JOURNAL
OF HALAL QUALITY AND CERTIFICATION

HALAL HYGIENE AND SANITATION

Tharwat Mamdouh Al-Bataineh[1] & Daryl DeJean[2]

[1]Food Regulatory, Specialist Food Safety and Halal Regulations; Ministry of Climate Change & Environment, United Arab Emirates. Dubai Al Ruwayyah 2 Area Beside Zayed University, Dubai – AlAin Road, Dubai
[2]Daryl DeJean | VP Product Development – PathogenFocus – USA -North Carolina

Corresponding author: Dr Tharwat Mamdouh Al-Bataineh
E-mail address: dr_thrwat@yahoo.com

Professional paper

ABSTRACT

Today, due to advances in non-thermal plasma (NTP) or atmospheric cold plasma (ACP), the halal industry can experience significant improvement in its standard operating procedures for air, surface and water disinfection and decontamination.

Providing a continuous, pervasive, stable and consistent level of biosecurity further ensures the prevention and reduction of harmful volatile organic compounds and microbes throughout the food supply chain. Proven against the most common food safety issues, from slaughter to processing, packaging and transportation, your halal food products can now experience the best possible disinfection and hygiene. These activities will contribute directly to the achievement of the strategic objective of food biosecurity, which aims to enable inclusive and efficient agri-food systems and is consistent with the Halal Regulation in specific aspects. This occurs through an organizational output: international standards, agreements and voluntary policies formulated to improve countries' access to and functioning of international markets. Through the issue, new and revised international standards and new technical procedures for food safety, quality and phytosanitary health are formulated and agreed by countries, serving as a reference for international harmonization.

The use of NTP or ACP improves all processes through its ability to quickly neutralize microbes, affect the actual product in the process, improve indoor air quality, provide plasma activated water and neutralize microbes that can affect the quality of the product. The latest area of research from the United States Department of Agriculture (USDA) is the use of NTP or ACP to improve the shelf life of produce. Due to the organic nature of the disinfectant produced in the plasma chamber, it was determined that the product does not undergo any physical or nutritional changes that can occur with irradiation. Non-thermal plasma (NTP) technology provides an innovative and effective dry surface cleaning method that offers several advantages over traditional wet cleaning techniques and also offers a unique and effective method for treating water, particularly in the contexts of disinfection and pollutant degradation. So NTSP helps in maintaining rigorous hygiene standards required in the halal food industry. During this session, you will learn how is Non-thermal plasma (NTP) technology is increasingly recognized for its potential in biosecurity applications due to its ability to inactivate a broad range of pathogens and about the extensive benefits and ongoing developments and improvements that USDA says are possible for using non-thermal plasma or cold atmospheric plasma to integrate this technology into halal food products.

Keywords: *Hygiene, Halal, Non-thermal plasma, Atmospheric cold plasma.*

Introduction

This paper was written as a business paper to provide insight into how non-thermal or atmospheric cold plasma has played and can continue to play a critical role in the future of not only halal but in food safety throughout the entire food supply chain. The research papers used to develop this paper are cited after the conclusion.

Food is not only an essential source of nourishment but also a source of pleasure, especially when it comes to meat. Meat contains several essential nutrients, including proteins, lipids, vitamins, and minerals (Biesalski, 2005). Several factors can influence meat quality during processing and storage and controlling these factors is important in the meat industry in order to ensure optimal quality and consumer satisfaction.

Of Ensuring food safety has been and remains a key objective for governments and policymakers, food industry, and researchers worldwide.

Nevertheless, new challenges may be posed by, inter alia, the increasing complexity of food supplies, accelerating climate change, intensifying international food trade, new food sources and technologies, circular economy, and sprawling urban agriculture. (Food and Agriculture Organization [FAO], 2022).

The most important aspect of any food safety program's standard operating procedure (SOP) and stringent hazard analysis and critical control point (HACCP) is rooted in proper hygiene and sanitation practices. For the purpose of this paper these two definitions apply:

1. Hygiene is defined as the practice of keeping yourself and your surroundings clean, especially in order to prevent illness or the spread of diseases.
2. Sanitation is the process of keeping places free from dirt, infection, disease, etc., by removing waste, trash and garbage, by cleaning food production spaces, etc.

Concentrating on safety, security, and sustainability is part and parcel of the EU's current pathogen management strategy, which has been summarized by May 2020 strategy paper From Farm to fork.

Currently, many efforts have been made to develop more effective halal-authentication detection systems.

Without the proper combination of hygiene and sanitation diseases can spread throughout the food chain. This paper will focus on the boxed area of the below diagram. By properly utilizing a proven non-thermal plasma (NTP) or atmospheric cold plasma (ACP) disinfection biosecurity solution we can successfully address the stringent hygiene and sanitation required in halal foods production. Implementing this technology throughout the food chain it is possible to reduce the potential for cross contamination from disease and other unwanted bioburden, volatile organic compounds (VOCs) and microbials.

Why the focus on non-thermal plasma over the years?

- Different temperatures can be achieved for different plasma species, mostly around room temperature.
- Uses energy more efficiently at low temperatures to gain better chemical selectivity/reactivity
- The electron temperature governs ionization and chemical processes
- Metastable state with a roughly zero net electrical charge.
- Only nonthermal plasma is applied to food products.

Mode of Action of Cold Plasma:

Plasma, which has been described as the fourth state of matter, is partially or fully ionized gas composed of positive and negative ions, electrons, free radicals, and neutral particles (Nehra et al., 2008). It is generated by applying an electric current across neutral gases, which results in the dissociation of the gaseous molecules (Conrads and Schmidt, 2000; Nehra et al., 2008). Plasma can be divided into two types based on temperature: high temperature plasma and low temperature plasma.

- High temperature plasma exists in a thermal equilibrium state in the range of 10 to 10 K (Nehra et al., 2008).
- Low temperature plasma can be further divided into thermal or nonthermal plasma. Thermal plasma exists in a local thermal equilibrium state with temperatures ranging from 4000 to 20,000 K (Bogaerts et al., 2002; Schluter et al., 2013).
- Non-thermal plasma, also known as cold plasma, exists in a non-equilibrium state with a temperature range of 300 to 1000 K (Nehra et al., 2008). High temperature and thermal plasmas are not suitable for use on heat sensitive foods because the heat transfer from the plasma to the food causes deterioration in the food's quality. Therefore, non-thermal plasma methods of pasteurization are of considerable interest to the meat industry. (1)

Intertwining of Halal and Tayyib

A balanced relationship between halal and food safety (Tayyib) control adds value in the food chain and improves confidence among Muslim consumers and those with various religious backgrounds. In addition, the advance of globalization and new processing technologies, new distribution strategies, new challenges and

new risks, different ingredients and preparation methods have exposed Muslims to uncertainty in identifying halal or haram due to ambiguity (Zunira Talib et al., 2010).

Maintaining high standards of hygiene and sanitation is crucial in Halal food production to ensure that the food not only meets religious compliance but is also safe and wholesome for consumption. Halal hygiene and sanitation practices encompass various aspects of food handling, processing, and storing, aligning with the principles of both **Halal** (lawful) and **Tayyib** (pure and wholesome).

