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APPLICATIONS OF COLD ATMOSPHERIC GAS PLASMAS FOR MICROBIAL DECONTAMINATION IN THE FOOD INDUSTRY

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Abstract:

The last 20 years have seen the emergence of a novel technology capable of generating gas plasmas in the open air and at temperatures that are only slightly above ambient. These so-called Cold Atmospheric Plasmas (CAP) have characteristics that render them particularly suitable for a variety of applications in the food industry. In this presentation prevalence will be given to microbial decontamination. In particular, understanding the mechanism of microbial inactivation is important as if the most lethal plasma species can be identified, it may prove possible to ‘tune’ the plasmas so as to maximise their production. Preliminary investigations undertaken by our group have gone some way to addressing this issue. One of the most promising applications of CAP is in the treatment of fresh uncooked foods, and results are presented here attesting to the efficacy of plasmas in inactivating a range of micro-organisms at or near the surface of fruits. The possibilities for using plasmas for destruction of allergens and spongiform encephalopathies are also considered.

Key words: Cold gas plasmas, Microbial Inactivation, Foods

1 Introduction

Thermal processing remains an important method for preserving a wide range of foods and it is widely used throughout the world in the food processing industries. Whilst providing an effective method of microbial decontamination of foods there remain a number of types of food that cannot be treated by thermal means. This is chiefly because thermal processing can induce unacceptable changes in foods such as destruction of important nutrients, or else can change the appearance or texture of foods so that it is no longer acceptable to consumers.

One class of foods that cannot be processed thermally by conventional means are fresh cut fruit and salad products. These convenience foods are increasing in popularity in industrialised countries and are seen as a reflection of lifestyle changes that are taking place in such countries. Their consumption has been shown to be associated with increasing incidences of foodborne illnesses [1]. Such foods have conventionally been treated with hypochlorite but this form of treatment is losing popularity partly because it has been shown to be of only limited efficacy but perhaps more significantly because its use is increasingly
becoming restricted by health agencies on the basis that chlorine residues could constitute a threat to health.

A method of treating such fresh commodities is therefore urgently required. One possible strategy is to make use of gas plasmas. Plasmas can now be generated under atmospheric conditions that are compatible with food treatment. Treatment is not strictly restricted to foods; gas plasmas could also be used to treat food processing equipment. This could be carried out in order to decontaminate the equipment of adherent micro-organisms or allergens or even prions. In this article the prospects of treating fresh foods with cold atmospheric gas plasmas is considered.

2 Gas Plasmas

Gas plasmas constitute natural phenomena such as aurora or flames, but they can also be created artificially and have been put to a variety of uses. About 20 years ago methods were developed that enabled gas plasmas to be created in atmospheric conditions and at temperatures that are only slightly above ambient temperatures. Plasmas have been referred to as the ‘fourth state of matter’ after solids, liquids and gases and are actually complex mixtures of ionised, free radical and metastable species all of which are extremely reactive and short-lived.

![Fig. 1: The anti-microbial effects of gas plasmas.](image)

Apart from chemical species, plasmas result in the generation of a number of important effects that are also useful in inactivating micro-organisms, these include electric fields and UV photons as shown in Figure 1. There are a number of ways of utilizing gas plasmas that could be applicable to food processing applications and these would obviously be related to the specific application. There has yet been no full scale application of cold gas plasmas in the food industry but future developments are likely to revolve around the following possibilities.

The first of these is the barrier glow discharge generated between two parallel electrodes (Fig. 2). In one particular application food could be conveyed through the discharge to achieve microbial decontamination.

A completely different configuration that has considerable potential is the so-called ‘plasma pen’ which is depicted in Figure 3. This results in the production of essentially a stream of gases that can be directed at the object to be treated. Each of these two designs has the capability to be scaled up in a number of different ways. For the plasma pen shown below
this could simply be scaled up or else replicated to produce what has been referred to as a ‘plasma brush’ [2].

Fig. 2: Barrier glow discharge generated between parallel plates.

Fig. 3: A plasma gas ‘pen’
3 Treatment of foods

As indicated above there are a number of applications of cold gas plasmas for the treatment of foods but there are also different stages at which gas plasmas could be applied to the treatment of foods. For some components of fresh salads the interior is essentially free of micro-organisms and it is the outer layers, or skin, that is contaminated with soil and organisms. The act of cutting is to draw the organisms from the surface into the interior of the flesh and deposit them there. One very good example of this is cantaloupe melons that have a reticulated skin that can trap soil and a number of incidences of Salmonella food poisoning have been attributed to this fruit [3].

![Figure 4: Treatment of a variety of micro-organisms on the flesh of melon treated with cold atmospheric plasma pen.](image)

Figure 4 shows the inactivation of a number of different organisms on the surface of melon achieved through the use of a plasma pen.

The bacteria are particularly susceptible whilst the yeast species requires longer treatment but high reductions in viable cell numbers were nonetheless obtained. The treatment of the flesh itself is shown below. Treatment was less effective than was achieved during the treatment of the pericarp of the same fruit (Fig. 5). Further investigation revealed that the organisms deposited onto the fresh cut fruit tissue were being internalised. This made it difficult for the lethal plasma species to reach the organisms. Whilst this was to a certain extent a consequence of the experimental protocols employed, it does have consequences for the mode by which treatment must be applied [4]. This relates to the sequence of operations such as cutting and treatment.
Fig. 5: Treatment of a variety of micro-organisms on the pericarp of melon treated with cold atmospheric plasma pen.

4 Future prospects for cold gas plasmas

Cold gas plasmas have definite potential for the treatment of fresh foods. Studies are being undertaken to identify the plasma species that are most lethal to micro-organisms so that once identified, operating conditions can be selected so as to maximise their production [5]. An often unconsidered aspect of experimental work with gas plasmas is that treatment must be proven not to impact negatively on the organoleptic and nutritional characteristics of the food but to date only limited investigations on this aspect of treatment have been performed. Scale-up remains a challenge to be confronted but there exists a number of different strategies that could be implemented to achieve this. This work has focussed on inactivation of micro-organisms on the surfaces of foods, however, other food-related applications exist. Deng et al. [6] have shown that cold gas plasmas have the potential to inactivate proteins attached to stainless steel. This may have positive implications for the removal of prions – an application that has consequences not only in food processing but also in the healthcare industries. In addition, gas plasmas could also be used to remove allergens from the surface of food processing equipment. Preliminary and as yet unpublished results from our laboratory have confirmed this.

References


