BOOK OF ABSTRACTS
I TRAINING SCHOOL

"Plasma applications for smart and sustainable agriculture"– PlAgri

17 – 19th March of 2021

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Plasma applications for smart and sustainable agriculture

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Contents

About

The 1st PlAgri Training School was aimed primarily towards young researchers (PhD students, young post-docs), as well as, researchers interested in obtaining the knowledge from different fields and also representatives from industry. The course was focused on integrating fundamental knowledge in this multidisciplinary field and understanding specific aspects of different requirements and expertise in topics such as:

Plasma physics in general;
Plasma-water interactions and chemistry;
Plasma sources;
Plasma diagnostics;
Waste water treatment;
Plasma treatment of seeds and plants;
Plasma sources for food processing: design, characterization and upscaling.

The 1st PlAgri Training School highlighted the most recent developments in each topic, promoting a strong interaction between experienced trainers working on different topics and trainees.

First Training School

The main focus of the school was on the state-of-the-art in the field of plasma agriculture. The trainees will have the opportunity to be acquainted with the latest accomplishments which will be presented in such level that trainees from different fields (sciences) can obtain a basic knowledge.

Dates and Location

Due to the situation with COVID -19 and travel restrictions, the First Training School has been organized as a hybrid event from 17-19th March 2021 in Hotel Termag, Jahorina, Bosnia and Herzegovina and under the local organization of the University of East Sarajevo (UES) and the Faculty of Technology Zvornik.

Local Organizing Committee

Prof Dragan Vujadinovic   Prof Milan Vukic   Ms Jelena Vulinovic

List of Abstracts – Talks

Wednesday 17th March of 2021

Why Non-equilibrium (Plasmas)?

Zoran Lj Petrović

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From standard textbooks in physics and engineering one could reach conclusion that thermodynamic equilibrium (TE) is the default state in nature and a starting point for descriptions of how nature works and how applications of certain scientific principles may come to fruition in practice. As a matter of fact, ever since the early days of the universe when it was filled with thermal plasma in its entirety TE has been rare and unusual condition. At best, one could speak of local TE (LTE) whereby temperature was used as a fitting parameter as it changed from a point to a point and strict conditions for TE are seldom met. In plasma physics the non-equilibrium (often called cold or low-temperature) plasmas (NEP) have been applied more and more in numerous high technologies including: light sources, thin film deposition, plasma etching for integrated circuit production, plasma treatment of materials, cleaning and functionalization of surfaces and many, many more. In particular recently a special subdivision (that has been difficult to develop) of atmospheric pressure low temperature plasmas have been shown to provide significant effects in plasma assisted medicine, agriculture, food industry, biotechnologies in a broader sense and many more as well as in pollution control and remediation. In this lecture we shall start from examples that motivated early days in NEP, through development of gas lasers, light sources and production of integrated circuits. We shall end by providing illustration on how NEP are used in medicine, agriculture and pollution control. Our main concern would be to provide understanding on which aspects of the non-equilibrium nature of plasmas need be developed, how to model and understand such plasmas and finally how to use the basic knowledge to optimize the applications. Particularly, we shall discuss the energy distribution function (EDF) and how it may be controlled even at the level of hole burning, the control of ion energies and fluxes, the optimized chemical kinetics and the role of sheaths and non-uniform fields. Basis for understanding and modeling such plasmas may be found in the physics of electron and ion swarms (transport and collisions). However, as it is usually developed for the local field equilibrium the main attributes that need be used to provide the underpinning of NEP are the so-called kinetic phenomena.

Key words: non-equilibrium, low temperature plasmas, charged particle transport, kinetic phenomena, swarms, atmospheric pressure plasmas, electron scattering cross sections.

Reactive Oxygen and Nitrogen Species: From Plasma Generation to Biological Function

David Graves

Lecturer: David B. Graves, Associate Laboratory Director, Princeton Plasma Physics Lab;
Professor, Department of Chemical and Biological Engineering, Princeton University;
Emeritus Professor, Department of Chemical and Biomolecular Engineering, UC Berkeley.