Key *objectives* for compliance to providing halal food products include:

1. *Control of cross contamination* between halal and no-halal foods but more importantly of impure substances such as *bioburden including microbials such as viruses, bacteria, molds and fungi.*
2. Use *Halal certified* ingredients, *cleaning agents and processing equipment* used throughout the food supply chain.
3. Avoid the use of *chemicals and pesticides.*
4. Halal slaughtering methods are conducted in a manner prescribed by Islamic law, which includes reciting the name of God at the time of slaughter, *ensuring the animal is healthy* at the time of the slaughter.
5. Properly address any potential of *microbial contamination* from waste disposal.
6. Use of *pure, safe water* in the processes and packaging.

The focus of halal is determining what is permitted. While certain aspects of ensuring halal are clearly stated, the process for ensuring halal environments can be improved. Incorporating tayyib into all halal food production facilities will only enhance the efforts in providing the permitted foods. Tayyib will create a more intense focus on hygiene, sanitation and disinfection throughout the food chain, ensuring the food is not only permissible but also beneficial for health and well-being.

The intertwining of halal and tayyib changes the market appeal of halal/tayyib produced foods. By producing food in a more ethic and environmentally friendly method, it sends a powerful message possibly commanding more widespread use of halal/ tayyib foods. Therefore, the products could demand a higher market value.

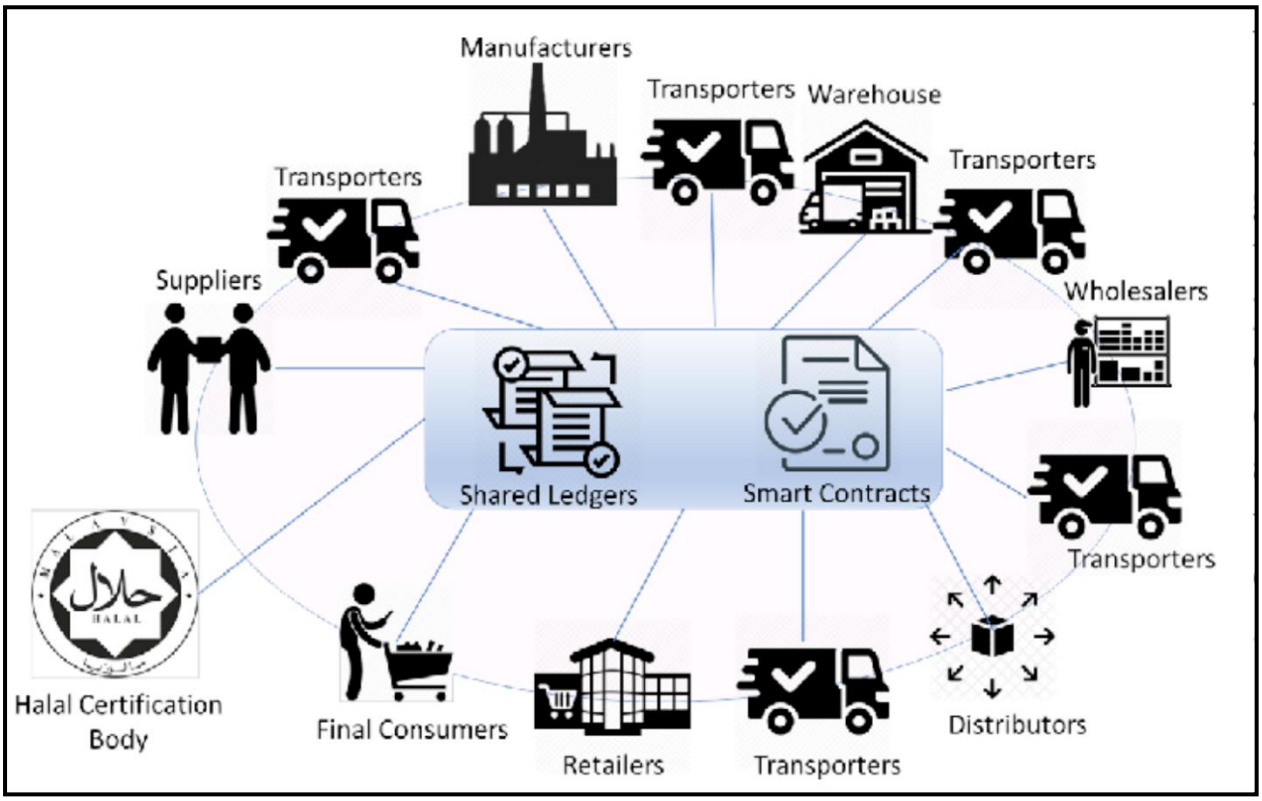


Figure 1. Introducing Non-Thermal Plasma or Atmospheric Cold Plasma into Halal/Tayyib

Non-thermal plasma (NTP) technology is increasingly recognized for its potential in biosecurity applications due to its ability to inactivate a broad range of pathogens, including bacteria, viruses, fungi, and spores, without the use of chemicals. Non-thermal plasma can be employed in halal food production facilities to enhance biosecurity measures in various settings. NTP can be used to sanitize livestock environments and equipment, reducing the risk of disease transmission among animals. (6) For instance, treating air or surfaces in barns and poultry houses can help in managing outbreaks of diseases like avian influenza or swine fever. In crop production, NTP can treat seeds or plants to eliminate surface pathogens, reducing the spread of plant diseases without chemical pesticides. (10)

NTP is effective in reducing microbial contamination on both food products and packaging materials, enhancing food safety and extending shelf life without altering the food's quality or nutritional value. (2)

Non-thermal plasma can be used to treat water, effectively destroying pathogens and degrading pollutants, making it a valuable tool for securing safe drinking water supplies and managing wastewater. (12)

NTP systems can inactivate airborne pathogens and reduce the spread of diseases in enclosed spaces like buildings, public transport, and aircraft.

Non-Thermal Plasma (NTP) technology addresses all the objectives for compliance to providing halal food products. By promoting tayyib, NTP may be the best economic solution that properly provides the needed approach for the intertwining of halala and tayyiba. As a result, from farm to fork, from crop to cup will have an increased level of purity and safety to promote high quality and healthy food products globally.

Non–Thermal Plasma Enhances SOP and HACCP

Advances in non-thermal plasma (NTP) technology could indeed bring substantial improvements to the halal industry, especially in enhancing standard operating procedures (SOP) and hazard analysis and critical control point (HACCP) to include tayyib process for disinfection and decontamination of air, surfaces, and water. NTP can contribute to your SOP and HACCP in several key ways.

