced. But these treatments require highly trained professionals and expensive, specialized devices. Non-thermal technologies, or NTPs, are processing techniques that increase microbiological food safety without degrading food quality as does heat treatment. They also extend product shelf life, preserve natural flavour and aroma, and achieve microbial inactivation without subjecting food to harmful heat-related effects. These assistances have led to a rise in interest in alternative food processing methods. One of these alternate novel generation methods is plasma technology[2]. The Figure 1.1 illustrates the image of utilization of thermal methods.

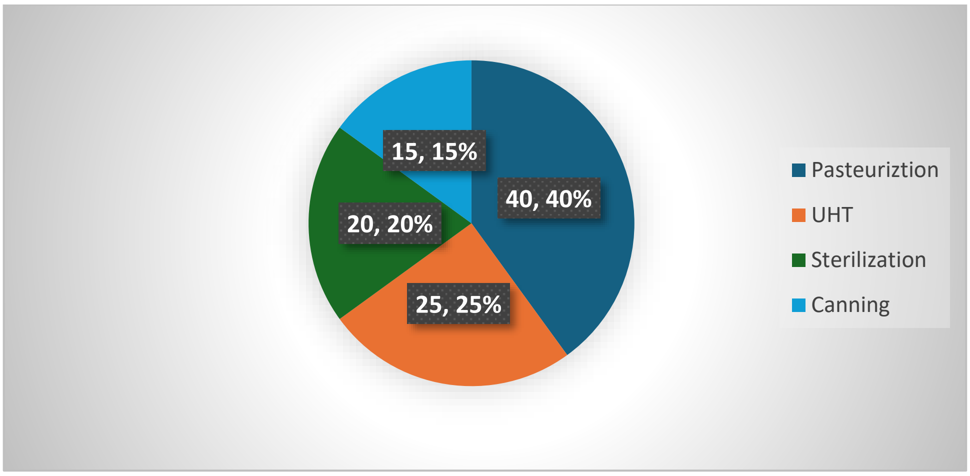

Figure 1.1 Utilization of Thermal methods

The fourth state of matter is considered to be plasma. The total amount of positively charged ions and negatively charged electrons in plasma is about equal. The relative temperatures of tellurium electrons and titanium ions are used to categorize plasma. They are often divided into two types: hot plasma (thermal plasma) and cold plasma (non-thermal plasma) [3].Cold plasma technology has several applications, particularly in the food processing sector. It is recognized for its superior effects on the bacteriological decontamination of various food products, ensuring consumer safety and extending shelf life. The Figure 1.2 illustrates the image of formation of plasma.

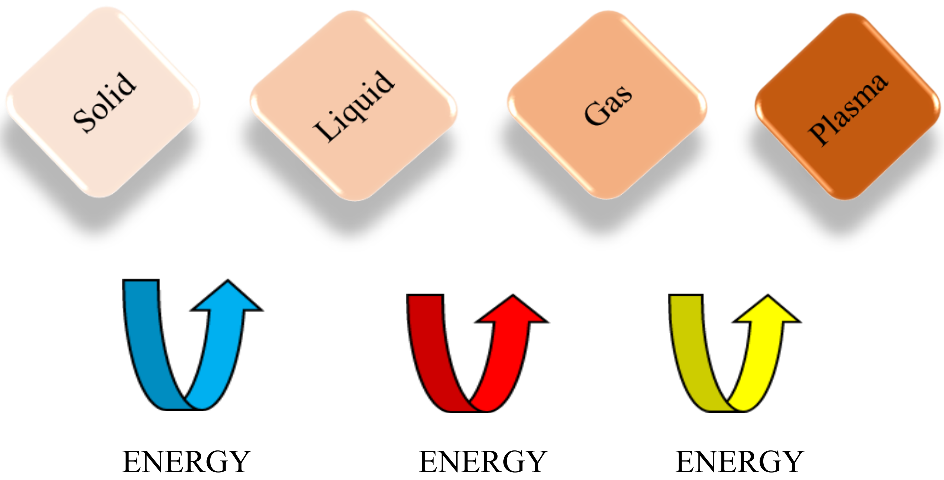

Figure 1.2 Formation of Plasma

CHAPTER 2

REVIEW OF LITERATURE

This chapter includes Review of Literature on Novel Application of Cold Plasma technology in Food processing. Various research findings relevant to the present work have been reviewed and presented under the headlines:

2.1 Potential of cold plasma technology in ensuring the safety of foods and agricultural sectors.

2.2 Application of cold plasma technology in the food industry and its combination with other emerging technologies.

2.3 Cold plasma technology: fundamentals and effect on quality of meat and its products.

2.4 Application of cold Plasma in Food Processing Industry.

2.5 Cold Plasma technology based eco-friendly food packaging biomaterials.

2.1 POTENTIAL OF COLD PLASMA TECHNOLOGY IN ENSURING THE SAFETY OF FOODS AND AGRICULTURAL SECTOR

Cold plasma (CP) technology establishes the potential for food decontamination, enzyme inactivation, toxin elimination, and packaging alterations. It elucidates that the CP pointedly reduces the microbial loads in different food products including saffron, where a 0.9 logarithmic cycle drop was attained. It effectively eradicates the pathogen such as yeast, mold and *E. coli*, ensuring microbiological safety without negotiating the food quality. Cold plasma can be used to reduce pesticide residues on fruits and vegetables, offering a potential alternative to traditional washing approaches. Studies shows that this treatment helps to preserve the nutritional and organoleptic properties of the food with negligible impact on the antioxidants and other bioactive compounds. The technology improves the shelf life of the plant material while preserving their biochemical attributes, creating it appropriate for a range of agricultural products. Beyond the food safety, cold plasma is employed for the soil remediation and enhancing seed germination, showcasing its adaptability in the agricultural products[4].