It has become apparent that the chemical species referred to as 'reactive oxygen and nitrogen species' (RONS) are usually key players in the effects of plasma on biological systems. Non-equilibrium plasma sustained in air are known to generate significant quantities of these species. Furthermore, it is well established that RONS are key actors in aerobic biology, with essential roles as agents in responding to challenges to both plants and animals from microbial infection and tissue damage, among many other roles. These species are formed and transformed via a class of chemical reactions referred to as 'oxidation-reduction' or 'redox' reactions. Biologists and biochemists study how redox processes are utilized in biological systems and have termed the field 'redox biology.' Some researchers in plasma biological studies point out that plasma biology can be thought of as a subset of applied redox biology. In this introductory lecture, I will discuss some basic features of plasma-generated RONS redox chemistry and some selected aspects of their biological functions.

Key words: reactive oxygen and nitrogen species, redox biology.

Chemistry in plasma treated liquids and methods of characterization

Petr Lukes

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The interactions of non-equilibrium plasmas with a liquid state represent a growing interdisciplinary area of research in the field of plasma science and technology. Different types of discharge plasmas generated either directly in the liquid, in the gas phase over and in contact with a liquid, or in the multiphase environments such as discharges in bubbles inside liquids or discharges contacting liquid sprays or foams are used. Depending on the type of discharge, its energy, and the chemical composition of the surrounding environment various types of physical processes and short and long-lived chemical species are produced by plasma in the liquid either directly, or transferred from the gas phase discharge plasma being in contact with the liquid. The primary species in typical case of humid air plasmas are OH, H, O and N radicals from the electron dissociation reactions of water, oxygen and nitrogen molecules. These species react with other primary species or with the surrounding gas or liquid molecules to produce secondary species such as $H_2O_2, NO, NO_2, O_3, HNO_2, HNO_3$, etc., or they diffuse away from each other to be available to react at or penetrate through the plasma-gas/liquid interface and dissolve into the bulk liquid, and subsequent chemical reactions can be initiated in plasma-treated liquid. These secondary aqueous-phase chemical reactions play very important role and can last in plasma-treated liquids for significant period of time after the solution's exposure to the plasma. Long-term chemical reactivity phenomenon of plasma treated liquids was called by different names (e.g., plasma activated water) and it is subject of study in different plasma medicine and agriculture motivated applications. Nevertheless, the properties of these liquids and duration of their activity are affected by many factors which determine a type, quantity and also lifetime of the reactive species being formed in such plasma-produced chemically reactive liquids. In this talk an overview of basic principles of plasma-liquid interactions will be presented with particular emphasis on the main chemical processes initiated in plasma-treated liquids and methods of their characterization.

Key words: plasma-liquid interactions, plasma activated water, plasmachemistry, ROS, RNS, peroxynitrite.

Plasma treatment of plants: puzzle games for biologists and physicists

Suzana Zivkovic

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Recent scientific, technological and methodological advances in the fields of plasma physics and plant physiology offer a wide range of possibilities for employment of plasma technology in treatment of plants. Application of PAW or direct plasma treatment represent an alternative and valuable approach to plant biotechnology being chemically-free, energy efficient, and environmentally friendly. However, the distinct mechanisms responsible for the positive effects of plasma treatment on plant cells are still vague. Plant calli cultures (calli grown aseptically on semisolid agar medium) and calli suspension cultures (calli grown aseptically in liquid medium in test tubes, shake flasks, or bioreactors) with or without addition of plant growth regulators are used to illustrate changes in physiological response of plant cells/tissues induced by plasma treatment. Key challenges and obstacles to achieve precise and localized *in vivo* treatments of living cells and tissues will be discussed in light of current knowledge in the field.

Key words: plant calli, *in vitro* culture, plasma treatment, PAW

Thursday 18th March of 2021

Plasma sources for treatment of liquids

František Krčma

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The lecture brings a general overview of plasma-liquid systems operating at atmospheric pressure. The water solutions including also colloidal solutions of micro and nanoparticles used in agricultural practice are forming the liquid medium. The plasma sources include gaseous plasmas interacting with still or moving liquid surface, gaseous plasmas interacting with water aerosol, discharges generated in bubbles and finally discharges generated directly in the liquid phase. The suitable geometries will be discussed with respect to their scalability needed for the real application in agricultural scale. Additionally, the power supplying systems will be briefly discussed with respect to their use by people without a special physical background.

Key words: discharge with liquid, discharge in liquid, discharge in bubbles, discharge in aerosol, plasma reactor, electrode configuration, power supply.