Applying NTP at specific stages, such as post-harvest or pre-packaging, can be designated as

critical control points. This is where intervention is crucial to prevent microbial contamination. Various reactive species enables it to effectively inactivate airborne pathogens, including bacteria, viruses, and fungi. These agents damage microbial DNA and cellular structures, leading to the inactivation of these pathogens. NTP can influence the size distribution and concentration of aerosols in the air. NTP can also neutralize allergens and other irritants in the air. The reactive species can break down allergenic proteins or render them non-allergenic, thus improving air comfort and healthiness. The same reactive species also have strong antimicrobial properties, capable of killing bacteria, viruses, and fungi on surfaces, which is especially useful for hygiene-critical environments like hospitals, food processing facilities, and cleanrooms. (13)

Non-thermal plasma (NTP) technology provides an innovative and effective dry surface cleaning method that offers several advantages over traditional wet cleaning techniques. NTP cleaning is particularly valuable for applications where the use of liquids is undesirable or where minimal residue and low environmental impact are priorities. NTP technologies are known for their ability to effectively eliminate microbes and pathogens in air and on surfaces without the need for high temperatures or harsh chemicals. This is particularly useful in the halal industry, with tayyib principles maintaining cleanliness and purity is essential.

These technologies do not rely on chemical disinfectants, which aligns well with halal and tayyib principles that emphasize safety and natural processes. NTP is considered a more "organic" or natural approach to various applications compared to processes that involve harsh chemicals or additives. This can help in preventing chemical residues in the air, on surfaces and in water, which is crucial for processes where purity is paramount, such as in food production or water purification. Non-thermal plasma (NTP) achieves the complete dissociation of molecules through its unique physical properties and mechanisms. The dissociation processes in NTP generate a variety of reactive species, including radicals (e.g., hydroxyl radicals, superoxide), which are highly reactive and can further interact with and break down other molecules breaking chemical bonds. The result is the dissociation of molecules into atoms or simpler molecules. Therefore, no harmful by-products are created due to complete dissociation.

Effectiveness in managing insect populations stems from its ability to generate reactive species and highly charged molecules, which can directly impact insects at various life stages. These agents can cause direct physical damage to the insects' bodies, disrupt their respiratory systems, or induce oxidative stress that damages cellular components. NTP can be used to protect crops from insect pests without the use of chemical pesticides. NTP can be employed in storage facilities and processing plants to control insects that contribute to food spoilage and contamination, such as weevils, moths, and beetles. (8) The effects of NTP on insects are immediate, which is beneficial for rapidly addressing severe infestations. NTP does not leave harmful residues that could contaminate crops, water, or affect non-target wildlife, making it safer than traditional chemical treatments. (3)

The application of these plasma technologies in food preservation could also benefit the halal industry by extending the shelf life of perishable products without the use of chemical preservatives, thus maintaining the natural quality of the food adhering to halal and tayyib (wholesomeness) principles. (7) By reducing the microbial load on fresh produce and packaged goods, NTP can extend the shelf life of these products. Longer shelf life is particularly beneficial in reducing food waste and enhancing the economic viability of transporting and storing halal food products over long distances. The use of NTP may provide the solution required by a new standard for the export and import of food products to demonstrate its purity. (5)

NTP can also be used to sterilize packaging materials used for halal foods. NTP effectively reduces surface pathogens on food products and packaging. This application ensures that the packaging does not become a source of contamination. Sterilizing packaging with NTP enhances food safety and quality, supporting compliance with both halal standards and global food safety regulations.

Non-thermal plasma (NTP) offers a unique and effective method for treating water, particularly in the contexts of disinfection and pollutant degradation. Its ability to generate a mix of reactive species without significantly increasing

water temperature makes it suitable for various applications. Using NTP to treat water used in the food processing industry ensures that it is free from harmful microorganisms and chemicals. This application ensures that the water used in the preparation, processing and wash downs of halal food processing facilities meet the highest standards of purity, crucial for washing and preparing foods according to halal regulations.

Chill water plants, essential components in centralized air conditioning systems for large buildings, require constant maintenance to ensure efficiency and prevent issues like microbial growth and scaling in the water circuits. Chill water systems can suffer from the growth of biofilms on heat exchanger surfaces and within piping. Biofilms reduce system efficiency by impairing heat transfer and can contribute to corrosion and clogging of pipes. NTP can effectively control biofilm formation and reduce microbial populations in the water.

The reactive species generated by NTP, such as ozone, reactive oxygen, and nitrogen species, have potent antimicrobial properties that disrupt biofilm matrices and kill the microorganisms they contain. Traditional water treatment methods often involve chemicals that can be harmful to the environment and may require careful handling. NTP can be used to purify and treat the water without the addition of chemical disinfectants. This treatment can reduce the concentrations of harmful pathogens, degrade organic contaminants, and even control the levels of certain chemicals. Corrosion and scaling are significant issues in chill water systems, leading to reduced efficiency and the potential need for costly repairs and downtime.

By improving water quality and reducing microbial content, NTP can indirectly help minimize conditions that lead to corrosion and scaling. Cleaner water means less scaling and reduced corrosion rates on metal surfaces. NTP offers an environmentally friendly alternative to chemical treatments. It reduces the need for chemical use in chill water systems, decreasing the environmental impact associated with chemical storage, handling, disposal, and potential spills. By treating the chill water system with NTP it prevents pathogens form being transmitted wherever the chill water system may aerosolize droplets. As a result, you can help reduce the likelihood of diseases such as legionella.

NTP can be used to remove odors from food products without chemical additives. This is especially useful in meat processing and spice treatment. Removing odors while maintaining the natural flavor and compliance with halal standards enhances the consumer acceptability of food products. The reactive species produced by NTP are also effective in neutralizing odors. They can chemically alter the structure of odor-causing molecules, rendering them odorless. NTP can break down VOCs without creating any byproducts due to complete dissociation. The result of the dissociation of a VOC is H, O and molecular C. Effective on formaldehyde, ethylene (rapid ripening agent for some produce), ammonia, and other contaminants of concern as per ASHRAE. (4)

It's essential that the use of NTP in halal food processing is recognized and certified by halal certification bodies. Compliance with both technical and religious standards must be ensured.

By incorporating NTP into halal food production, businesses can leverage advanced technology to support sustainability, enhance product safety and quality while adhering to strict halal principles. This integration not only aligns with Islamic dietary laws but also addresses broader consumer demands for ethical and safe food practices.