2.2 APPLICATION OF COLD PLAMA TECHNOLOGY IN THE FOOD INDUSTRY AND ITS COMBINATION WITH OTHER EMERGING TECHNOLOGIES

Cold plasma functions at low temperatures, preserving the sensory qualities of food, unlike traditional thermal methods. Cold plasma is considered as an environmentally friendly as it produces minimal leftover and consumes a lesser amount of energy compared to the conventional approaches. Cold plasma is being used more and more in conjunction with nanotechnology—such as nanoparticles and nanoencapsulation—to increase food packing and preservation. To increase CP's effectiveness, other non-thermal technologies like ultrasound and pulsed electric fields are also being mixed with it. High pressure processing in conjunction with CP enables more efficient microbial inactivation while maintaining product quality. The combination of PEF, ultrasound, and cold plasma increases the permeability of cell membranes and deactivates bacteria [2].

2.3 COLD PLASMA TECHNOLOGY FUNDAMENTALS AND EFFECT ON QUALITY OF MEAT AND ITS PRODUCTS

Innovative non-thermal method called cold plasma has showed promise in the disinfection of meats and meat products. The effect of CP on meat products' colour, pH, lipid oxidation, and microbiological quality depends on the length of exposure and energy used. With a limited emphasis on pH, the majority of researchers have instead focused primarily on the effects of CP on the microbes and colour of meat. It has been demonstrated that CP treatment effectively renders food-borne bacteria from raw meat and its derivatives inactive. CP processing has an impact on the qualitative characteristics of meat and meat products. Additionally, the cold plasma has been shown to enhance the visual quality retention of meat throughout storage. The efficiency of cold plasma processing is influenced by a number of intrinsic and extrinsic factors, such as the surface characteristics, meat types, microbe types and characteristics, the potential for antimicrobial organisms to spread and disperse on interfaces, the duration of these organisms' lives both during and after CP processing, process conditions, cost-effectiveness, etc[5].

2.4 APPLICATION OF COLD PLASMA TECHNOLOGY IN FOOD PROCESSING

The potential of cold plasma technology as a cutting-edge, non-thermal technique to increase the shelf life of fresh vegetables is examined in this section. The extremely energetic gas known as cold plasma has the ability to inactivate enzymes, suppress microbes, and alter packing materials, all of which can enhance product quality and prolong shelf life. The literature review goes over the fundamentals of cold plasma generation, its working mechanisms, and how it is used in different fresh produce products. It also emphasizes the possible advantages of cold plasma treatments in terms of improving food safety and minimizing food waste. Cut fruits and vegetables can have their shelf life extended and microbiological contamination decreased with the use of cold plasma. Fresh produce can retain its sensory attributes and nutritional worth by applying cold plasma at room temperature. The possibility of chemical remnants found in food can be decreased by using cold plasma as an environmentally friendly replacement for artificial preservatives. Fresh vegetables may brown and become less discoloured when cold plasma eliminates enzymes that cause enzymatic browning, like the polyphenol oxidase[6].

2.5 COLD PLASMA TECHNOLOGY BASED ECO-FRIENDLY FOOD PACKAGING BIOMATERIALS

When it comes to hydrophilicity, poor thermo-mechanical behaviours, and barrier properties, biopolymers are inherently inferior to standard plastics. Consequently, the possibility to develop packaging materials with particular qualities is provided by biopolymers or their film modifications. A powerful technique for non-thermal food processing, cold atmospheric plasma (CAP) or low temperature plasma (LTP) has found extensive use in the food business lately. It was initially developed to increase the surface energy of polymers for improved adhesion and printability, but it is now a useful method for surface cleaning food products and food packaging materials. Food deterioration may be less likely if cold plasma is used to create reactive oxygen species on the surface of the biopolymer. These species may have antibacterial properties. Although its initial objective was to increase the surface energy of polymers for improved adhesion and printability, it has subsequently evolved into a useful method for surface decontamination of food products and food packaging materials. Reactive oxygen species that are created on the surface of biopolymers by cold plasma have antibacterial properties that can lower the chance of food spoiling. The adherence of biopolymers to other materials can be increased by cold plasma, which makes it easier to create composite packaging structures with better qualities. With minimal processing and food stability guaranteed, these cutting-edge, creative food processing techniques allow for a compromise between higher quality and financial limits[7].

CHAPTER 3

METHODOLOGY

3.1 MODES OF COLD PLASMA GENERATION

The production of cold plasma is a multipart technique that comprises the ionization of a gas into an extremely energetic state. This ionization can be proficient by several procedures. The various methods are:

3.1.1 DIELECTRIC BARRIER DISCHARGE (DBD)

- The powered electrode and the ground electrode are the two electrodes that comprise the dielectric barrier discharge equipment.
- By placing a high voltage in between these electrodes, DBD plasma is produced.
- A dielectric material, such as polymer, glass, quartz, or ceramic, is used to cover one or both electrodes.
- It is divided by a variable gap that can range from 0.1 mm to several centimetres.
- DBDs handle information quickly and are more efficient[8]. The Figure 3.1 illustrates the image of Dielectric Barrier Discharge.

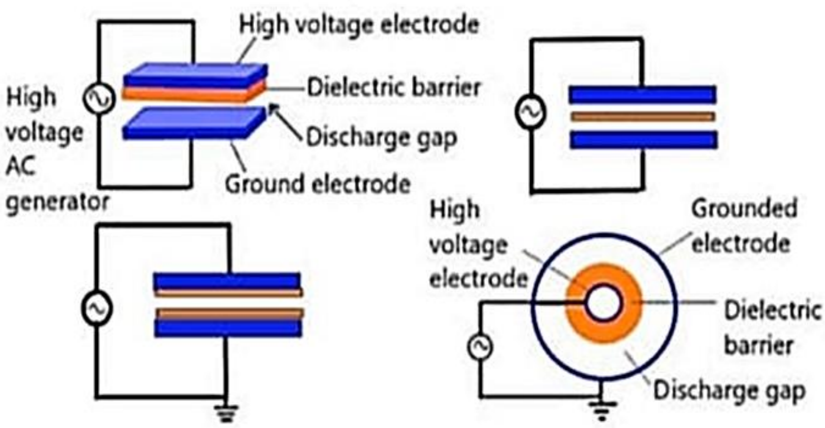

Figure 3.1 Dielectric Barrier Discharge

3.1.2 PLASMA JET (PJ)

- Two concentric electrodes make constitute a plasma jet gadget.
- The inner electrode generates radiofrequency energy by being connected to an external energy source, such as a radio frequency source, while the outer electrode is grounded.
- As a result, it reacts with the target chamber's ionizing working gas, comes out of the nozzle, and takes on the appearance of a "jet-like" item.
- Plasma is generated when an electric current flow through a gas, such as helium, oxygen, or a combination of gases, interacting with the gas to cause ionization[9]. The Figure 3.2 illustrates the image of Plasma Jet.