Mass spectroscopy diagnostics of sources and reactive species in atmospheric plasmas

***J. Benedikt*[1], *T. Winzer*[1], *C. Schulze*[1]**

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In this contribution, molecular beam mass spectrometry (MBMS) for detection of neutral reactive and stable species and positive and negative ions from atmospheric pressure plasmas will be introduced and discussed in detail[1,2,3]. The advantage of mass spectrometry is that it measures the directly at the surface, the place of interest for any surface treatment, and it is not limited by existence of accessible optical transitions. Additionally, mass spectrometry provides absolute densities of the measured species when properly designed and carefully calibrated. With the application of threshold ionization mass spectrometry (TIMS) it can even provide information about vibrational excitation of the detected species or about electronically excited metastables. The challenging part is The ion mass spectrometry can provide information about the formation of positive and negative ions (and ion clusters) in the effluent and provides supporting information about the influence of variety of species (including impurities) on plasma chemistry. These experimental results serve for validation of plasma-chemistry models and rate-equation calculations, which can provide deep insight into the whole plasma and plasma-surface interaction. Several examples of investigation of plasma chemistry processes in gas mixtures and at the surface relevant for plasma medicine or plasma agriculture applications including liquid treatments will be discussed.

Key words: atmospheric non-equilibrium plasmas, molecular beam mass spectrometry, threshold ionization mass spectrometry, ion mass spectrometry.

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Upscaling of plasma sources for food processing applications

Jörg Ehlbeck

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Scaling up equipment or processes from laboratory scale to pilot plant scale or even industrial scale is almost always a major challenge. Therefore, this process is usually carried out gradually in small steps. These scaling processes are sometimes particularly difficult in the field of plasma technology. The plasma processes that are an exception here are often already found as successful implementations in industrial applications. Examples of this are the use of dielectrically impeded discharge in the pre-treatment of plastic films for printability (shopping bags, credit cards, Tesa film, etc) or in the low-pressure range with microwave plasmas in semiconductor production or for the coating of architectural glass. Many applications in the food industry are under high cost pressure. Here, plasma processes must be carried out cost-effectively. This often leads to the requirement to operate in air and under atmospheric pressure. These operating conditions are a great challenge for some plasma sources. Plasmas under these conditions can contract and the resulting high local heat input into the surrounding components can lead to damage or reduced lifetime of the plasma source. With high-frequency excited plasma sources, ignition of the plasma is often problematic. Nevertheless, plasma processes are also in industrial use in the food sector. KHS, for example, has successfully launched the Plasmax process for coating PET bottles. Here it has been possible to make a plasma process suitable for mass throughput in low pressure. Plasma processes directly applied to foodstuffs are mainly at the research stage or at various stages of scaling up. Before they can be used on an industrial scale, however, the approval issues must first be clarified.

Key words: upscaling, microwave plasma sources, fresh cut produce.

How to Write a Good Journal Paper (or Thesis)

Ray Boxman

School of Electrical Engineering, Tel Aviv University, Israe

The tutorial will present a recipe for writing good “research reports”, including theses, internal reports, and especially journal papers. The critical elements of each section of the research report will be reviewed, and content, organization, and style conventions will be discussed. The research report should be centered on a well defined research question. In the Introduction, the importance of a clear gap sentence and statement of purpose will be emphasized. The requirement for providing sufficient detail in the Methodology section for duplicating results will be explained. The differences in theoretical papers will be explained. The proper order for presenting Results – location, presentation, and comment - will be explained. The principle of heads-up display in technical drawings will be presented. The need to differentiate between results and interpretation will be emphasized. The organization of the Discussion, from narrow comments to broad implications, will be presented, and appropriate language to express the relative certainty of explanations, i.e. from speculation to proof, will be explained. Answering the research question and summarizing the key results and their implications in terms of 3 points the author wishes the reader to remember will be suggested as the organizational mode for the Conclusions. The difference between an indicative and an informative Abstract will be explained, as well as the need for the latter. Finally, suggestions for interacting with journal editors and responding to reviewers’ comments will be presented..

Key words: research report, journal paper, thesis, internal report, abstract, scientific writing, gap sentence, research question, statement of purpose, location sentence, presentation sentence, conclusions.

