Cold Plasma in Field of Animal Husbandry

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As an innovative technology in biological applications, cold plasma is widely used in oral treatment, tissue regeneration, wound healing, and cancer therapy, etc., because of the adjustable composition and temperature which allow the plasma to react with bio-objects safely. Reactive oxygen species (ROS) produced by cold plasma regulate cell activity in an intensity- and time-dependent manner. Cold plasma exposure at a high intensity or an extended time shows excellent performances in killing various microorganisms existing in the environment or on the surface of animal food, and preparing inactivated vaccines, while cold plasma treatment within the appropriate conditions improves chicken growth and reproductive capacity. The potential applications of cold plasma treatment in relation to animal-breeding environments, animal health, their growth and reproduction, and animal food processing and preservation are introduced, which are all beneficial to the practice of animal husbandry and guarantee good animal food safety results.

cold plasma animal husbandry animal health food safety

1. Introduction

Animal husbandry is an important part of modern agriculture, which focuses on the animal-breeding environment, animal health, their growth and reproductive performance, and animal food processing and preservation. Several factors, such as environmental pollution and the abuse of antibiotics, have severely affected the progress of animal husbandry, and the health and safety of both animals and human beings. Exploring new technologies and methods to improve animal husbandry practices and ensure the safety of animal food consumption is an urgent requirement for the healthy development of animal husbandry. As a safe and environmentally friendly form of technology, cold plasma has a potential application value in the field of animal husbandry [1].

2. Cold Plasma Improves Animal Breeding Environments and Health

The presence of a variety of microorganisms and animal excreta in the animal-breeding environment can increase the risk of disease in animals. The purification of their breeding environment can not only provide animals with a healthy and comfortable space, but can also help to reduce the risk of biological pollution. Cold plasma can not only effectively inactivate methicillin-resistant *Staphylococcus aureus*, *Dermatobacter acne*, *Escherichia coli*, and *Salmonella typhimurium* in the environment [2][3], but can also reduce harmful volatile organic compounds and odors in the air [1]. This fact shows that cold plasma has the potential to purify the breeding environments of animals. In addition to indirectly protecting the animals'health by improving their breeding environments, the

disease resistance of animals can be improved by directly injecting the vaccines, where inactivated vaccines play an increasingly important role in the healthy development of animal husbandry practices. At present, cold plasma has been used in the preparation of inactivated vaccines against Newcastle disease and H9N2 influenza viruses. Cold plasma treatment administered for an appropriate amount of time (plasma jet, 2 min) can inactivate the virus without destroying its antigenic determinant. Compared with the traditional inactivated vaccine, which is prepared using formaldehyde, cold plasma can induce higher specific antibody titers for protecting chickens from Newcastle disease and avian influenza [4]. Therefore, cold plasma is expected to be used in the future to improve animal-breeding environments and protect the life and health of animals.

3. Cold Plasma Improves Animal Growth and Reproduction Outcomes

The growth and reproductive performance of animals are factors directly related to production level and economic development outcomes. In recent years, researcher's laboratory studied the effects and mechanisms of cold plasma on chicken growth and reproduction rates [5][6][7][8][9][10]. Researchers observed that cold plasma treatment administered to chicken HH20-stage embryos at an appropriate intensity (voltage at 11.7 kV) and for an appropriate amount of time (1 min) promoted embryonic development, while the administration of high doses of cold plasma (voltage at more than 11.7 kV, treatment time of 4 min) resulted in the death of chicken embryos through the destruction of the antioxidant defense pathway in a dose-dependent manner, which resulted in an excessive accumulation of reactive oxygen species (ROS) and reductions in the numbers of genes and proteins related to embryonic development and the concentration of adenosine triphosphate (ATP) present in skeletal muscles [5]. In addition, researchers observed that an appropriate amount of cold plasma (voltage at 11.7 kV and treatment time of 2 min) improved the growth of chickens, which showed significant increases in their average daily weight gain and tibia length. The improving mechanism of cold plasma treatment on chicken growth outcomes was related to the increased ATP level and ROS homeostasis, which were mediated by mitochondrial respiratory metabolism and the antioxidant defense system; moreover, cold plasma increased the expressions of thyroid and growth hormones and insulin-like growth factor through regulating the demethylation level of growth-related hormone biosynthesis and energy-metabolism-related genes in the skeletal muscles and thyroids of chickens [6][9].