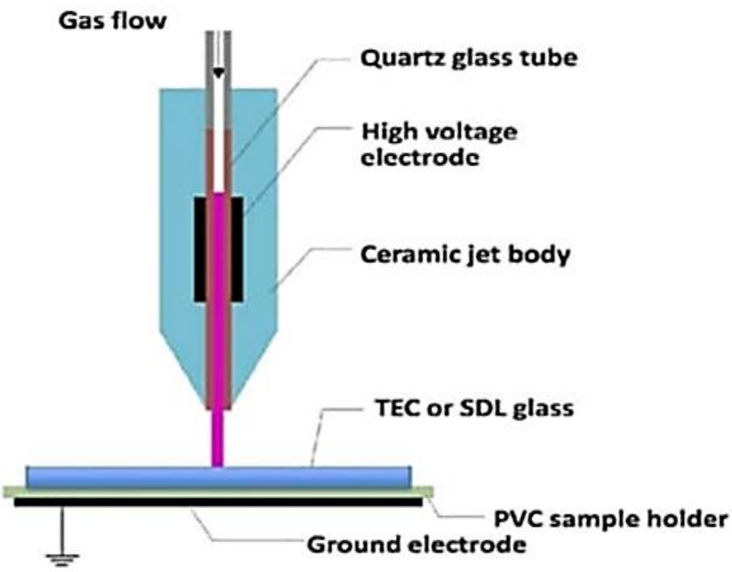

Figure 3.2 Plasma Jet

3.1.3 CORONA DISCHARGES (CD)

- A bright light that is concentrated in space close to edges, sharp points, or thin wires in an extremely fluctuating electric field is known as a corona discharge.
- Under atmospheric pressure, a non-uniform electric field strength forms the plasma.
- A weak ionized plasma is produced when the high electric field close to the electrode overwhelms the gas breakdown strength.

- In this scenario, relatively little energy is needed to break down the gas.
- This technique is mostly used to treat heat-sensitive foods while maintaining their functional and textural characteristics[10]. The Figure 3.3 illustrates the image of Corona Discharge.

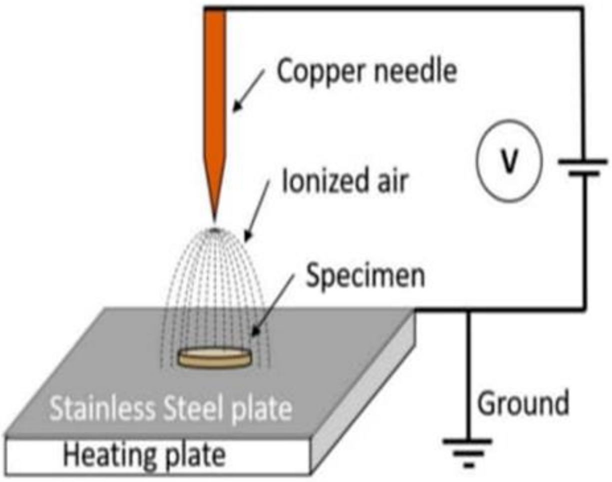

Figure 3.3 Corona Discharge

3.1.4 MICROWAVE (MW)

- A magnetron emits electromagnetic waves with a typical frequency of 2.45 GHz, which are utilized to create microwave discharges in microwave plasma creation.
- Without the need for electrodes, the microwave fields accelerate the electrons in gas molecules to create cold plasma.
- Low atmospheric pressure plasma can be produced using this technology.[11].

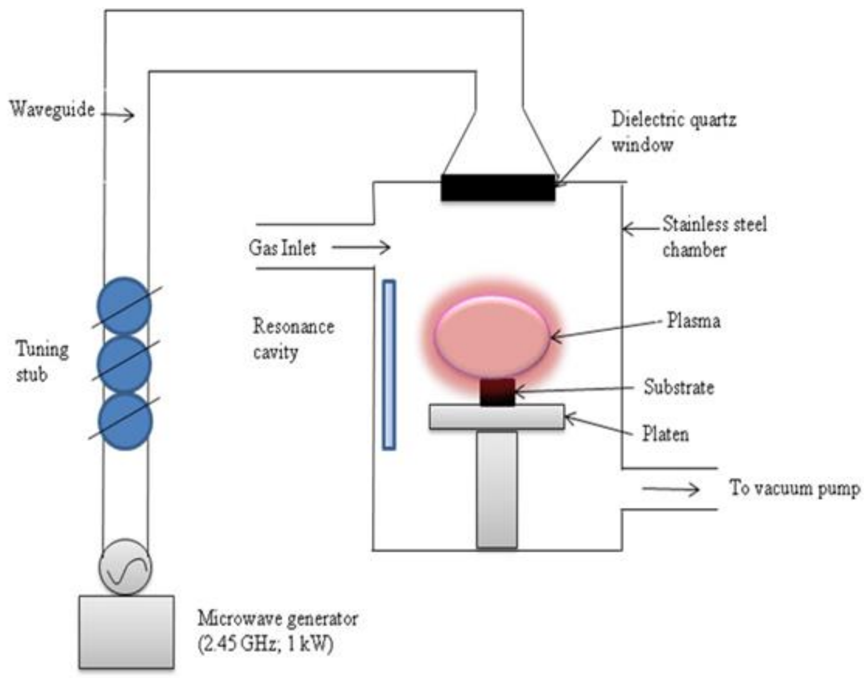

Figure 3.4 Microwave Generator

3.2 MECHANISM OF COLD PLASMA

- Cold plasma consists of reactive species of oxygen and nitrogen, UV radiations etc.
- At first there is a chemical interaction of radicals, reactive species and charged particles with cell membrane.
- Then the UV radiation causes damage to cell membranes and cellular components.
- Finally, DNA strands get broken by UV generated during recombination of plasma species.
- This helps to remove both bacteria and mold effectively and prevents enzymatic browning there by increasing the shelf life of the product [12]. The Figure 3.5 illustrates the image of mechanism of cold plasma.