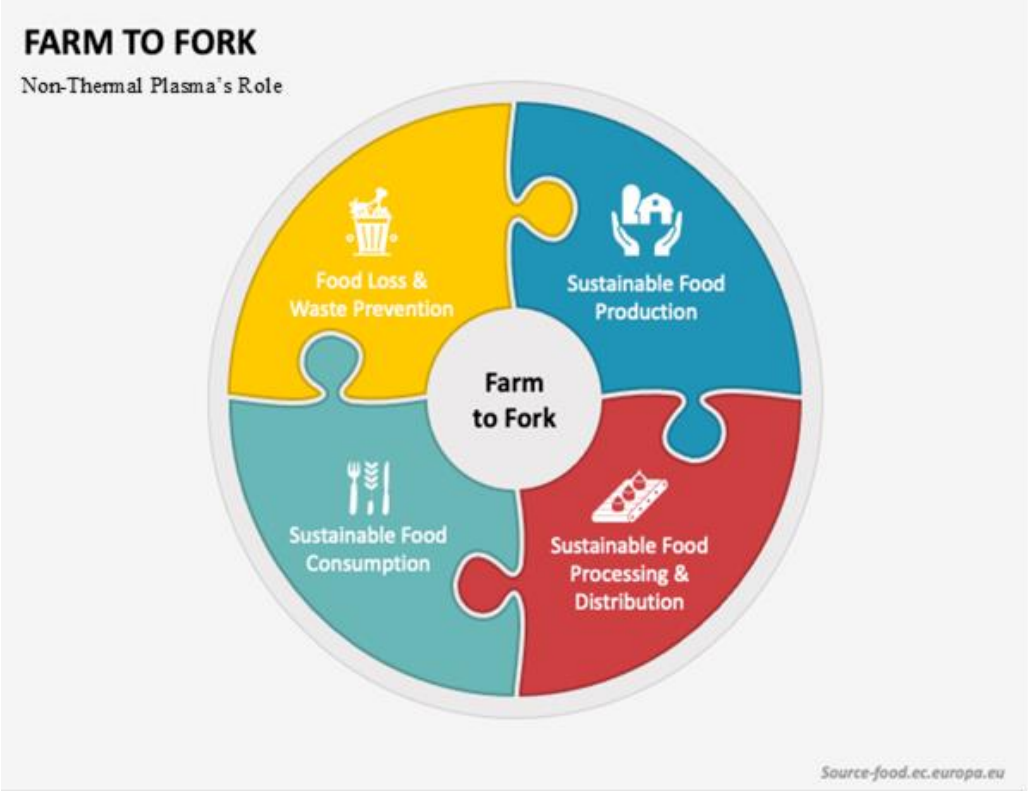


Figure 2. The Benefits of Non-Thermal Plasma Throughout the Halal Food Chain

The implementation of non-thermal plasma sterilization processes (NTSP) throughout the entire halal food production chain from slaughter to processing, packaging, and transportation—can significantly enhance food safety and hygiene. This technology's integration supports strategic objectives in food biosecurity, which are crucial for creating inclusive and efficient agri-food systems. Here's how NTSP aligns with these goals and halal regulations fulfilling many aspects of halal requirements.

NTSP effectively addresses common food safety issues by eliminating pathogens and reducing spoilage organisms at every step of the food supply chain. Its ability to maintain a high level of disinfection continuously ensures that halal food products are protected against contamination throughout their journey from farm to table.

By providing a stable and consistent disinfection method, NTSP helps in maintaining rigorous hygiene standards required in the halal food industry. This adherence to cleanliness is a critical component of halal regulations, which emphasize the need for purity and sanitation in all aspects of food handling and processing.

NTSP's chemical-free and efficient decontamination process aligns well with halal principles, which prohibit the use of substances harmful to human health and require that all processing and handling methods preserve the integrity and wholesomeness of food. By ensuring that no toxic residues contaminate the food products, NTSP supports the stringent compliance requirements of halal certification. (9)

The implementation of NTSP can lead to safer food supply chains, reducing foodborne illnesses and increasing the overall quality of food products. This contributes to more inclusive agri-food systems by enhancing consumer trust and accessibility to safe, high-quality halal food products, thus supporting food security and public health.

NTSP's role in ensuring continuous and effective disinfection directly contributes to the strategic objective of food biosecurity, which is to prevent, control, and mitigate risks to food safety from farm to fork. By enabling safer and more efficient food handling and processing practices, NTSP helps in achieving these objectives. (9)

Overall, the adoption of NTSP in the halal food industry not only ensures compliance with specific halal regulations but also significantly contributes to broader goals of enhancing food safety, supporting sustainable practices, and

promoting public health and food security. This makes it an integral technology for modernizing and improving food production systems.

Regulations and Guidance

Government

There are many common standards and recommendations for sanitary design developed by government and industry organizations. Outside the United States, laws and regulations that address sanitary design and cleaning and sanitizing practices include Cleaning and Validation Guidelines in Canada (Canada HPFB 2005, Timmerman 2013), Law on Food and Feed and subordinated regulations in Germany (Timmerman 2013, USDA FAS 2015), Regulations and the Machinery Directive in Europe (CEN 2009, Timmerman 2013), and the Codex Alimentarius, which provides voluntary international sanitation standards (FAO 2003, Timmerman 2013). In the U.S., the Department of Agriculture (USDA) Food Safety & Inspection Service (FSIS; USDA FSIS 2016) provides guidelines for equipment used in meat, poultry, and egg product facilities. The USDA Agricultural Marketing Service (AMS) (USDA AMS 2016) also has an approval process for dairy equipment. The Food and Drug Administration (FDA) addresses equipment fabrication and cleanability in its Current Good Manufacturing Practice in Manufacturing, Packaging, and Holding Human Food (cGMPs) (21 CFR Part 110). As directed in the Food Safety Modernization Act of 2011, GMP standards will be updated in 2018 through the recent Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive. Controls for Human Foods regulation (21 CFR Part 117).

Halal Regulations

The halal dietary laws determine which foods are "lawful" or permitted for Muslims. These laws are found in the Quran and in the Sunna, the practice of the Prophet Muhammad, as recorded in the books of Hadith, the Traditions. Islamic law is referred to as Shari'ah and has been interpreted by Muslim scholars over the years. The basic principles of the Islamic laws remain definite and unaltered. However, their interpretation and application may change according to the time, place, and circumstances. Besides the 2 basic sources of Islamic law, Quran and the Sunna, two other sources of jurisprudence are used in determining the permissibility of food, when a contemporary situation not explicitly covered by the first two basic sources. The first is Ijma, meaning a consensus of legal opinion. The second is Qiyas, meaning reasoning by analogy. In the latter case, the process of Ijtihad, or exerting oneself fully to derive and answer to the problem, is used.

Non-government organizations

Nongovernmental organizations, including 3-A Sanitary Standards Inc. (3-A SS) (3-A Sanitary Standards 2016), European Hygienic Design Group (EHEDG) (EHEDG 2004), and National Sanitation Foundation (NSF) (NSF 2016) International have also established standards and recommendations that stress the importance of hygienic design and sanitation practices (Schmidt and Erickson 2005). 3-A SS was originally developed for use in the dairy and egg industries (Schmidt 2013). 3-A SS works with other industry groups to improve standards, and they are active in training, workshops, and sharing knowledge. They provide assurance by conducting on-site evaluations of equipment based on general principles of hygienic design, construction, fabrication, installation, operation, and maintenance (3-A Sanitary Standards 2016, Schmidt 2013).

The European Hygienic Design Group (EHDG) is a consortium of equipment manufacturers, food industries, research institutes, and public health authorities that provide standards for processing equipment construction and design, (EHDG 2004). The group provides technical support for European legislation that requires that handling, preparation, processing, and packaging of food be done using hygienic machinery and in hygienic premises (CEN 2009and ISO 2012). EHDG guidelines include accepted materials of construction, instructions for construction of equipment, functional requirements for the prevention of microbial harborage sites and pathogen growth, and instructions for validating the effectiveness of hygienic design of equipment. The organization also performs validation testing on equipment to evaluate

cleanability (EHEDG 2004, Schmidt and Erickson 2005, Timmerman 2013). The cleaning validation standards under EHEDG stress finding a balance between theoretically proven methods and practical realization of those methods (Timmerman 2013).

