SVII-2

高電圧・プラズマの農水応用；栽培・保存などへの活用
Agricultural and Fishery Applications of High-Voltage Plasma; Utilization for Plant Cultivation and Food Preservation

高木 浩一
Koichi Takaki

岩手大・工
Faculty of Engineering, Iwate University

1. Introduction

An intense pulsed electric fields (PEFs) and plasmas applications in agriculture and fishery industrial fields using biological effects are investigated actively. The applications are roughly categorized as decontamination of air and liquid, growth rate control of plants, preservation of harvested fruit and vegetables, and food processing [1]. The electric fields with a pulse length of longer than 10 µs are generally used for electroporation because the cell membrane acts as a capacitor and has to be charged to a sufficient voltage to cause membrane defects [2]. The application of ns PEFs to biological cells results in intracellular effects with the intense electric field inside the cell seemingly adding a new stress to the internal biological system which will potentially be used for biotechnology, medical treatment and agricultural applications. The electric fields also work to collect airborne dust, which includes bacteria, fungi, pollen, algae, dusts, endotoxins, mycotoxins, and viruses, due to the electrostatic effect [3]. This technique can be used in preservation of vegetables, fruits and marine products [4]. The discharge plasma produces chemically active species, such as atomic oxygen (O), ozone (O_3) and hydroxyl radicals (OH), which work to inactivate the pathogenic fungi and bacteria. Additionally, underwater discharge produces nitric acid, which works as a fertilizer [5]. The paper describes the effect of the high-voltage and plasma on plant growth rate, mushroom yield, and preservation term of marine products.

2. Improvement mushroom yield

Figure 1 shows the *L. edodes* crop harvested under five different pulsed voltage stimulation conditions. One group was cultured without pulsed voltage stimulation and was used as a reference, i.e., the control group. Three groups were stimulated by a single high-voltage pulse with three different amplitudes: 50, 90, and 125 kV. The last group was stimulated 50 times with a 50 kV pulsed voltage. The yield of the fruit body was evaluated as the total weight harvested during four seasons. It includes the crops from all 15 logs, appropriately averaged. The yield of the control group was only 2 g in the first harvesting season, autumn of 2007, because the *L. edodes* species used in the present experiment mainly fruits in the spring. In this case, the 30 g weight of fruit bodies was harvested from only one log. The yield from the first season increased from 2 to 73 g when a 50 kV pulsed voltage was applied. The yield increased from 73 to 153 g when the number of voltage treatments

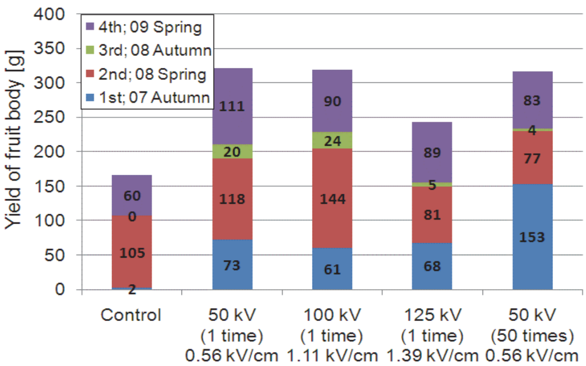

Figure 1. Total weight of cultured *L. edodes* for various electrical stimulation conditions.

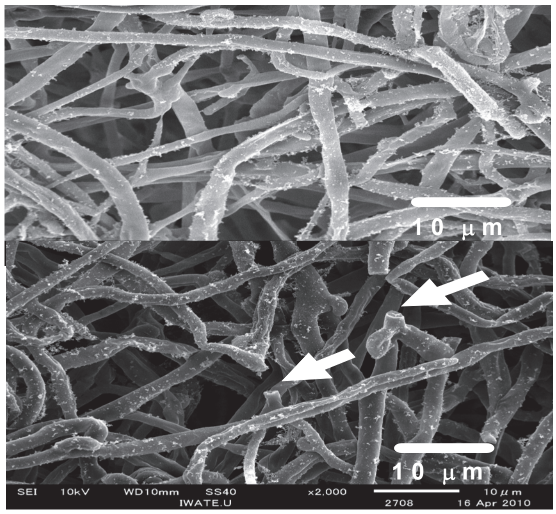

Figure 2. SEM images of *Lentinula edodes* hypha before (top) and after (bottom) applying 10 kV pulse high-voltages.

increased from 1 to 50. **Figure 2** shows scanning electron microscope (SEM) images of hyphae before and after applying pulse voltage. It is confirmed that some parts of the hyphae are ruptured with force generated with the pulse electric field. The application of the pulse electric field generates the forces to the hyphae. Many parts of the hyphae are displaced by the force and some hyphae are ruptured. This is candidate of triggering fruit body formation.