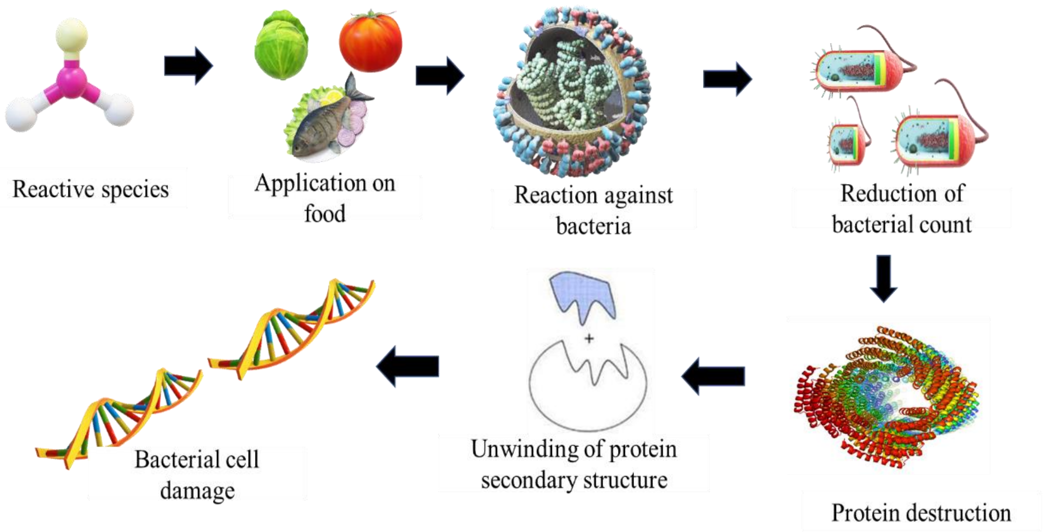

Figure 3.5 Mechanism of Cold Plasma

3.3 TYPES OF COLD PLASMA

Plasma is classified based on the following aspects; The Figure 3.6 below illustrates the types of plasma:

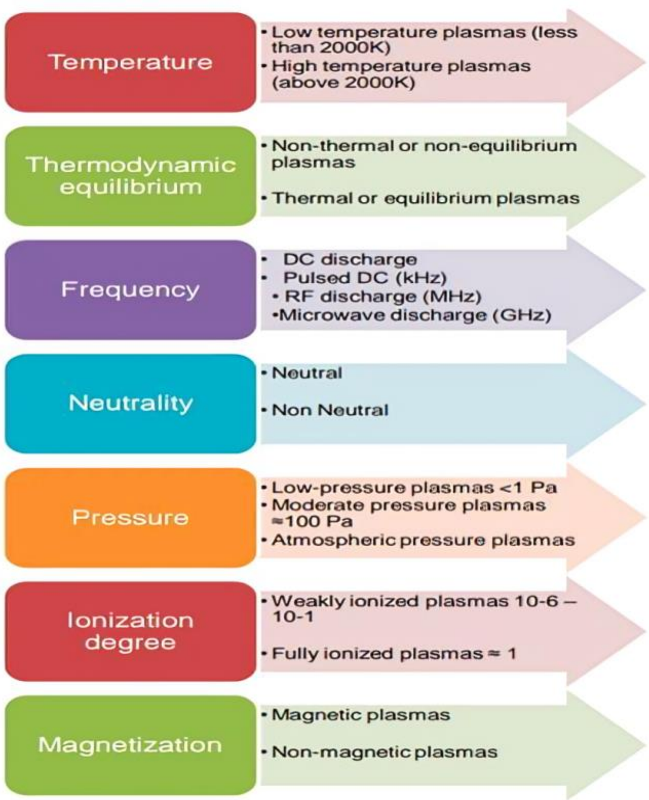

Figure 3.6 : Types of Cold Plasma [13]

CHAPTER 4

RESULT AND DISSCUSSION

4.1 APPLICATION OF COLD PLASMA TECHNOLOGY IN FOOD PROCESSING:

4.1.1 ALLERGEN DEGRADATION APPROACH

- New research has shown that non-thermal therapy can lessen food allergenicity.
- Thus, the CP can be used to reduce the allergenicity of foods that include common allergens such as wheat, fish, eggs, peanuts, tree nuts, soy, and milk.
- After being exposed to direct plasma therapy for five minutes, shrimp tropomyosin's allergenicity was lowered by up to 76%.
- Hence CP helps to develop hypoallergenic food products.
- It has been investigated the potential of eradicating numerous allergens by using cold plasma, including a-casein, b-lactoglobulin, a-lactalbumin, b-conglycinin, tropomyosin, glycinin, conglycinin etc.
- Studies states that the result of this non thermal method on the core allergens in soy protein isolate, b-conglycinin and glycinin[14].

4.1.2 MEAT AND POULTRY INDUSTRY

- Cold plasma is extremely effective in reducing microbial load on meat and poultry products, including destructive pathogens like *Salmonella, E. coli, and Listeria.*
- As an innovative curing agent, cold plasma exhibits promise in providing alternatives to conventional nitrite-based techniques. Some research suggests that cold plasma may have tenderizing effects on meat.
- Cold plasma may help preserve or enhance the red colour of meat[15].

4.1.3 ANTIMICROBIAL ACTIVITY

The Figure 4.1 depicts the Antimicrobial Activity of Cold Plasma.