The National Sanitation Foundation (NSF) is involved in developing standards for equipment used in food service and retail worldwide. They have also developed general standards for food processing equipment, and have worked with 3-A SS to develop specific standards for equipment used in meat and poultry processing. NSF also provides a variety of certification, auditing, and training programs (Schmidt and Erickson 2005, Schmidt 2013).

Figure 3. Global Food Safety Certifications

The greatest impact of Non-Thermal Plasma (NTP) technology extends beyond just the technical capabilities in food safety and biosecurity—it also plays a critical role in shaping international standards, agreements, and voluntary policies. When these technologies are integrated into organizational outputs, they can significantly enhance global trade and market access for countries. NTP contributes in many ways to affect policies, standards and practices at all levels of international governments.

By demonstrating the efficacy and safety of NTP technologies in the food processing and preservation sectors, organizations can formulate international standards that encourage their adoption. These standards can help harmonize methods and practices across borders, ensuring that food products meet safety and quality benchmarks globally.

NTP's ability to improve food safety and extend shelf life can be a key factor in trade agreements. Countries that adopt NTP technologies can ensure their food products are less likely to be rejected on the grounds of safety concerns, thus facilitating smoother trade relations and access to international markets.

Organizations might develop voluntary policies that promote the use of environmentally friendly and sustainable technologies like NTP. Adoption of such policies can enhance a country's reputation as a responsible trade partner committed to sustainable practices and high safety standards.

By aligning with international standards and agreements facilitated by NTP technology, countries can improve their market access. This is particularly significant for developing countries, which can leverage such technologies

to boost their compliance with global food safety norms and penetrate more competitive markets.
The integration of NTP technology can also lead to the development of better regulatory frameworks that support innovation and safety in food processing. This helps countries ensure that their food products are not only safe but also competitive in the international marketplace.
As more countries recognize the benefits of NTP in meeting international standards, it can drive wider adoption and spur further innovations in food safety technologies. This can lead to a virtuous cycle of improvement, adoption, and standardization, pushing the entire industry towards higher safety and quality standards.
By aligning the capabilities of NTP technology with organizational outputs like international standards and policies, countries can not only enhance their domestic food safety measures but also significantly improve their participation in global food markets. This strategic approach helps in achieving broader economic and health objectives at the international level.
Aligning Non-Thermal Plasma (NTP) technology with organizational inputs such as international standards and technical procedures significantly enhances food safety, quality, and phytosanitary health. This alignment facilitates the creation and revision of standards that are crucial for global trade and public health. Here's a breakdown of how this process contributes to international harmonization:

Research Focus on Non-Thermal Plasma Role in Food Safety, Halal and Tayyib

Non-thermal plasma (NTP) or atmospheric cold plasma (ACP) technology significantly enhances various aspects of food processing and handling through multiple beneficial mechanisms. Research focuses on the ability for NTP to improve processes across different stages due to its versatility in breadth of applications.

NTP and ACP are highly effective at inactivating a broad range of pathogens, including bacteria, viruses, and fungi. This capability is crucial for ensuring the microbiological safety of food products from processing through to packaging and storage.
The ability to apply these plasmas directly to food products without damaging them or altering their nutritional and sensory qualities is a significant advantage. For instance, treating fruits and vegetables with plasma can reduce microbial load while maintaining freshness.
In food processing environments, maintaining clean air is essential to prevent airborne contamination of products. NTP and ACP can be used to treat air, removing pathogens and volatile organic compounds (VOCs), thus improving the overall quality of the indoor environment.
NTP and ACP can be used to produce plasma activated water, which possesses antimicrobial properties. PAW can be used for washing food products, cleaning surfaces, and even as part of the processing steps, enhancing the microbial safety of the process without the use of harsh chemicals. (11)
Beyond ensuring safety, the reduction of microbial load by NTP and ACP can also improve the shelf life and quality of food products. This is particularly important in industries where the spoilage of products can lead to significant economic losses.

The integration of NTP and ACP technologies into food processing and handling not only addresses safety concerns but also contributes to sustainability by reducing the need for chemical sanitizers and preservatives. This aligns well with modern consumer preferences for more natural products and environmentally friendly manufacturing practices. Overall, NTP and ACP offer comprehensive benefits that can significantly enhance the efficiency, safety, and quality of food production processes.

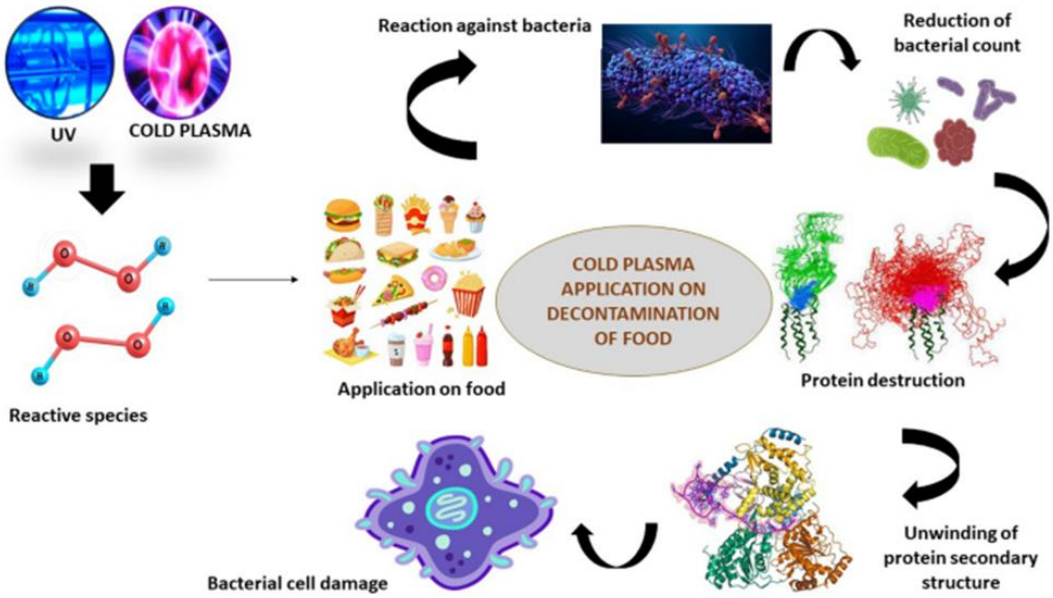
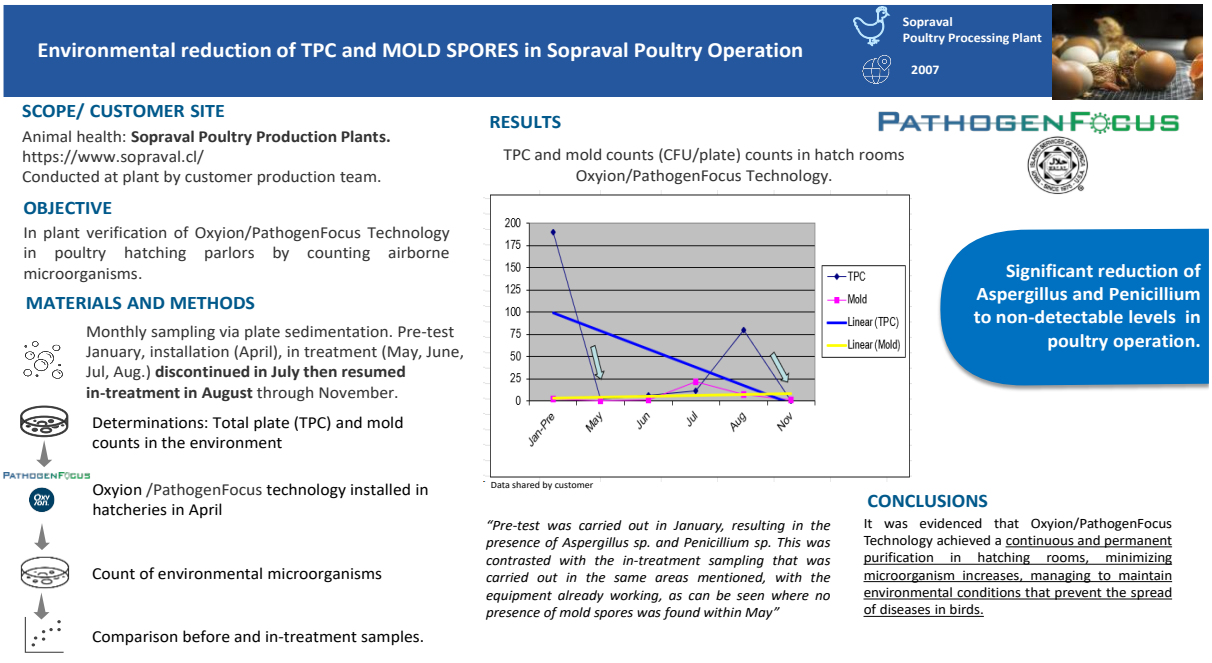


