Acoustic impact on electric discharge parameters during sterilization of freeze-dried products

T Ya Asadullin, I G Galeev, A O Sofronitskiy and M M Gizeev
Kazan National Research Technical University named after A.N.Tupolev – KAI
Russia, 420111 Kazan, K Marx St, 10

TYaAsadullin@kai.ru

Abstract. The possibility of using a gas discharge plasma for sterilization of freeze-drying products directly in the process of their vacuum packaging for long-term storage is considered. An alternating current electrical discharge was used as a source of sterilizing action. In order to increase the homogeneity of the processing of the products, sound waves were applied to the electrical discharge. The effect of acoustic effects was investigated in the pressure range from 10 to 100 Torr, and the sound frequency from 50 to 400 Hz. A noticeable effect of sound waves on the discharge behavior was identified and optimal conditions were determined for increasing the uniformity of the sterilizing effect on the processed products.

1. Introduction
Today, plasma technologies are finding increasingly diverse applications in many practical areas. One of the relatively new applications of plasma is food biotechnology, where plasma of various types of gas discharge is used for bactericidal processing and sterilization of food products in order to improve storage conditions without using additional chemical preservatives.

The sterilizing effect of the gas discharge is mainly based on the bactericidal properties of the following factors accompanying the gas discharge:
- ultraviolet radiation arising during the burning of many discharges;
- ozone synthesis, resulting from the burning of discharges in the air;
- ionizing effects of charged particle fluxes;
- high temperature peculiar to, for example, arc discharge.

Freeze-dried products are a variety of foods, usually already prepared and directly consumable, that have been dehydrated by vacuum. This allows you to almost completely preserve the nutrients, vitamins, trace elements, even the original form, natural smell, taste, color, provided that the vacuum packaging is preserved and its contents are sterilized immediately before packaging. In the future, the storage of freeze-dried products does not require the creation of special conditions, for example, refrigeration units.

For the sterilization of products and the inner surface of the packaging during the packaging process, it is convenient to use a gas electrical discharge that will be created inside the packaging during the vacuum process. Continuing air exhaust will remove the gaseous products of the reactions caused by the discharge. Porosity and dielectric properties of sublimated products provide high quality sterilization.
To obtain high efficiency of creating sterilizing agents in the form of ozone and ultraviolet radiation at low heat generation, it was possible to use such types of discharge as pulsed, barrier, spark and glow discharging alternating current. This paper considered the spark and glow discharges of alternating current due to the relative simplicity of their organization.

2. Experimental results

In order for the effect of the bactericidal factors of the electric discharge on the processed products to be more effective, the distribution of the discharge parameters over the packaging volume must be uniform. As is known, often achieving a uniform discharge is a difficult task even in specially organized conditions of laboratory installations, especially with increasing energy parameters of the discharge. The conditions of the packaging process differ sharply from stable laboratory conditions.

The presence of the processed product inside the discharge volume and the evacuation of air greatly complicates the task of obtaining a homogeneous distribution of the parameters of the gas discharge plasma. Moreover, it is more difficult to obtain the same reproducible result in the bulk packaging process. To improve the homogeneity of the plasma treatment of a substance, various methods can be applied, for example, applying a magnetic field [1, 2].

In [3], the possibilities of influencing the parameters of a gas discharge plasma with the help of specially created acoustic waves were considered. These sound waves, under certain conditions, can contribute to the alignment of plasma parameters over the volume of the discharge chamber. This ability can be used to improve the homogeneity of the parameters of the gas discharge plasma in the process of packaging sublimated products. Acoustic waves, with adjustable frequency and amplitude, emitted inside the pumped package can provide a more uniform distribution of sterilizing effects.

The schematic diagram of the experimental setup is presented at figure 1. For the convenience of observing the process of processing the sublimated product by electric discharge, the vacuum chamber is made of transparent Plexiglas. Freeze-dried products are poured in an even layer onto a metal plate that is simultaneously one of the electrodes and one of the walls of the vacuum chamber. The second electrode is made branched so that an electric discharge occurs in different areas of the vacuum chamber, and the processing of sublimated products proceeds evenly. A speaker is installed under the metal plate.
At the very beginning of the experiment, air was pumped out of the vacuum chamber using a vacuum pump to a pressure of the order of ≈30 Torr. Then a high voltage was applied to the electrodes and a discharge was initiated. The picture of the discharge is presented at figure 2. At first, the discharge channel appeared between different branches of the electrode and periodically changed its position in the chamber, soon it was stopped at a certain point in the space of the chamber and no longer changed its position.

The discharge behavior during the experiments was recorded on a high-speed video camera. Videos were analyzed in slow motion.

In order for the discharge channel not to stop at one point, it was decided to act on it with acoustic waves. The effect of acoustic waves of different frequencies and amplitudes was tested. Significant impact had a low frequency wave of 50–400 Hz, and the best result was achieved at a frequency of 250 Hz. The impact increased with increasing amplitude. With the optimal conditions the discharge changed its location dozens of times per second and did not stop at one point. Thus, it was possible to achieve uniform processing of sublimated products with an electric discharge plasma.

The presence of a product layer on the lower plate of the discharge chamber had practically no effect on the discharge behavior under optimal sound application, when the discharge quickly moved along the surface of the plate. In the absence of sound application at the point where the discharge had stopped, the products had a strong thermal effect and began to burn.

![Figure 2. Photo taken during the experiment.](image)

3. Conclusion
An experimental study was performed to verify the effect of acoustic wave application on the plasma processing of freeze-drying products for sterilization purpose. It was found that additional acoustic wave application improves the efficiency and uniformity of processing. During the experiments, the optimal processing conditions were identified.

Acknowledgments
With the support of a grant from the state assignment of the "Ministry of education and Science of the Russian Federation" for "Fundamental problem of formation and ways of managing the distribution of internal characteristics of a gas discharge" No. 3.6564.2017/ Basic part.
References

[1] Asadullin T Ya, Galeev I G 2017 J. of Phys. Conf. Ser. The magnetic field application for the gas discharge plasma control in processes of surface coating and modification 789 012003

[2] Timerkaev B A, Andreeva A A, Sofronitskiy A O 2017 J. of Phys. Conf. Ser. Discharge creeping along the surface in the process of cleaning and strengthening of the materials surface 789 012063

[3] Galechyan G A 1995 Physics-Uspekhi 38(12) 1309-30