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Application of Cold Plasma Treatment in Food Processing

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SUMMARY

Cold plasma technology is an emerging food processing treatment which devises wide range of applications especially in various food processing sectors. Cold plasma is known to have greater effects towards the microbial decontamination of various food products to ensure the food safety and shelf life to consumers. Cold plasma uses several reactive gaseous species which are likely less ionized for the inactivation of microbe's present in meats, poultry, fruits, and vegetables. The beginning of the 21st century has witnessed a growing demand of secure and healthy foods. The food industry is adopting novel non-thermal food processing technologies. Cold plasma is one such promising non-thermal food processing method which uses charged, highly reactive gaseous molecules and species to inactivate contaminating microorganisms on foods and packaging materials.

INTRODUCTION

Food wastage is the major problem wide-reaching due to lack of farming practices and postharvest processing. Higher production and growth with the lack of handling practices lead to the huge food losses. Microbes and pathogens are the major constraint which causes food spoilage at altered times from farm to fork. Increasing alarm towards food safety among consumers, makes the food industries and regulation agencies to focus more on food quality factors which are responsible for spoilage. Hence, there is a vigorous effort taken towards the food safety consideration and it's led to a solution for using many non-thermal preservation techniques in place of thermal food preservation techniques.

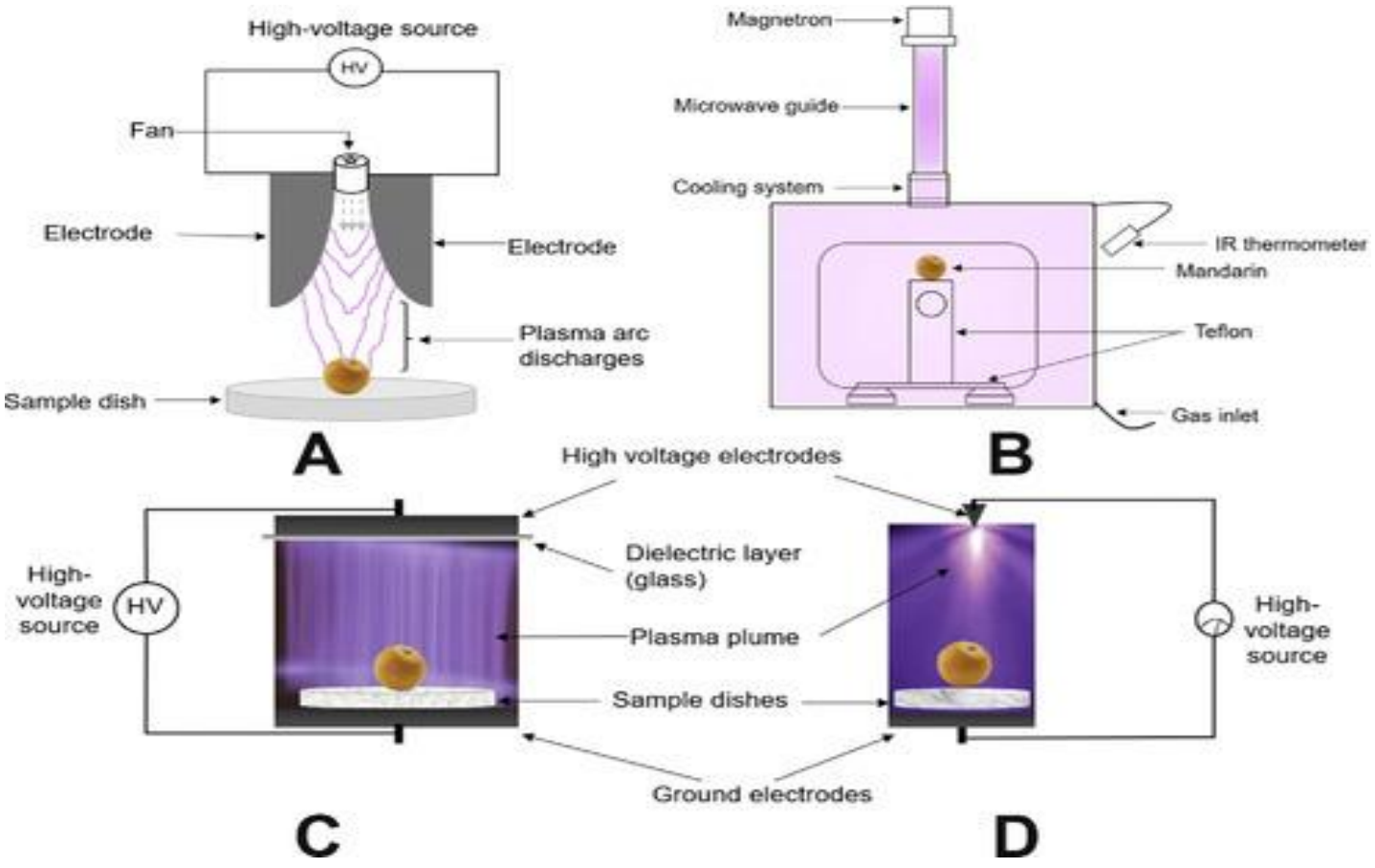

Fig 1. Effects of Non-thermal Plasma Technology on functional food components

Cold plasma technology is an emerging non-thermal food processing treatment which has wide range of applications in food sectors particularly in decontamination off. The term plasma is the Greek word (meaning "moldable substances") was first described by the chemist Irving Langmuir in 1920's. Over the years plasma found its usage in electronics and polymer industries for the surface alteration of various polymers. However this technology attracted persistent attention of many researchers and food industries for its application in food sector. CPT (Cold Plasma Technique) is found to be a powerful technique for the decontamination of food products including sporulating and pathogenic organisms. Plasma can be explained as the fourth state of matter after solids, liquids, and gases. When a material is subject to continuous energy, its state changes from solid to liquid and further to gas. When the gas is subjected to further energy, the gas gets ionized and forms free electrons and ions breaking away from their orbital. This resultant state called plasma has very high temperatures and often needs vacuum. The Sun, Lightening during rain is some examples of natural plasmas. Cold plasma is generated when the gas is partially ionized at atmospheric pressure or low-level vacuum. The resultant cold plasma consists of free electrons, ions, UV radiation, and reactive chemical species like O_3, NO, NO_2, etc.

Principle and mechanism of Cold Plasma Treatment:

Plasma sterilization effect was first documented and patented in the year 1968 by Menashi. When the food surface contaminants are exposed to reactive species produced by plasma there will be an accumulation of electrostatic forces at place where the high energy flows. The energy flow further induces radical bombardment action and hence cell lysis occurs. The impact of radical bombardment causes the lesions on the surface makes the microbial cell weak to repair quickly which results in cell destruction. This phenomenon is termed as "plasma etching". Plasma etching causes DNA and chemical bonds denaturation, thus produces an antimicrobial effect on the cell.

Factors affecting plasma treatment

- Power level to generate the plasma
- Gaseous mixture and Intensity of gases species
- Length of exposure
- Flow rate, Pressure and design of the system
- Other factors - Relative humidity, pH and Nature

Applications of cold plasma treatment:

Cold plasma technology shows promising dimensions for various sectors of food processing. It includes

1. Grain science and processing sector

Food grains and legumes were investigated for *Aspergillus spp*. and *Penicillum spp.* before and after treatment with plasma products showed significant log reduction after exposure for 15min; depending upon the method of generation, treatment time and type of starch present in the food grains. Cold plasma species are able to alter the starch properties. Cold plasma reactive species acts on food grains and causes surface modification, molecular degradation/granular etching or corrosion. Application of cold plasma was effectively studied on various food grain starches such as rice starch, zein, pea protein isolates, brown rice and basmati rice to improve its functional properties by surface and molecular modification of starch. CP (Cold plasma) helps in improving the swelling capacity, decreasing the cooking temperature, pasting viscosity, water solubility and water holding capability of food grains. When oxygen containing cold plasma is used for food rich in fats; it may induce lipid oxidation and reduce the acceptability.

2. Food packaging

Originally cold plasma technology was employed for improving the surface modification and printability for packaging materials. Currently, CP treatments are utilized for the food packaging and bio-films treatments to enhance its antimicrobial and mechanical properties. It is proved that when plasma products acts on food packages

it causes the surface functional group activation/addition or surface energies production to make positive impact on the various packaging properties include glazing, sealability, moisture/gas barrier property etc. It is considered to be reliable and cost effective technology. Recently cold plasma was utilized for in package processing to avoid the post packaging contamination.

3. Meat and Egg processing sector

In meat sector, CP application was reported on beef, pork and chicken meat quality, microbial decontamination and shelf life extension. The result states that the cold plasma species are effective against *E. coli*, *salmonella* species, *L.monocytogenes*, yeast and mold species on meat surface. CP decreases the immobilization of water in protein myofibrillar network and changes its functional properties of packed meat. CP technology application is found to have positive effects on surface decontamination of egg shell membrane against *S. enteritidis* and *S. typhimurium* microorganism.