Figure 4. Cold plasma treatment advancements in food processing and impact on the physiochemical characteristics of food products (Farooq, S., Dar, A.H., Dash, K.K. et al. Food Sci Biotechnol 32, 621–638 (2023). https://doi.org/10.1007/s10068-023-01266-5)

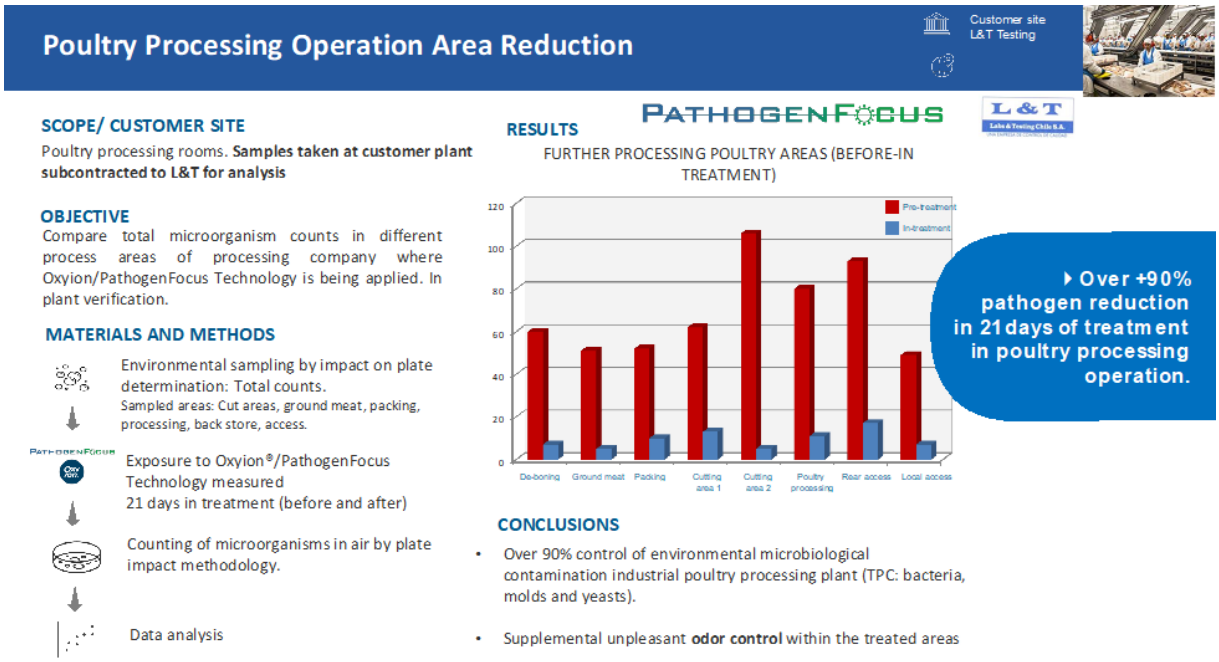
The USDA's exploration into using NTP and ACP technologies to enhance the shelf life of produce could lead to significant improvements in food safety, waste reduction, and economic efficiency within the agricultural sector. Continued research and development in this area may pave the way for wider adoption across the industry, benefiting both producers and consumers by providing fresher, safer, and more sustainable food options.

Case Study Results

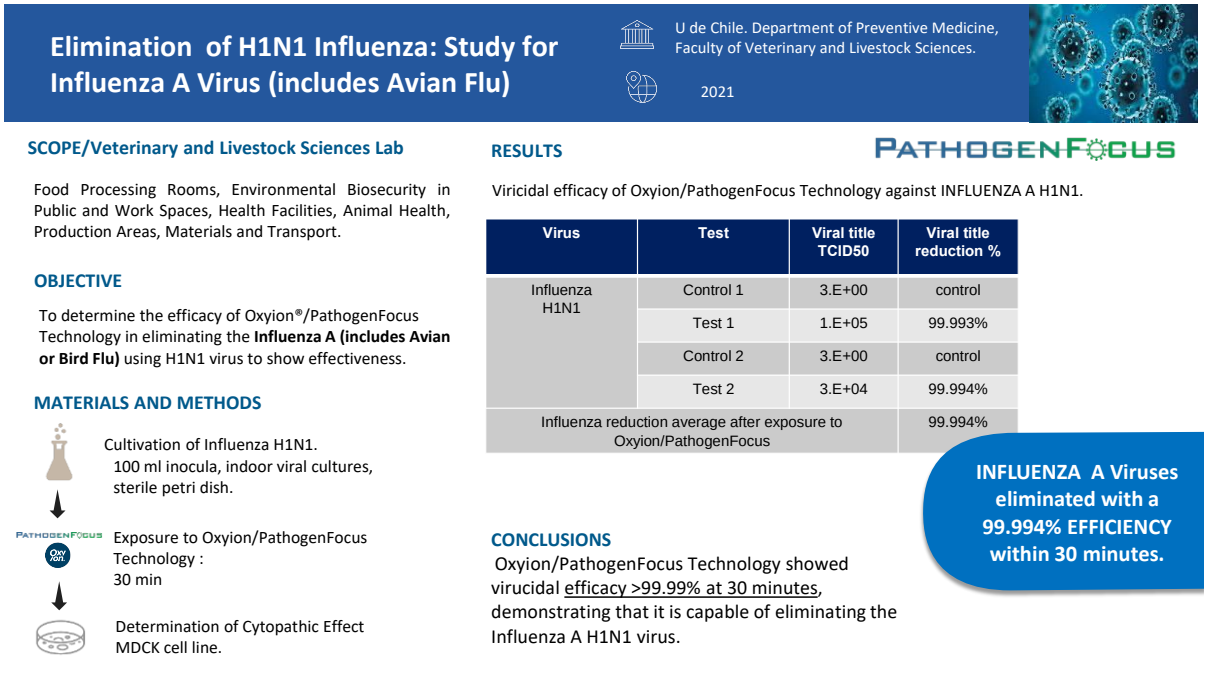
This was a study conducted "in-situ." The site director stated he was having issues with mold in the hatch rooms. Air and surface samples were taken in January. The NTP solution was application engineered based upon the sampling results.