The role of chemically or physically induced redox processes in wastewater treatment

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Most aqueous waste streams contain a complex spectrum of pollutants including inorganic and organic contaminants with a plethora of chemical and physical properties. It is hence not surprising that single unit processes are usually not capable of dealing with all pollutants present or are at least not equally suited to treat each of them. In response to that engineers usually assemble a series of unit processes in so-called treatment trains, often a combination of three to seven individual steps based on physical, biological, and chemical treatment. The present talk examines the role of chemically or physically induced redox processes in wastewater treatment. It will give an overview on advantages and disadvantages of individual processes, specifically ozonation, advanced oxidation and chlorine-based treatments. Besides discussing their ability to eliminate target contaminants, it will discuss the risk of forming undesired byproducts. Moreover, it will discuss general principles on how to integrate oxidation and reduction processes in treatment trains in such a way that the treated water is stable, non-toxic and fit-for-purpose.

Key words: wastewater treatment, chemical oxidation, treatment trains, trace organic contaminants, disinfection byproducts.

How to study the degradation process of organic contaminants in plasma systems for water treatment

Ester Marotta

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The study of reaction mechanisms in organic chemistry requires the identification of the intermediates and of the products of the process under study and the determination of the kinetics of their formation and of the reactants disappearance. These elements are of fundamental importance also for the study of the degradation mechanisms of organic contaminants in plasma processes applied for water treatment. In addition, a key role for understanding the chemical processes activated by plasma is the determination of the reactive species involved, since they differ in identity and in concentration depending on the experimental operating conditions and on the plasma source employed. The strategies applied for understanding the role of the reactive species are often based on the comparison of the results (kinetic data and product distribution data) obtained under different operative conditions (working gas, solution pH, ..) or with different plasma sources, on the selective quenching of specific reactive species and on the parallel study of the reactions of the organic compound of interest with individual selected reactive species. In the lecture, these concepts will be explained and examined with reference to case studies taken from our research and from the literature with particular attention to the analytical techniques used for the identification and quantification of intermediates and products of the degradation process of the organic contaminants both in the gas and in the liquid phase.

Key words: plasma processes, water treatment, reaction mechanisms, degradation products analysis.

Plasma sources for the treatment of seeds and plants

Joanna Pawlat

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The presentation will be dedicated to the overview of existing low temperature plasma devices devoted to the agricultural purposes. Selected perspective designs of plasma generators based on electrical discharges and working at the atmospheric pressure and at the low pressure will be presented. Designs of plasma devices of various research groups including electrical parameters, geometry, type of the discharge and the treatment environment/ substrate gas will be discussed. Special attention will be paid to the non-equilibrium plasma solutions based on the dielectric barrier discharges, glide arcs and jet-type reactors. We will analyze the possibilities and goals of plasma application in selected steps of agricultural production cycle: for bactericidal, fungal and viral decontamination; for removal of excessive chemical contaminants; for synergetic use with traditional fertilizers, pesticides and plant health products; for stimulation of germination, growth and biomass production, etc. The real challenges in the low temperature plasma treatment of plants and seeds at the dry and wet condition, which are related to perspective costs, scaling up and economic feasibility will be briefly discussed.

Key words: plasma reactors, electrical discharges, treatment of seeds, treatment of plants, GAD, barrier discharge.

Soil – bio aspect

Jana Simeckova

Faculty of AgriScience, Mendel University in Brno, Czech Republic

Soil is a common thing in our life and we are thinking to take it for granted. But at the same time it is something really exceptional due to its meaning as well as its uniqueness. Soil is still the unreplaceable matter for the food production. But there is not one soil, the variability of soil properties is huge and many relationships have not been understood, yet, and perhaps even described. Our current knowledge and techniques have limited ability to understand all interactions. This is also due to the fact that the soil environment is unusually variable with respect to the location (even within a few meters), history of its development. Moreover, the influence of mankind is very significant and in some cases even critical. We must not forget that soil is living organism with many ties to the environment, with which it interacts significantly. Each of our actions can lead to irreversible damage to the soil environment, each new technology or process must be very carefully checked to avoid soil damage and to keep it healthy for growing crops. During the lecture "Soil – the bio aspect" it should be introduced the basic information about soil. It comprises introduction of physical, physical-chemical and organic properties of soil and main soil types. The selected techniques and procedures used for the soil properties characterisation will be briefly described.

Key words: soil, soil properties, edaphon, soil and environment.