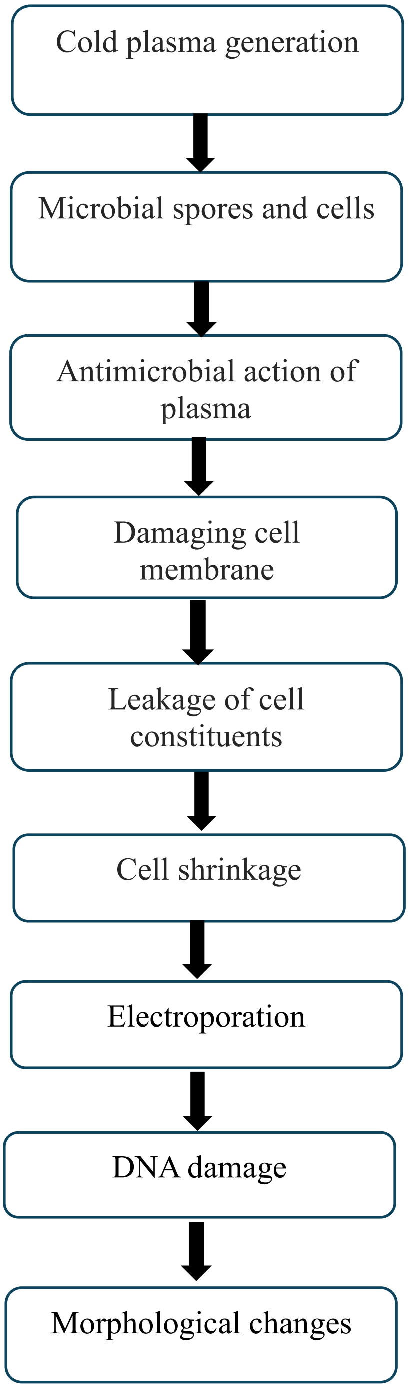

Figure 4.1 Antimicrobial Activity of Cold Plasma Technology [16]

4.1.4 FRUITS AND VEGETABLE INDUSTRY

- Cold plasma can be used to disinfect fruits and vegetables in place of chlorine and water treatment.
- Fruit firmness can improve the life span of fruits.
- It was demonstrated that CP therapy might increase the hardness of freshly sliced apples both immediately following treatment and six hours later. [17].
- It helps for preserving morphology of fruit.
- Also, CP offers an exclusive quiescent for the processing thermosensitive items due to its non- thermal characteristics.
- Similarly relevant to fruit surface sterilization and enzyme inactivation [3].

4.1.5 DAIRY INDUSTRY

- Cold plasma could be a substitute milk processing technique because it is less likely to affect the color, pH, flavor and nutritional value of the milk and milk products.
- Cold plasma can effectively eradicate pathogens like *E. coli, Listeria monocytogenes,* and *Staphylococcus aureus* in milk and dairy products.
- By tumbling microbial load, cold plasma can increase the shelf life of dairy products[18].

4.1.6 FOOD PACKAGING

The Figure 4.2 illustrates the Application of Cold Plasma in Food Packaging:

Figure 4.2 Application of Cold Plasma in Food Packaging [7]

4.2 ADVANTAGES OF COLD PLASMA TECHNOLOGY

The Figure 4.3 shows the Advantages of Cold Plasma Technology:

