Process and Quality Study of Cold Fresh Pork Under Low Temperature Plasma Treatment

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Abstract. As a novel green cold sterilization technology, low-temperature plasma has great potential application in food storage and preservation. In this paper, a low-temperature plasma discharge technology was adopted to treat the surface of cold fresh pork, and its bactericidal effect was observed by changing the discharge power and exposure durations, which indicated that the total number of colonies could be reduced by 2 log values under the optimized treatment process of (400 W, 30 s). The quality test showed that the volatile basic nitrogen (TVB-N) value of the treated group was significantly lower than that of the untreated group, reaching 7.38 mg/100 g after storage for 5 days compared with 9.67 mg/100 g for the untreated group. PH value and juice loss rate was decreased into a certain degree level after plasma treatment, indicating that plasma treatment inhibited the activity of endogenous enzymes to some extent and delayed the freshness reduction of cold fresh pork. It can be seen that, low-temperature plasma has an obvious inhibitory effect on microorganisms on the surface of fresh cold pork, and has no negative effect on pH and juice loss rate, which can prolong the storage and preservation period.

Keywords: Low temperature plasma · Storage preservation · Total number of colonies · Quality analysis

1 Introduction

In the traditional preservation and processing of meat and meat products, controlling and inhibiting the growth and reproduction of microorganisms are key technologies, generally including heating, reducing moisture activity, temperature reduction and preservatives addition. Traditional processing processes usually produce some undesirable chemical products or cause changes in sensory properties, and the by-products produced during processing cause changes in flavor or nutrients. Therefore, traditional processing techniques are often used for foods that are easy to handle, such as cooked products. With the progress of science and technology, consumers are pursuing higher and higher quality of life, so preserving the material characteristics of food itself becomes the key step to be processed, In particular, how fresh products can better retain

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the quality of food itself such as cold fresh pork, brings new challenges to food processing methods [1].

As a new non-thermal food processing technology, low-temperature plasma technology has attracted more and more attention from scholars at home and abroad. Compared with food thermal processing technology, this technology has the advantages of safety, mildness, simple operation and low cost, and has been widely used in material processing [2], electronics [3], polymer processing, biological medical devices and biological materials and other fields [4]. The characteristics of low temperature plasma is able to produce a large amount of reactive oxygen species (reactive oxygen species, ROS) and reactive nitrogen (reactive nitrogen species, RNS) in the atmospheric conditions, of which ROS refers to oxygen atoms or groups with active chemical properties, including ozone, hydrogen peroxide, singlet oxygen molecules, superoxide anion radicals, hydroxyl radicals, etc. RNS refers to derivatives centered on nitric oxide (NO), including nitrogen oxides such as nitrogen dioxide (NO2), nitrogen trioxide (N2O3), and nitrogen tetroxide (N2O4) [5]. These active substances can inhibit or kill microorganisms by interacting with the surface of meat and its related products [6].

A large number of literature studies show that plasma has an obvious bacteriostatic effect. Dirks et al. [7] reported that dielectrically barrier discharge (DBD) can effectively inhibit the growth of microorganisms on the skin surface of skinless chicken breast and thigh, and reduce the total number of microorganisms by a logarithmic value. Ulbin-Figlewicz et al. [8] used He and argon plasma to treat the surface of pork, and found that He plasma treatment has a significant bacteriostatic effect, and the total number of microorganisms, yeast, mold and cold-loving microorganisms in pork are reduced by about 1.90, 1.14 and 1.60 (lg (CFU/g)) respectively, and the effect is more obvious with the extension of treatment time. In contrast, argon plasma has a lower inhibition effect on microbial growth. Zhang et al. [9] found that low-temperature plasma treatment of beef can enhance the surface brightness of beef during cold storage, reduce the red color, and have no significant negative impact on the pH and texture characteristics of beef. Therefore, low-temperature plasma technology, as a new non-thermal processing technology, has shown its advantages compared with traditional thermal technology, including safety, mild, non-destructive, simple operation and low cost.