Basics of Optical Diagnostics of Atomic and Molecular Species in Plasmas

Stephan Reuter

Polytechnique Montréal, Canada

Non-thermal plasmas generate reactive species at low gas temperatures. In plasma agriculture, these species are responsible for effects that increase growth, kill plant pathogens, or fixate nitrogen. Optical methods help to investigate the plasma generated reactive species. This training school lecture presents the basics of plasma spectroscopy and the standard methods to determine atomic and molecular concentrations in plasmas and in the plasma gas phase. An experimentally simple method to gain information about the plasma is optical emission spectroscopy (OES). Optical emission spectra contain information about the electron properties and densities, the electric field, the species concentration and temperature, and the dynamics in the plasma. Optical emission spectroscopy can, however, only detect excited species, as only these emit light. An analysis of OES data to gain atomic or molecular ground state concentrations is complex and will be impossible, if the relevant plasma conditions are unknown. Linking optical emission spectra with numerical models makes it possible to determine ground state species concentration, but the accuracy is limited by the experimental and modeling errors and the evaluation will be intricate and lengthy. Alternatively to OES, optical absorption spectroscopy can be used to characterize a plasma. This experimentally slightly more complex method yields intrinsically calibrated atomic and molecular ground state densities. Approaches to gain space resolved data from absorption spectroscopy will be discussed in the lecture. The basics of absorption spectroscopy, the typical setups that are used, and the most common techniques that are applied will be presented. The lecture concludes with key references for application of absorption and emission spectroscopy in low temperature plasma research.

Key words: plasma spectroscopy, optical emission spectroscopy, absorption spectroscopy, atomic and molecular species concentrations.

Friday 19th March of 2021

Plant response to stress induced by seed treatment with plasma: the biochemical context

Vida Mildaziene

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The research of effects induced in seeds and growing plants by plasma treatments has extended the knowledge about ability of plant seeds to suscept and to respond to signals from the environment. The chain of events in the multifactorial seed response to plasma still remains to be established, but certain important processes have been elucidated recently. The persistence of the induced effects for the entire vegetation of annual plants implies that plasma effects on seeds are transduced to growing plants and persist for a long time. PIAgri community is facing the intriguing challenge - to resolve complex pathways originating from the short exposure of seed to plasma and leading to numerous changes in plant growth, communication and production or even to changes in the next plant generations.

Key words: seed stress; cold plasma; upstream effects; downstream effects; phytohormones; ROS; gene expression; proteome; photosynthesis; secondary metabolism.

Connecting the dots: from plasma physics to plant biology

Milica Milutinovic

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Seed germination and early seedling growth are the most sensitive growth stages for plants, especially crops, to a wide range of environmental stressors. Many efforts have been made to enhance seed germination and seedling vigor by applying various methods. As an alternative to chemical treatments, plasma technology could be one of the emerging technologies to enhance seed germination. “Plasma Agriculture” potentially offers increased production with less impact on ecosystem, giving rise to various beneficial effects such as inactivation of seed/plant-borne pathogens, enhancement and increased crop yields, and maintained good food quality. This presentation will attempt to review the effect of non-thermal plasma (NTP) and plasma activated water (PAW) on seeds and emphasis will be given to the change in the physical and biochemical properties of seeds. In treatments where seeds are in direct contact with plasma or afterglow, the surface of seeds undergoes a variety of changes. During the plasma treatment, depending on the plasma conditions, the surface is activated so other functional groups can be attached ($-COOH, -COH, -COO, -NH_2, -OH, -NO,$ etc.) leading to the changes on seeds’ surface. Similarly, PAW contains large amounts of chemically active species produced in plasma and at the plasma-liquid interface which can be transferred from the interface volume to the liquid bulk and are able to trigger desired responses in biological samples i.e. increase of germination percentage, decontamination of both seeds and plants and faster growth. Further, we will discuss the change in biochemical analysis, e.g., the variation in phytochemicals and antioxidant levels of seeds after plasma treatment with the aim to clarify the key mechanisms underlying plasma-agricultural applications in order to better understand, control, and scale up these new processes.

Key words: non-thermal plasma, PAW, seed, seed germination.