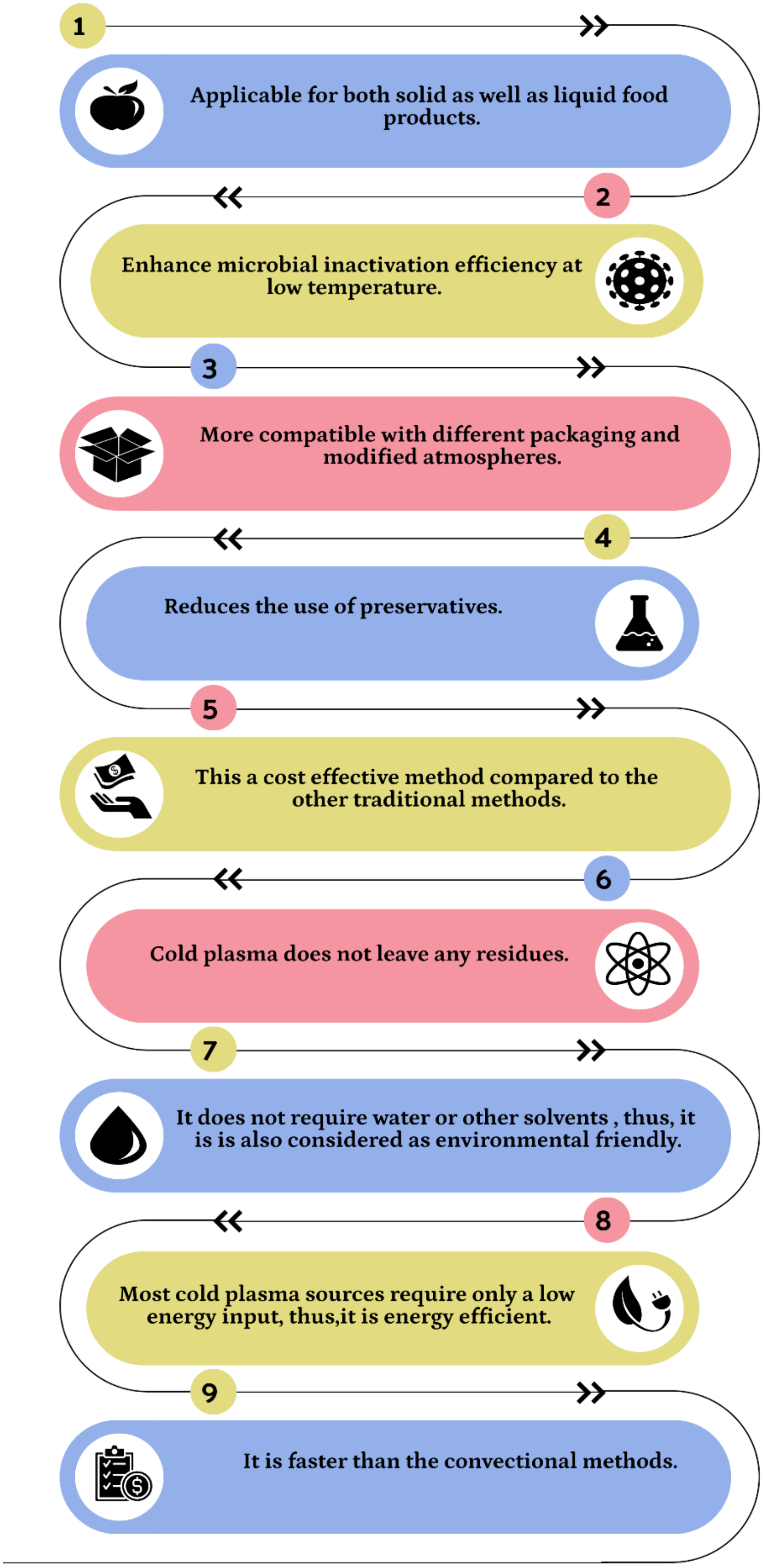

Figure 4.3 Advantages of Cold Plasma Technology [6]

4.3 LIMITATIONS OF COLD PLASMA TECHNOLOGY

- Since the plasma effect is a surface phenomenon, cold plasma is not employed to inactivate endogenous enzymes that are present throughout the entire fruit.
- High fat goods should not be processed using the cold plasma approach as it may cause lipid oxidation.
- This method also rises acidity, decreases colour and fruit firmness.
- The cost of the plasma processing is huge due to the use of noble gases.
- Treatment of bulky and irregularly designed food is problematic.
- Several ROS has incomplete penetration into food products. CP also entails additional safety measures as the process is carried out using very high voltages.
- It may affect the sensory and nutritional attributes of the food to some extent during the processing.
- Restricted volume and size of the food for treatment because microbial inactivation occurs on the food surface and thus reactive plasma species can only penetrates foods to limited extent[19].

CHAPTER 5
CASE STUDY

Case study title: **"Effect of atmospheric cold plasma treatment on structural, thermal, and mechanical properties of pea protein isolate edible films."** [20]

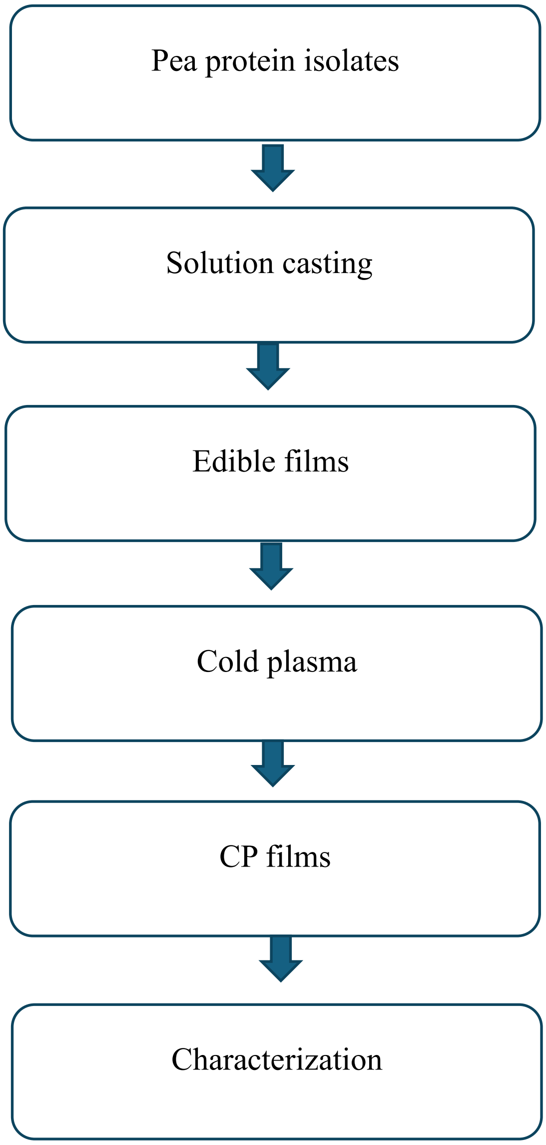

Figure 5.1 Flowchart of application of CP in pea protein isolates edible films.

- Based on the above study, it is found that cold plasma can improve the functional characteristics of food constituents. The Figure 5.1 illustrates the flowchart of application of cold plasma in pea protein isolates edible films.
- Cold plasma treatment of pea protein isolates results in certain compositional and structural alterations.
- These changes are related to deviations in surface hydrophobicity and have been experimentally demonstrated to affect the capacity of protein-rich pea flour to bind water and fat.
- Increasing the hydrophobicity will aid in enhancing the barrier qualities and quality of the films.
- It was observed to impede protein solubility and decrease protein aggregation.
- ACP can interrupt the secondary structure of proteins in the films, altering α-helices into β-sheets.
- This structural conversion can affect the mechanical properties and biodegradability of the films.
- ACP-treated PPI films often displays an improved tensile strength and elongation at the break compared to the untreated films.
- This indicates the modified mechanical performance and resistance to deformation.
- Additionally, the use of cold plasma technology will improve the films' thermal stability. [20].

CHAPTER 6

6.1 RECENT ADVANCES IN COLD PLASMA TECHNOLOGY

- Cold plasma technology has recently been expanded into hydrogenation of vegetable oils to produce trans - free edible oils.
- The application of CP technology in food processing includes functionality alteration of food components, enrichment of seed germination performance, improved physiochemical properties of grains and degradation of agrochemical deposits.
- This process can used to modify the surface properties of cereal grains. Atmospheric plasma pre-treatment of wheat straw followed by fermentation improved the ethanol yield by up to 52%[21].
- Plasma treatment can also encourage changes in the crystallinity and gelatinization of starch.
- Cold plasma oxidation technology has emerged as a promising technology for aqueous and gaseous pollutant removal.
- Plasma treatment can be used for averting fungal growth and further mycotoxin production.
- Cold plasma used as a pre-treatment tool for anaerobic digestion of food leftover.
- Cold plasma has also been employed for the processing of packaging materials in order to improve barrier properties and confer antimicrobial activity[22].