Semen quality is an important indicator of animal reproductive performance, which is closely related to the fertility, litter size, and survival rate of the offspring [11]. Sperm DNA hypomethylation can promote embryo development and differentiation, while hypermethylation leads to spermatogenesis disorders and sperm quality defects [12]. In vivo and in vitro experiments showed that the appropriate administration of cold plasma treatment (voltages at 11.7 kV, treatment time of 20 s for in vitro spermatozoa and 2 min for in vivo semen) improved male-chicken sperm quality and fertility via the increases in serum testosterone and sperm ATP levels, which were regulated by DNA demethylation, miRNA differential expression, semen ROS homeostasis, and sperm mitochondrial metabolism [7][8][9]. In addition, cold plasma affected the proliferation of chicken Sertoli cells through the adenosine-monophosphate-activated protein kinase-rapamycin target protein signaling pathway, which were target-regulated by miR-7450 and miR-100 in a dose-dependent manner (voltage at 11.7 kV, treatment time of 30 s increased

Sertoli cell viability and growth whereas more than 60 s led to cell viability inhibition and cell apoptosis); this was beneficial to provide nutritional and structural support for the spermatogenesis process [10]. Therefore, cold plasma can be administered to improve the growth and reproductive performance of poultry; however, it remains unclear in the literature whether it can successfully promote the growth and reproduction of livestock. The optimization of cold plasma treatment conditions and its mechanisms need to be explored in future research.

4. Cold Plasma Is Beneficial to the Processing and Preservation of Animal Foods

Fresh animal food easily deteriorates or even rots during storage due to microbial contamination. Therefore, processing fresh animal food by killing microorganisms can extend its shelf life [13]. ROS, reactive nitrogen species (RNS), and nitric oxide (NO) produced by cold plasma play a key role in the inactivation of microorganisms and the formation of nitrite in meat products [14]. As a food additive, nitrite is often used to pickle meat products and prevent the contamination of pathogenic microorganisms, such as *Clostridium botulinum*, *Staphylococcus aureus*, and *Clostridium perfringens* [15]. Cold plasma technology is used in the research, at present, to pickle pork sausages because cold plasma-producing ROS may directly result in microbial death by destroying microbial DNA; on the other hand, nitrite formed by cold plasma treatment can maintain the color, flavor, and lipid oxidation of pork [14]. Cold plasma as a safe and effective form of technology has been applied in research to extend the shelf life of animal food [16]. Studies have shown that cold plasma can effectively inactivate *Listeria monocytogenes*, *Escherichia coli*, and *Salmonella* present in fresh chicken, pork, and beef products [17][18][19]; reduce the *Escherichia coli* in milk [20] and *Salmonella* on the surface of eggs [21]; and does not damage the quality of meat, milk, and eggs [19][20]. In addition, cold plasma technology can be applied for the successful preservation of animal food because of its advantage of sterilization. Studies have shown that the shelf life of chicken breasts packed in bags was effectively extended [16] because of the application of cold plasma (DBD, voltage at 80 kV and treatment time of more than 3 min), which can deactivate the *Escherichia coli* in the bags [22]. Therefore, cold plasma can be applied in the processing of animal foods, extending their shelf lives.

5. Conclusion

Cold plasma technology has shown great application potential in the field of animal husbandry. The effect of cold plasma on bio-object mainly depends on the levels of bioactive substances, such as ROS, RNS, and NO, which are produced in an intensity- and time-dependent manner. Therefore, it is particularly important to control the intensity level and treatment time of cold plasma therapy. The various applications of cold plasma to the practices of sterilization, biological purification, vaccine preparation, food processing, and improvements to animal growth and reproductive capacity are conducive to promoting the healthy development of animal husbandry practices. However, cold plasma treatment conditions require further optimization and its mechanisms need to be further studied in the research.

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