According to the plasma generation system, low-temperature plasma discharge generally includes dielectrical barrier discharge (DBD), atmospheric plasma jet (APPJ), gliding arc discharge [10] and corona discharge [11]. Compared with other low-temperature plasma technologies, the gliding arc discharge technology adopted in this paper has the characteristics of simple operation and large processing area, and the ionized gas generated by the discharge has strong active bactericidal characteristics, and has shown extensive bactericidal effect on various foodborne microorganisms [12]. Based on the good bactericidal effect of gliding arc discharge technology, this paper would explore its application in the cold sterilization of food, took cold fresh meat as the treatment object, studied the deactivation effect of this technology on the surface microorganisms of cold fresh pork, and evaluated the impact of gliding arc discharge treatment on the quality of cold fresh pork.

2 Materials and Methods

2.1 Materials and Reagents

Cold Fresh pork was bought at Beinong Supermarket, and PCA Plate Counting Medium from Beijing Oboxin Biotechnology Co., Ltd, and Aseptic Homogeneous Bag from Ningbo Scientz Biotechnology CO., Ltd, and Hydrochloric Acid Standard Solution from Shenzhen Bolinda Technology Co., Ltd.

2.2 Plasma Generating Device

The atmospheric plasma discharge device was mainly composed of a power source, a processing chamber, a gas flow test table, As shown in Fig. 1. There were two parallel copper electrodes in the reaction chamber (length 93 mm, thickness 3.6 mm, gas from the top of the reactor) The cold fresh meat sample was placed in the lower part of the reactor port. When the gas passed through the reactor, it was broken down by a voltage of 10 kV between the two copper sheets to generate a gliding arc discharge, and the raw meat sample at the lower end of the reactor was processed. Processing parameters for plasma discharge included sliding arc discharge power, gas flow rate, and processing time.

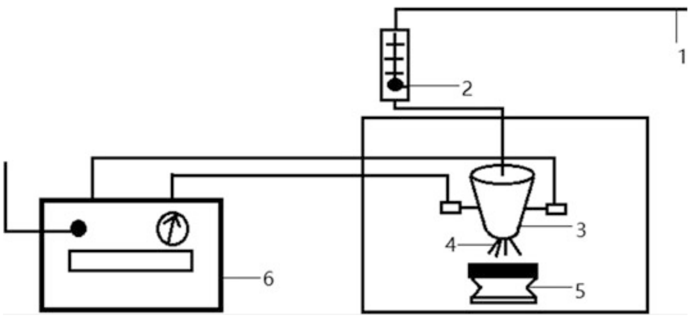

Fig. 1. Atmospheric plasma discharge equipment. 1. Gas source, 2. gas flow tester, 3. reaction chamber, 4. sliding arc discharge, 5. sample stage, 6. power supply

2.3 Method

2.3.1 Raw Material Processing

Cold fresh pork was cut into pieces of uniform size, thin thickness and uniformity of 20 ± 1 g. The power was set as 450 W, the gas flow rate was 40 L/min, with atmospheric plasma (0, 15, 30, 60 s). When the treatment time was set to 30 s and the gas flow rate was 40 L/min, it was treated with atmospheric plasma (0, 300, 350, 400, 450, 500 W). The meat sample was placed in a homogenized bag, with addition of 180 mL of physiological saline, and was homogenized for 1–2 min. After gradient dilution, the plate was plated with appropriate dilution, and then cultured at 37 °C for 24 h to count the colony. The sterilization rate could be calculated as follows:

Sterilization rate = $\frac{No-Np}{No} \times 100$

Among them in the function: No: control group colony number, CFU/g, N_P: treatment group colony number, CFU/g

2.3.2 TVB-N Value

Determination of TVB-N values by semi-micro distillation. By weighing 10 g ground pork in a beaker, adding 100 mL distilled water, stirring evenly, for 30 min filtration. 5 mL of filtrate, and 5 mL magnesium oxide suspension (10 g/L) was mixed, and distilled to be titrate with 0.01 mol/L standard hydrochloric acid solution, according to the amount of hydrochloric acid calculated by the amount of TVB-N. Primary freshness: TVB-N value $\leq$ 15 mg/100 g; secondary freshness 15 mg/100 g, TVB-N value $\leq$ 20 mg/100 g; metamorphic meat: TVB-N value > 20 mg/100 g. Following equation:

TVB-N (mg/100 g) = $\frac{V_1 - V_2 \times C \times 14}{m \times 5/100} \times 100$

Where V_1 and V_2 represent the volumes of HCL required for titration of the mixture with shrimps and the one without shrimps (ml); C is the concentration of HCL used in this study (M); and m denotes the weight of shrimps sample (g).