6.2 SAFETY CONCERNS

Novel non -thermal techniques such as cold plasma technology, is being developed at a great pace in response to consumer demands in order to provide them with fresh, convenient and quality products. Unlike traditional thermal techniques that provide limited benefits, cold plasma technologies have much more to offer. Due to deliberate changes made to the food or its environment, safety evaluation is not at all easy with active packaging. If cold plasma is not designed and used properly, it may cause negative impacts [23].

In spite of its advantages, the regulatory landscape for cold plasma technology is more multipart, requiring thorough safety assessments before the marketable applications. The variability in cold plasma technology methods like dielectric discharge barrier, plasma jet, corona discharge, etc provides the demands tailored safety evaluations for diverse applications in the food industry[10],[11].

However, the impact of cold plasma technology on food quality can differ based on the treatment constraints, demanding further research to found the standardized protocols. Also, the widespread implementation of cold plasma technology faces encounters, including regulatory hurdles and the need for comprehensive safety obligations to confirm the absence of the toxic by-products[24].

CHAPTER 7
FUTURE TRENDS

- Forthcoming trends point to an emphasis on optimizing the processing parameters, scaling applications, and assimilation of cold plasma with other preservation approaches[22].
- Understanding its mechanisms and probable toxicological effects is another range of research focused on safeguarding the safety and effectiveness in commercial applications[2].
- Evaluating the ability of cold plasma method on numerous food product processing as it is cost -effective as well as environmentally friendly method.
- Also, research focuses on developing plasma sources that particularly targets the harmful microorganisms without affecting the beneficial ones[3].
- Enhancing the storage life of food products is a globally faced challenge and cold plasma technology will show positive effects on it [6].The Figure 7.1 shows Future trends of cold plasma technology.

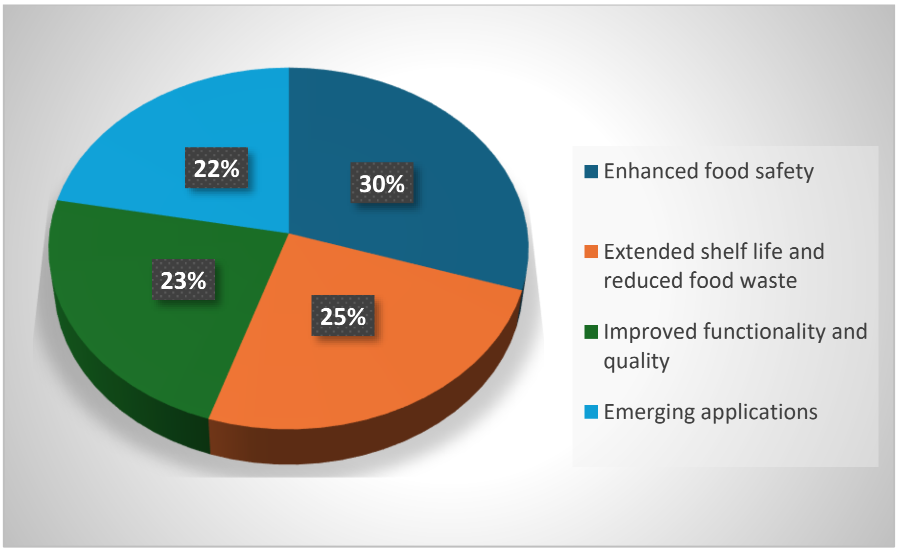

Figure 7.1 Future trends of cold plasma technology

CHAPTER 8
CONCLUSION

Cold plasma technology is novel, non-heat transferable, cost effective and environment-friendly method. It is extensively applied in the food processing sector. As it is an ultra-fast sterilization and preservation technique[25] .The rapid growth of microorganisms is the most problematic thing in front of the food processing industry so this technique is very vital in the deactivation of microorganisms in order to rise the storage life and offer high-quality food products[3]. Additionally, it aids in maintaining the microbiological purity of food by preventing physicochemical alterations. However, realizing the full potential of this technology requires addressing prevailing challenges. Compared to traditional thermal methods, cold plasma minimizes quality loss, retaining sensory attributes, nutrients, and overall product integrity[16].

Optimizing processing parameters for the exact food matrices, ensuring consistent results across changeable conditions, and scaling up applications while preserving cost-effectiveness are crucial areas for future research and development[2]. Several diverse cold plasma technologies have been developed, each with different advantages and disadvantages. The synergistic hurdle effect of CP with other emerging technologies, including nanotechnology, on food or food packaging materials could be further explored and applied more widely to assure food safety, in addition to the formerly published publications[13].

REFERENCE

[1] R. Thirumdas, C. Sarangapani, U.S. Annapure, Cold Plasma: A novel Non-Thermal Technology for Food Processing, Food Biophysics 10 (2015) 1–11. https://doi.org/10.1007/s11483-014-9382-z.

[2] Y. Ucar, Z. Ceylan, M. Durmus, O. Tomar, T. Cetinkaya, Application of cold plasma technology in the food industry and its combination with other emerging technologies, Trends in Food Science & Technology 114 (2021) 355–371. https://doi.org/10.1016/j.tifs.2021.06.004.

[3] F.-G. Chizoba Ekezie, D.-W. Sun, J.-H. Cheng, A review on recent advances in cold plasma technology for the food industry: Current applications and future trends, Trends in Food Science & Technology 69 (2017) 46–58. https://doi.org/10.1016/j.tifs.2017.08.007.

[4] V. C, M. M, A. Ga, Potential of Cold Plasma Technology in Ensuring the Safety of Foods and Agricultural Produce: A Review, Foods (Basel, Switzerland) 9 (2020). https://doi.org/10.3390/foods9101435.