The NTP device was installed in late April. The treatment period was established to take 1 month for the impact and effectiveness to be noted. To ensure that the device was indeed making this significant of an improvement, he turned off the device in July. The CFU counts dramatically increased. He turned on the device again in late August and noted the results previously achieved when the device was activated replicated. The result was this company implementing NTP across their poultry facilities throughout South America.



Another poultry facility was challenged by microbials throughout the processing facility. In-situ sampling was completed and a third-party lab completed the analysis. After application engineering based upon the pretreatment results, the appropriate number of NYTP devices were installed. After 21 days of utilizing NTP continuously for 21 days, a significant reduction in the microbials were noted. As the device continued being utilized the reduction continued to increase.



This was conducted in a lab setting. A major concern in the poultry industry is Avian Flu Virus. NTP effectively reduces the likelihood of transmission of the disease. This demonstrated how NTP plays a critical role in virus reduction in farms and food processing facilities.

Conclusion

The integration of non-thermal plasma (NTP) or cold atmospheric plasma (ACP) into the production and processing of halal food products holds significant potential, with the USDA highlighting ongoing developments and possible improvements. The advancements and recommend future research by the USDA clearly show how NTP can be beneficial for the halal food industry.

NTP and ACP are effective at reducing microbial contamination on food surfaces, including pathogens that are common concerns in halal food processing. This aligns well with the stringent cleanliness requirements of halal standards, helping to ensure that food products are safe and pure as per Islamic law.

Given that halal standards prohibit the use of substances that are harmful or impure, the chemical-free nature of NTP and ACP makes these technologies especially attractive. They provide a way to disinfect and preserve food without introducing any foreign chemicals or residues, maintaining the natural integrity of the food.

Unlike some traditional preservation methods that can affect the taste, texture, or nutritional value of food (such as irradiation or chemical preservatives), NTP and ACP treat foods without high heat or chemicals. This preserves the food's original qualities, which is crucial for consumer acceptance and compliance with halal certification.

NTP and ACP are energy-efficient and environmentally friendly technologies. This sustainability aspect is increasingly important as consumers and regulatory bodies alike are pushing for more eco-friendly practices in all industries, including food production.

NTP and ACP can also be used in innovative packaging solutions that extend the shelf life of perishable goods without the need for preservatives. For example, incorporating plasma-treated materials in packaging can help keep food fresh longer by continuously controlling microbial growth.

By integrating NTP and ACP technologies, halal food producers can not only meet but exceed current standards, potentially opening up new markets where stringent food safety and quality are prioritized. This could give them a competitive edge in both domestic and international markets.

As these technologies become more integrated into halal food processing, they can also influence the development of new halal standards and regulations, particularly around modern and innovative methods of maintaining food safety and quality.

The USDA's focus on enhancing these technologies signifies a promising future for their application in halal food production. As research continues and these technologies are further refined, they could become a standard part of halal food processing, offering benefits from farm to table.

RECOMMENDATION

There is a continuing need for effective antimicrobial processes suitable for application to fresh and fresh-cut fruits, vegetables, meat and other food products, It

is anticipated that cold plasma, in all its many forms, will be a cornerstone technology in that effort. As it matures, it will prove to be one of the most important technologies of the last several decades to arise for application to these commodities. The rapidly expanding body of cold plasma research, academic and industrial, is on pace to support a sea change in how fresh produce is cleaned and preserved in the coming decades.

Think about a challenging situation concerning how to ensure proper hygiene and sanitation in your facilities. Whether it be in air, surface or water NTP offers a potential solution.

Treating the air also impacts surfaces that the air contacts. For water NTP can offer stability p maintenance as well as maintenance reducing microbials and biofilms.

Further work is needed for food dielectric properties, what is the efficiency and how should be the process of plasma flow, contact time, surface effects, commodity shape and contact surface features, for a constellation of antimicrobial processes.

Further work is needed for DNA dissociation of Non-Halal traces in all surfaces or protein of Non-Halal animal, in the slaughterhouse, in the process of preparing halal food.

References

1. Korean Journal For Food Science of Animal Resources: Use of Atmospheric Pressure Cold Plasma for Meat Industry, Juri Lee, 1Cheol Woo Lee, 1Hae In Yong, 2Hyun Jung Lee, 2Cheorun Jo, 2,3and Samooel Jung1,*
2. Journal of Food Protection, Vol 71, No 9, 2008, Pages 1922-1925: Effect of Reactive Oxygne Species-H Generating System for Control of Airborne Microorganisms in a Meat-Processing Environment, J.R. Patel and X. Nou, (USDA, Agricultural Research Center)
3. Experimental and Applied Acarology (2022) 88:139-152: Short-time cold Atmospheric Cold Plasma Exposure Can Kill All Life Stages of the Poultry Red Mite, Dermanyssus gallinae, Under Laboratory Conditions, Vanessa Ruster (.) et al.
4. International Journal of Low-Carbon Technologies 2022, 17, 446-455: Environment Pollutants Removal with Non-Thermal Plasma Technology, Buyong Chen, Yuanhao Wang, et al.
5. Hindawi Journal of Food Qulaity, Vol 202, Article ID 8866369, 8 pages: Effect of Cold Plasma on Quality Retention of Fresh-Cut Produce, Hadi Bagheri (Health Research Center, Life Style Institute, Baqiyatallah University of Medical Sciences, Tehran, Iran) and Sepideh Abbasadeh (Department of Nutrition and Fodo Hygiene, Faculty of Health, Baqiyatallah University of Medical Sciences, Tehran, Iran)
6. Frontiers in Veterinary Science, 9/1/2023: Exploring the Potential of Cold Plasma Therapy in Treating Bacterial Infections in Veterinary Medicine: Opportunities and Challenges, Parvin Mohseni (Department of Pathnobiology, Faculty Veterinary Medicine, Shahid Bahonar University of Kerman. Kerman, Iran) et al.
7. Applied Food Research 3 2023 100258: Recent Advances in Non-Thermal Processing Technology For Enhancing Shelf Life and Improving Food Safety, Farhana Mehraj Allai (Deaprtment of Post-Harvest Engineering and Technology, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India) et al.
8. Food Biophysics 2017 10:1-11: Cold Plasma: A Novel Non-Thermal Plasma Technology for Food Processing, Rohit Thirumdas, Chaitanya Sarangapani, Uday S. Annapure (Department of Food Engineering and Technology, Institute of Chemical Technology, Mumbai 40019, India)
9. Research Society and Development, v 11, n 3, e15611326261, 2022: Effects of Non-Thermal Plasma on Food Nutrients and Cereal Based Raw Materials, Jefferson Henrique Tiago Barros (Universidade Estadual de Campinas, Brazil) et al.
10. Applied Sciences: Review on Recent Applications of Cold Plasma for Safe and Sustainable Food Production: Principles, Implementation, and Application Limits, Mohamed Majdi Cherif (Energy, Water, Environment and Process Laboratory, National Engineering School of Gabes, Universit of Gabes, Gabes 6072, Tunisia) et al.
11. Science Direct Food Control Volume 142, December 2022, 109268: Effect of Plasma Activated Water (PAW) on Physicochemical and Functional Properties of Foods, Abhipriya Patra, et al.
12. International Journal Environmental Research and Public Health 2022 Jun; 19(11): 6630: Plasma-Activated Water for Food Safety and Quality: A review of Recent Developments, Mizanur Rahman, et al.
13. Cell Press Reviews: Trends in Biotechnology, Nov 2020, Vol 38, No 11: Cold Plasma, a New Hope in the Field of Virus Inactivation, Arijana Filipic (Department of Biotechnology and Systems Biology, National Institue of Biology, Vecna Pot 111, 1000 Ljubijana, Slovenia), et al.
14. FDA (2008). Guidance for industry: Guide to minimize microbial food safety hazards of fresh-cut fruits and vegetables. Accessed on 5/12/14 http://www.cfsan.fda.gov/guidance.html.
15. Niemira, B. A. (2012a). Cold plasma decontamination of foods. Annual Review of Food Science and Technology, 2012(3), 125–142.
16. Niemira, B. A. (2012b). Cold plasma reduction of Salmonella and Escherichia coli O157:H7 on almonds using ambient pressure gases. Journal of Food Science, 77, M171–M175.