3. Improvement mushroom yield

Figure 3 shows photographs of *Brassica rapa var. perviridis* at 28 days of cultivation for various plasma irradiation times. The plasma was irradiated in the drainage water for 10 and 20 minutes each day. One group consisted of three cultivated pots. Another group (the control) was cultivated without plasma irradiation. All *Brassica rapa var. perviridis* plants grew by 28 days of cultivation. The leaf size of the plants increased with plasma irradiation, changing with the irradiation time. The use of plasma in the water can supply many kinds of chemical species, such as OH, O, O_3, NO_2, NO_3, and H_2O_2, among others. Nitrate and nitrous species in the drainage water were measured to clarify the effect of plasma irradiation on the plant growth rate because nitrous nitrogen typically works as a fertilizer in plant cultivation [5].

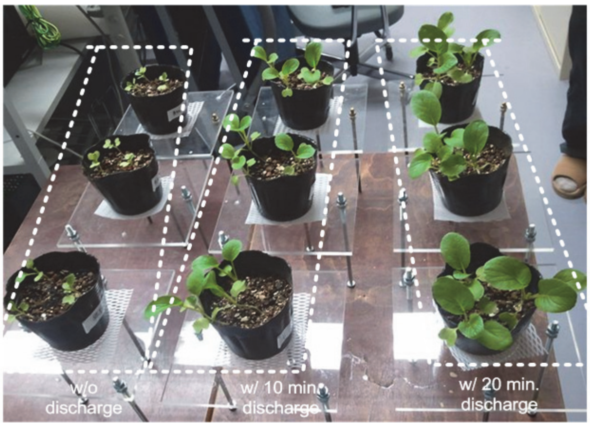

Figure 3. Photographs of *Brassica rapa var. perviridis* cultivated for 28 days at (a) w/o plasma and with (b) 10 min. or (c) 20 min. of irradiation per day.

4. Preservation of marine products

AC electric field was used to improve a freshness of perishable food such as purple sea urchin. **Figure 4** shows the gel electrophoresis profile obtained by the SDS-PAGE analysis. For the group which did not apply the AC electric field at the time of a freeze, the amount of molecules with the molecular weight of less than 70000 has increased, and the amount of molecules with the molecular weight of 150000~180000 has decreased. This indicates the

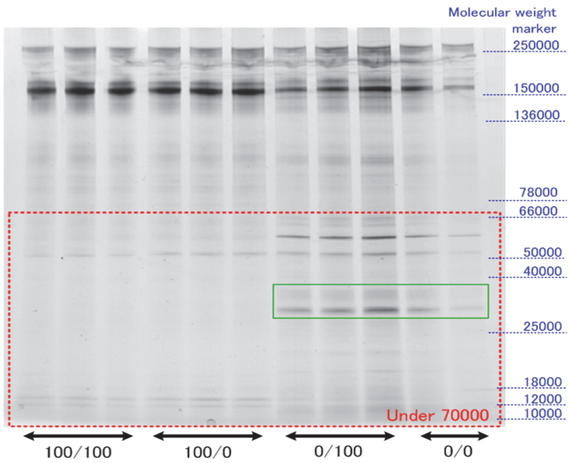

Figure 4. Gel electrophoresis profiles. [Output voltage in freezing / in defrosting].

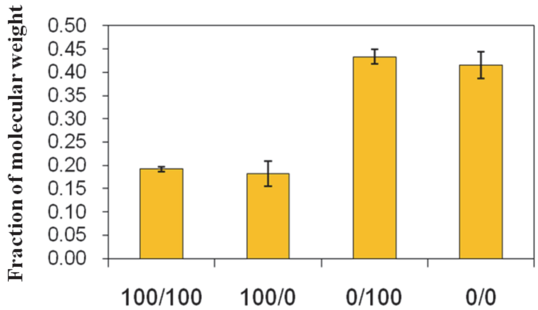

Figure 5. Amount of proteins with the molecular weight of less than 70000. [Output voltage in freezing / in defrosting].

decomposition of protein, which is digestion. Furthermore, when the AC electric field was applied to purple sea urchin at the time of a freeze, the amount of protein with the molecular weight of less than 70000 has decreased by 50% in **Fig. 5**. This fact shows that the decomposition of proteins is inhibited by the effect of the AC electric field at the time of a freeze. However, there was no influence on the amount of protein with the molecular weight of less than 70000 by applying the AC electric field at the time of defrosting. From these results, it is possible that the effect of the AC electric field improves the technique keeping freshness because the decomposition of proteins is related to freshness of foods.

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