[5] J. Akhtar, M. Abrha, K. Teklehaimanot, G. Gebrekirstos, Cold plasma technology: fundamentals and effect on quality of meat and its products, Food and Agricultural Immunology 33 (2022) 451–478. https://doi.org/10.1080/09540105.2022.2095987.

[6] R.P. Karkhanis, S.P. Singh, A Review: Application of Cold Plasma in Food Processing Industry, Journal of Scientific Research and Reports 30 (2024) 243–258. https://doi.org/10.9734/jsrr/2024/v30i31876.

[7] C. Karthik, R. Mavelil-Sam, S. Thomas, V. Thomas, Cold Plasma Technology Based Eco-Friendly Food Packaging Biomaterials, Polymers 16 (2024) 230. https://doi.org/10.3390/polym16020230.

[8] H. Turkoglu Sasmazel, M. Alazzawi, N. Kadim Abid Alsahib, Atmospheric Pressure Plasma Surface Treatment of Polymers and Influence on Cell Cultivation, Molecules 26 (2021) 1665. https://doi.org/10.3390/molecules26061665.

[9] F. Lisco, A. Shaw, A. Wright, J. Walls, F. Iza, Atmospheric-pressure plasma surface activation for solution processed photovoltaic devices, Solar Energy 146 (2017) 287–297. https://doi.org/10.1016/j.solener.2017.02.030.

[10] S. Wais, P. Mohammed, Influence of Magnetic Field on Characteristics of Corona Discharge in Wire-Cylinder Electrodes Configuration, Plasma 4 (2022) 764. https://doi.org/10.3390/plasma4040039.

[11] Microwave plasma emerging technologies for chemical processes - de la Fuente - 2017 - Journal of Chemical Technology & Biotechnology - Wiley Online Library, (n.d.). https://scijournals.onlinelibrary.wiley.com/doi/abs/10.1002/jctb.5205 (accessed September 18, 2024).

[12] U. Vaka, M. Ramkumar, Application of non-thermal plasma technology for enhancing food processing and storage: A Review, Food Chemistry Advances 5 (2024) 100788. https://doi.org/10.1016/j.focha.2024.100788.

[13] International Journal of Emerging trends in Engineering and Development Issue 2, Vol.4 (May 2012) ISSN 2249-6149, International Journal of Emerging Trends in Engineering and Development (2012).

[14] X. Dong, J. Wang, V. Raghavan, Critical reviews and recent advances of novel non-thermal processing techniques on the modification of food allergens, Critical Reviews in Food Science and Nutrition 61 (2021) 196–210. https://doi.org/10.1080/10408398.2020.1722942.

[15] J. Luo, W. Yan, M.M. Nasiru, H. Zhuang, G. Zhou, J. Zhang, Evaluation of physicochemical properties and volatile compounds of Chinese dried pork loin curing with plasma-treated water brine, Sci Rep 9 (2019) 13793. https://doi.org/10.1038/s41598-019-50351-5.

[16] A. Los, D. Ziuzina, S. Akkermans, D. Boehm, P.J. Cullen, J. Van Impe, P. Bourke, improving microbiological safety and quality characteristics of wheat and barley by high voltage atmospheric cold plasma closed processing, Food Research International 106 (2018). https://doi.org/10.1016/j.foodres.2018.01.009.

[17] S. Tappi, A. Berardinelli, L. Ragni, M. Dalla Rosa, A. Guarnieri, P. Rocculi, Atmospheric gas plasma treatment of fresh-cut apples, Innovative Food Science & Emerging Technologies 21 (2014) 114–122. https://doi.org/10.1016/j.ifset.2013.09.012.

[18] M. Korachi, F. Özen, N. Aslan, L. Vannini, E. Guerzoni, D. Gottardi, F. Ekinci, Biochemical changes to milk following treatment by a novel, cold atmospheric plasma system, International Dairy Journal 42 (2014). https://doi.org/10.1016/j.idairyj.2014.10.006.

[19] O.O. Olatunde, K.A. Shiekh, S. Benjakul, Pros and cons of cold plasma technology as an alternative non-thermal processing technology in seafood industry, Trends in Food Science & Technology 111 (2021) 617–627. https://doi.org/10.1016/j.tifs.2021.03.026.

[20] K. Gaikwad, Effect of atmospheric cold plasma treatment on structural, thermal, and mechanical properties of pea protein isolate edible films, Sustainable Chemistry and Pharmacy 37 (2023). https://doi.org/10.1016/j.scp.2023.101398.

[21] M. Nikzadfar, A. Kazemi, R. Abooei, R. Abbaszadeh, M.S. Firouz, A. Akbarnia, M. Rashvand, Application of Cold Plasma Technology on the Postharvest Preservation of In-Packaged Fresh Fruit and Vegetables: Recent Challenges and Development, Food Bioprocess Technol (2024). https://doi.org/10.1007/s11947-024-03380-6.

[22] C.J. Hernández-Torres, Y.K. Reyes-Acosta, M.L. Chávez-González, M.D. Dávila-Medina, D. Kumar Verma, J.L. Martínez-Hernández, R.I. Narro-Céspedes, C.N. Aguilar, Recent trends and technological development in plasma as an emerging and promising technology for food biosystems, Saudi Journal of Biological Sciences 29 (2022) 1957–1980. https://doi.org/10.1016/j.sjbs.2021.12.023.

[23] A.I. Muhammad, T. Ding, D. Liu, Safety Evaluation of Cold Plasma Technology, in: T. Ding, P.J. Cullen, W. Yan (Eds.), Applications of Cold Plasma in Food Safety, Springer, Singapore, 2022: pp. 341–349. https://doi.org/10.1007/978-981-16-1827-7_15.

[24] J. Bora, T. Khan, N.K. Mahnot, Cold Plasma Treatment Concerning Quality and Safety of Food: A Review, Current Research in Nutrition and Food Science Journal 10 (2022) 427–446.

[25] B.A. Niemira, Cold plasma decontamination of foods, Annu Rev Food Sci Technol 3 (2012) 125–142. https://doi.org/10.1146/annurev-food-022811-101132.