Imaging and electrical diagnostics of non - equilibrium plasmas at atmospheric pressure

Ronny Branderburg

Leibniz Institute for Plasma Science and Technology / University of Rostock

Non-equilibrium plasmas have been intensively studied in the context of material processing, environmental remediation, ozone generation, excimer lamps and plasma display panels. Research on atmospheric pressure non-equilibrium plasmas intensified also because of its high potential for applications in agriculture [1]. Plasmas have a large potential for the decontamination of gases and water, which is an important requirement for a sustainable agriculture. Furthermore, plasma treatment of seeds can increase their germination rates and efficiencies. Plasma treatment has shown to enhance plant growth. The seeds, but also food, and food processing tools can be protected from or decontaminated of fungi and bacteria. A large variety of plasma sources that have been developed for such applications. However, the understanding of these discharges is needed to enable stable and reproducible processes [2, 3]. Furthermore, the specific conditions will show unexplained phenomena being worth for further research. Plasma diagnostics contains electrical measurements, optical and spectroscopic techniques as well as flux and surface analysis techniques [3]. This lecture will give an introduction to electrical diagnostics, and optical imaging. Both are non-intrusive diagnostics. Electrical characterization includes the measurement of electrical operation parameters such as the applied voltage, current and power dissipated in the plasma. The lecture will explain the main techniques and show, how such measures are useful for the determination of discharge modes and discharge power. In this context, it will also demonstrate how equivalent circuits are used for the interpretation of electrical measurements [4]. Optical imaging diagnostics allows for the imaging of the plasma morphology and its spatially and temporally resolved development. The lecture will cover the most common method for the investigation of plasmas, namely its photography by means of intensified charge coupled device (ICCD) cameras [3, 5]. The spatio-temporally resolved luminosity of individual transient discharges can be recorded by optoelectronic streak cameras, while time-correlated single-photon counting is the most sensitive technique for the spatio-temporal and spectral resolved recording of repetitive weak and transient discharges [5, 6]. Both methods will also be explained in the lecture.

Key words: atmospheric pressure plasmas, plasma diagnostics, electrical characterization, imaging.

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Characterization of plasma treated food products: quality, safety and assessment techniques

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Foods are very complex matrixes, being characterized by very different compositional, microstructural and stability properties. In addition, food products are considered meta-stable systems, that undergo to a plethora of biological, physico-chemical and sensorial modifications during time, that can differently interact as a function of storage conditions, such as temperature, relative humidity and surrounding atmosphere. In this so complicated scenario, the response of food products to emerging processing technologies has to be carefully considered and clarified, taking into account the most important factors of their safety, quality and stability, together with their modification during the shelf-life. In this direction, the subject of this training activity will be the application of a scientific multi-analytical approach, aimed at evaluating the effect of plasma treatment on the key aspects of different food products. For this aim, specific case studies on food products characterized by different kind of degradative reactions and intrinsic safety, quality and stability issues will be showed. Particularly, among them, experimental results on response to the plasma treatment of fresh-cut fruit and vegetables will be showed, in terms of microbial sanitation, enzymatic activity and endogenous metabolic response, together with related overall quality and nutritional aspects. In addition, an overall overview of the plasma application and effects on raw/minimally processed seafood products will be presented, with particular attention to the oxidative response, considering the important of unsaturated fatty acids content for this kind of products. Finally, results of plasma sanitation of packed foods will be showed, considering the new risks related to the contamination of external packaging surfaces bound to the pandemics; for this application, a typical experimental approach for the study of shelf-life packaging dependent foods will be illustrated.

Key words: plasma treatment, food safety, food quality, food stability, multi-anlytical approach.

Cost Action PlAgri

A continuous increase in demand for food caused by population growth represents a serious challenge for the humankind. Even in regions where food is plentiful, safety of the food cycle is increasingly important. Improving the sustainability of agriculture and at the same time reducing the adverse effects of agriculture on the environment requires efficient technologies that enhance productivity while maintaining food quality and safety. This COST action aims to investigate the potential of low-temperature plasmas (cold plasmas), as a green alternative to conventional chemicals in agriculture to improve yields, increase size and robustness of plants and reduce (or eliminate) the need for antifungal agents. It will aim to break the classical field boundaries for a new dimension in sustainable agriculture with lower chemical impact. The Action will address the use of plasmas for treating food and packaging. The Action aims to combine numerous European scientific communities dealing with plasma, biology, agriculture and food processing to identify and develop food production applications. Transfer of plasma technology to the industry will be based on understanding plasma's most essential processes with further considerations including (Novel food) legislations, energy consumption, food safety and quality. The Action will help define a new field in science by a coordinated, joint effort across the Europe and broader, through exchange and better use of resources and by intensive study of the basic mechanisms within the context of the well thought out present or future applications, more informations can be found at `https://plagri.eu`.

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