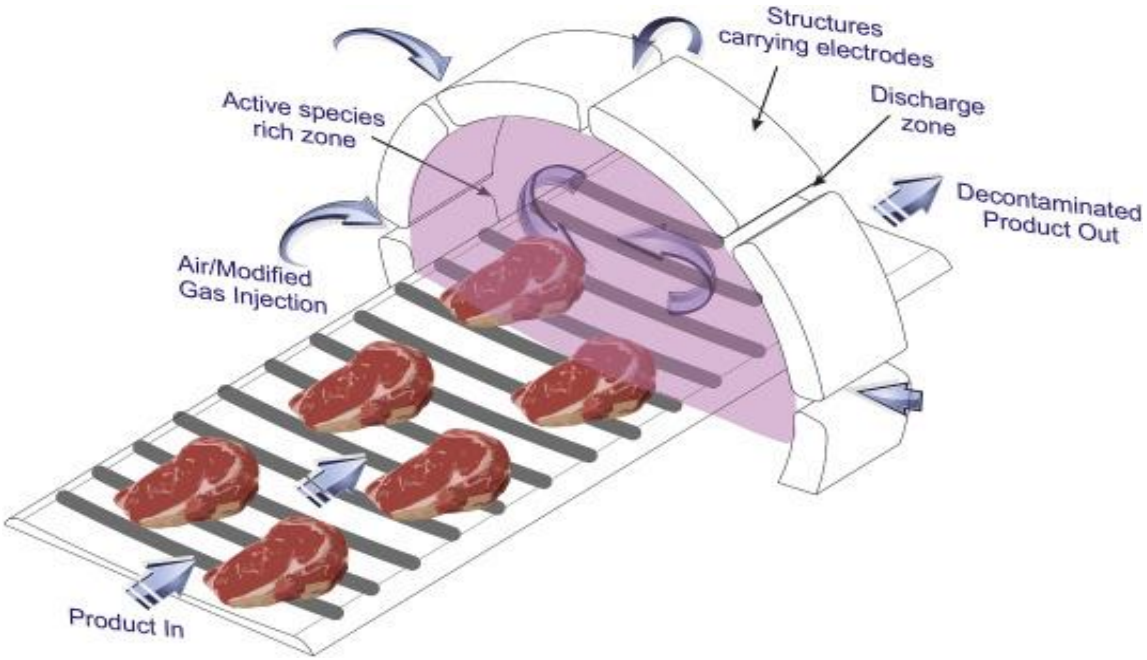

Fig 2. Cold Plasma technology application on Meat

4. Dairy processing sector

The cold plasma has tested on various milk products including whole milk, skim milk, UHT (Ultra High Temperature) milk and sliced cheese. The results of the study forecasted that cold plasma could be an alternative milk processing techniques because it is less likely affected the color, pH, flavor and nutritional value of the milk products. Plasma application on milk and milk products could probably be an effective technique in enhancing their shelf life and keeping quality.

5. Fruits and vegetable processing sector (F&V)

Cold plasma treatment is said to be an original technique since its replaces chlorine and water for decontamination of several fruits and vegetables. Cold plasma treatments on fruits and vegetable products includes like berries, cherries, apple, melon, kiwi etc. were studied. Results proclaim that CP treatments on the surface of fruits & vegetables alter the pH and acidity of the food produce. This change occurs when active species of plasma reacts with moisture on the surface. It is also found that the treated produce shows slight changes in texture (firmness) and color during their storage period.

6. Waste water (Effluent) treatment

Waste water disposal is now being a major issue faced by food industry since water coming out of food industry is with high concentration of organic loads. So far various thermal, chemical and filtration techniques are used for waste water treatments. ROS (Reactive Oxygen Species) of cold plasma have been reported to cause prompt changes in the degradation or decomposition of liquid waste.

7. **Agriculture sector**

Agrochemical residues are identified to cause much human health disorder as they contain potentially toxic elements discharged during cultivation and processing.