17. Niemira, B. A., & Gutsol, A. (2010). Nonthermal plasma as a novel food processing technology. In H. Q. Zhang, G. Barbosa-Cánovas, V. M. Balasubramaniam, P. Dunne,
18. D. Farkas, & J. Yuan (Eds.). Nonthermal processing technologies for food (pp. 271–288). Ames, Iowa: Blackwell Pub.
19. Niemira, A. B., & Sites, J. (2008). Cold plasma inactivates Salmonella stanley and Escherichia coli O157:H7 inoculated on golden delicious apples. Journal of Food Protection, 71(7), 1357–1365.

Further Reading

1. Bermudez-Aguirre, D., 2019. In: Advances in Cold Plasma Applications for Food Safety and Preservation. Elsevier, London, UK.

Relevant Websites

1. Cell, 2017. The Potential of Cold Plasma for Safe and Sustainable Food Production. https://www.cell.com/trends/biotechnology/fulltext/S0167-7799(17)30299-8. (Accessed 25 February 2020).
2. ILSI, 2016. Cold Plasma: A Case Study in Critical Factors Affecting Development. https://www.youtube.com/watch?v¼FN6vuSKQt5Q. (Accessed 25 February 2020).
3. Knowable Magazine, 2018. Scientists Look to New Technologies to Make Food Safer. https://www.knowablemagazine.org/article/technology/2018/scientists-look-newtechnologies-
4. make-food-safer. (Accessed 25 February 2020).
5. Purdue University, 2013. In-package Cold Plasma Generation. https://www.youtube.com/watch?v¼HPcsTav95nc. (Accessed 25 February 2020).
6. Science, 2016. Healthier Blueberries, Thanks to a Blast of Purple Plasma. https://www.sciencemag.org/news/2016/12/healthier-blueberries-thanks-blast-purple-plasma. (Accessed 25 February 2020).
7. (Food and Agriculture Organization [FAO], 2022).

HALAL HIGIJENA I SANITACIJA

Tharwat Mamdouh Al-Bataineh[1], Daryl DeJean[2]

[1]Food Regulatory, Specialist Food Safety and Halal Regulations; Ministry of Climate Change & Environment, United Arab Emirates. Dubai Al Ruwayyah 2 Area Beside Zayed University, Dubai – AlAin Road, Dubai
[2]Daryl DeJean | VP Product Development – PathogenFocus – USA -North Carolina

Autor za korespodenciju: Dr. Tharwat Mamdouh Al-Bataineh
E-mail adresa: dr_thrwat@yahoo.com

Stručni rad

SAŽETAK

Danas, zahvaljujući napretku u netermalnoj plazmi (NTP) ili atmosferskoj hladnoj plazmi (ACP), halal industrija može doživjeti značajno poboljšanje u svojim standardnim operativnim procedurama za dezinfekciju i dekontaminaciju zraka, površine i vode.
Pružanje kontinuiranog, prodornog, stabilnog i dosljednog nivoa biosigurnosti dodatno osigurava prevenciju i smanjenje štetnih hlapljivih organskih spojeva i mikroba u cijelom lancu opskrbe hranom. Dokazano protiv najčešćih pitanja sigurnosti hrane, od klanja do obrade, pakiranja i transporta, halal prehrambeni proizvodi sada mogu doživjeti najbolju moguću dezinfekciju i higijenu. Ove aktivnosti će direktno doprinijeti postizanju strateškog cilja biosigurnosti hrane, koji ima za cilj da omogući inkluzivne i efikasne poljoprivredno-prehrambene sisteme i u određenim aspektima je u skladu sa Halal uredbom. Ovo se dešava kroz organizacioni rezultat: međunarodni standardi, sporazumi i dobrovoljne politike formulisane da poboljšaju pristup zemalja i funkcionisanje međunarodnim tržištima. Kroz izdanje, nove i revidirane međunarodne standarde i nove tehničke procedure za sigurnost hrane, kvalitet i fitosanitarno zdravlje su formulisane i dogovorene od strane zemalja, služeći kao referenca za međunarodnu harmonizaciju.
Upotreba NTP ili ACP poboljšava sve procese kroz njegovu sposobnost da brzo neutrališe mikrobe, utiče na stvarni proizvod u procesu, poboljšava kvalitet vazduha u zatvorenom prostoru, obezbeđuje vodu aktiviranu plazmom i neutrališe mikrobe koji mogu uticati na kvalitet proizvoda. Najnovije područje istraživanja Ministarstva poljoprivrede Sjedinjenih Država (USDA) je korištenje NTP ili ACP za poboljšanje roka trajanja proizvoda. Zbog organske prirode dezinficijensa proizvedenog u plazma komori, utvrđeno je da proizvod ne trpi nikakve fizičke ili nutritivne promjene koje mogu nastati zračenjem. Tokom ove sesije naučit ćete o opsežnim prednostima i tekućim razvojima i poboljšanjima za koja USDA kaže da su moguća za korištenje netermalne plazme ili hladne atmosferske plazme za integraciju ove tehnologije u halal prehrambene proizvode.

Ključne riječi: *Higijena, Halal, Netermalna plazma, atmosferska hladna plazma.*