The application of pulsed discharge for sterilization of freeze-dried product

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Abstract. Freeze-dried products are food products prepared by using the freeze-drying method. Freeze-drying is a technology of removing water from fresh products by vacuum method. In the production of food products it allows almost completely preserve their nutrients, vitamins, minerals, even the original form, natural smell, taste, color under a variety of storage conditions. During the drying process, the residual water content reaches a value of about 10%. For safe and secure preservation of dehydrated products, it is necessary to sterilize them and the package properly during the packaging process. For this purpose, it is convenient to use a pulsed gas discharge, which will be ignited inside the package during the vacuuming process. The pulsed nature of the discharge provides high efficiency of creating sterilizing agents in the form of ozone and ultraviolet radiation at low heat deposition. Air exhaust removes gaseous reaction products caused by the discharge. The porosity and dielectric properties of freeze-dried products provide high quality sterilization.

1. Introduction
Low-temperature plasma of gas discharges has a great number of various ways for technical applications[1-5]. In this case, it is a very important to achieve of its limiting characteristics, increase the stability of the discharge, increases the uniformity of its characteristics[6-9], the application of the discharge in the stationary and non-stationary forms for different target products [10-11], etc. For these purposes, it is important carrying experimental and theoretical studies, e.g. [12-14].

Low-temperature plasma of gas discharges be in the use for a long time for sterilizing effect on undesirable microflora. Applicability of discharge for purification of air, water, for exposure to a variety of surfaces is known. The sterilizing effect of the gas discharge is mostly based on the bactericidal properties of the following factors accompanying gas discharges:
- ultraviolet radiation that occurs during the burning of many discharges;
- synthesis of ozone arising from the combustion of discharges in the air;
- ionizing effect of charged particle fluxes;
- high temperature, typical, for example, arc discharge.

In recent times a large number of publications related to using the low-temperature (cold) plasma gas discharges for direct effects on food to improve their storage and transportation conditions are appeared.
For these purposes, mainly used different variants of pulse discharges, such as spark and barrier discharges. There is also evidence of the use of a complex of micro-arcs to produce of cold stream 45 °C) ionized gas to sterilize the surface of the meat.

2. A method of sterilization of freeze-dried products directly in the process of their packaging using vacuum method

In this paper, we offer a method of sterilization of freeze-dried products directly in the process of their packaging using vacuum method.

Freeze-dried products are food products prepared by using the freeze-drying method. Freeze-drying is a technology of removing water from fresh products by vacuum method. In the production of food products it allows almost completely preserve their nutrients, vitamins, minerals, even the original form, natural smell, taste, color under a various of storage conditions. Properly prepared and packed products have a very long period of safe storage, reaching up to tens of years.

Well-known that the presence of water is one of the necessary conditions that favorably affect at the development of undesirable microflora (bacteria, microbes, fungi and viruses). In the drying process, the residual water content is brought to very small values about 10%. In addition, before the vacuum freeze-drying stage, exists the stage of shock freezing, which is also devastating to certain types of microflora. However, despite such processing conditions, part of the primary microflora can be saved in ready-to-store freeze-dried products. The inner surface of the packaging may also contain undesirable organisms.

Application of plasma technologies for bactericidal treatment has a number of advantages than classical types, such as heating (pasteurization) and the use of various additional substances-preservatives. Heating and using the preservatives change the structure, nutritional properties and taste of products. The limitation of plasma bactericidal treatment is its mostly superficial nature of exposure.

Due to the fact that the freeze-dried products are usually small granules of porous structure and because of containing low water level, they are good dielectrics, the penetrating bactericidal effect of sterilizing factors of gas-discharge plasma, obviously, will be higher than in the case of non-dehydrated products.

**Figure 1.** Schematic diagram of the installation.
To improve the quality of bactericidal treatment it is necessary to combine the process of final sterilization with packaging of freeze-dried products process. Special vacuum vessel are used for vacuum packaging of products, which can provide vacuum to the level of residual pressure <1 kPa. Low-density gas will require much lower values of voltage for discharge ignition. In addition, it is easier to organize a diffuse combustion mode of the discharge at lower pressures, which fills the entire volume. In this case, the uniformity of the impact of bactericidal plasma factors on the processed products will be higher.

As mentioned above, to obtain bactericidal factors, it is convenient to use a pulsed gas discharge. That should be ignited inside the package during the vacuuming process. The pulsed nature of discharge provides high efficiency of creating sterilizing agents in the form of ozone and ultraviolet radiation at low heat deposition. To organize a pulse discharge, the product in the package is clamped between two electrodes (cathode and anode) and high voltage is applied (Fig. 1). In the process of air exhausted of the package, breakdown conditions are achieved, and a pulsed gas discharge occurs, which has a sterilizing effect. Continued air exhausted removes gaseous reaction products caused by the discharge. The porosity and dielectric properties of freeze-dried products provide high quality sterilization.

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