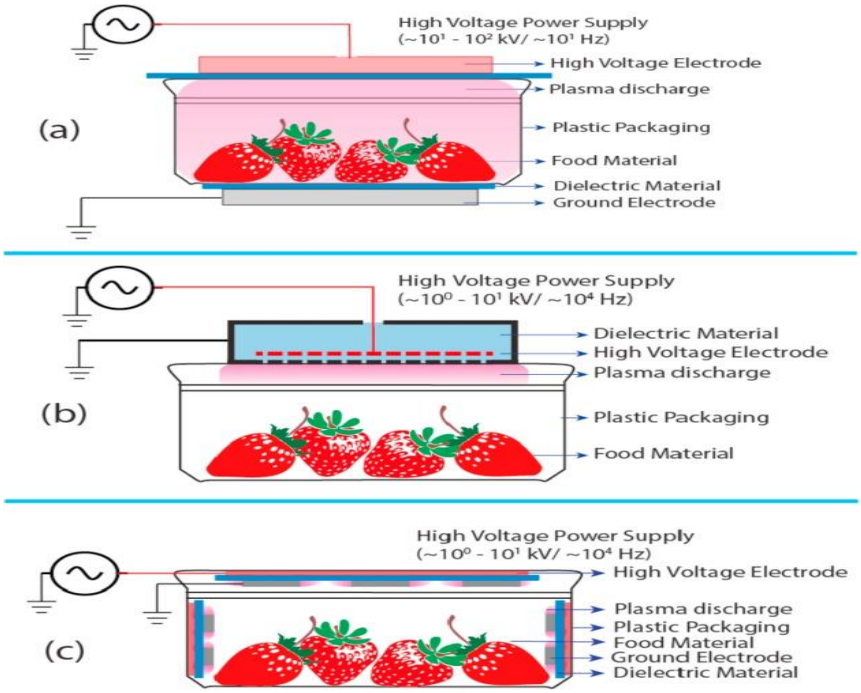

Fig 2. Package treatment for pesticides residues present in strawberries

CP treatments are considered to be effective against the agrochemical residues like pesticides, insecticides etc., found on food materials which are applied to control crop infestation and weeds. In package treatment were done for pesticides residues present in water and strawberries with DBD plasma discharge for 5-8min. Results showed that the high dense pesticide compounds were degraded in to smaller chemical compounds possess less toxicity than parental compounds. Seed germination is enhanced when treated with plasma and found to increase water imbibitions capacity of seeds and reduction in the microbial growth.

Advantages:

- Microbial inactivation efficiency can be achieved at low temperature.
- Suitable for treating sensitive raw and fresh food products.
- Requires less power input for operation.
- Doesn't alter or damage the key food nutrients.
- Reduces the risk caused by thermal and chemicals processing of food materials.
- Reduces water usage and solvent system for processing.
- Don't alter the sensory and nutritional properties of food materials.
- Plasma is environmentally safe
- Equipment cost is low, when least cost noble gases are used for processing

Limitations:

- Treatment of bulky and irregularly shaped food is difficult.
- Restricted volume and size of the food for treatment.
- Several ROS species has limited penetration into food products.
- It may affect the sensory and nutritional attributes of the food.
- It may accelerate lipid oxidation and causes negative impact.

Future Aspect:

In the current days, application of cold plasma technology is reported to be used for various food products decontamination. However, CP treatment is not commercially used in the food industry, since the current research is majorly concerned on the plasma properties and processing on various food products. The regulatory aspects of CP treatment should be covered to ensure the health of food supplies. The effect of cold plasma on nutritional and sensory attributes has to be addressed to commercialize this technology. CP could be a breakthrough technology for future food preservation. Although recent results are promising, continued research and development efforts are needed for cold plasma to move toward commercialization. Some key areas include determination of modes of action; optimization of gas mixtures to balance power consumption, antimicrobial efficacy, and feed gas cost; and improving speed, efficacy, and compatibility with existing food handling and packaging systems. Parallel research tracks will see the development of cold plasma systems intended to sanitize packaging materials and in areas where sanitizer-resistant pathogen bio-films form, such as food contact surfaces, drains, and conveyor belts. With these developments on the horizon, cold plasma is positioned to be a flexible, effective sanitizing process for the food processing industry in the near future.

CONCLUSION

Safe food requirement being the current demand by consumer necessitates food scientists and researchers of the food industries to focus on enhancing the food quality and shelf stability through various novel technologies. Cold plasma technology is gaining interest among researchers and scientists because of its uniqueness among other thermal and non-thermal treatments includes operation under low temperature for short time period and food quality integration. In that aspect, cold plasma can be versatile technology with great potential to benefit the areas of food industry.

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