2.3.3 pH Determination

The treated samples were stored under refrigeration at 4°. The samples taken at the same time every day were measured with a pH meter. Each sample was recorded and the pH meter was rinsed with distilled water. Three groups of samples were run in parallel for five days.

2.3.4 Juice Loss Rate

The samples of cold fresh pork were measured after treatment; the samples were taken at the same time every day (for five days), and the quality of the absorbent paper was measured after the surface juice was removed. The difference between the quality of the Nth day and the quality of the first day was the same as that of the first day. The quality of cold fresh pork after one day of treatment is the rate of juice loss from cold pork.

3 Results and Discussion

3.1 Sterilization Effects

Cold fresh meat was just slaughtered pig carcass, rapid cooled at low temperature down to 0–4 °C, during which the main effect of temperature is to inhibit the activity of enzymes and the growth and reproduction of most microorganisms. However, in the process steps of processing, storage, transportation and marketing steps, it was difficult to avoid infecting microorganisms in the environment, which thus affected the hygienic level of cold fresh pork. In this study, the effect of low-temperature plasma treatment on the inactivation of microorganisms on the surface of cold fresh pork was first studied. Figure 2 shows the influence of different plasma discharge powers on the total number of colonies on the surface of cold fresh pork. In order to accelerate the test effect, the storage temperature of cold fresh pork was set at room temperature.

Compared with the control group, there was no significant change in the total number of colonies on the surface of cold fresh pork treated with plasma. With the extension of storage duration time, the total number of colonies on the surface of cold fresh pork began to increase, and the total number of colonies on the surface of the control group exceeded 6 log values at day 2.2, reaching the standard of rotten pork. In contrast, the plasma-treated samples showed a reduced total number of colonies on their surfaces, all of which did not satisfy the criteria for putrefied meat until the third day. The higher the discharge power, the longer it will take for the cold fresh pork to reach the decay level, especially for discharge powers over 400 W. The storage time of cold fresh pork can reach 5 days, extending the shelf life by twice. This may be because the higher the power, the higher the gas ionization degree, the higher the electron density and ion density in the plasma, so as to improve the interaction degree between plasma and microorganisms from the pork surface, resulting in enhanced sterilization intensity. Among the active ingredients of low temperature plasma are hydroxyl radicals, which are strong oxidants and can exist for a long time. Choi et al. [13, 14] studied the effects of atmospheric plasma discharge on microorganisms in instant pickles by generation spectra and found that OH present in plasma is an important bactericidal component.

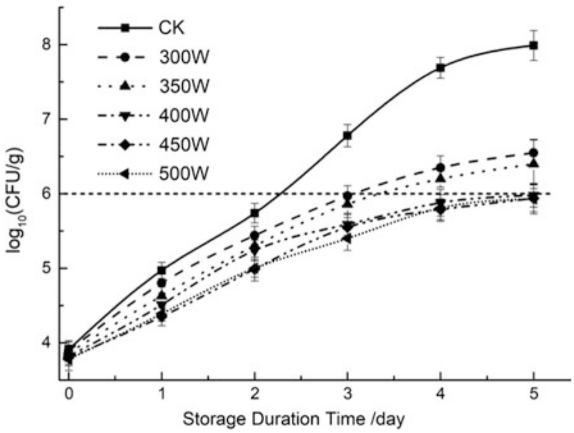

Fig. 2. Effects of discharge power on the sterilization rate of cold meat surface with plasma exposure duration time of 45 s and gas flow of 40 L/min

In order to study the influence of time accumulation effect on sterilization effect, the influence of different exposure time at the same power on the total number of bacterial colonies on the surface of cold fresh pork was studied as shown in Fig. 3. Although the active ingredients in the plasma have bactericidal effect, during the interaction between the plasma and microorganisms, the active ingredients in the plasma will also act on the surface of cold fresh pork, causing a certain degree of damage to the surface of chilled meat. Does this damage affect the quality of cold fresh pork? The following will be verified from TVB-N, pH and juice loss rate.

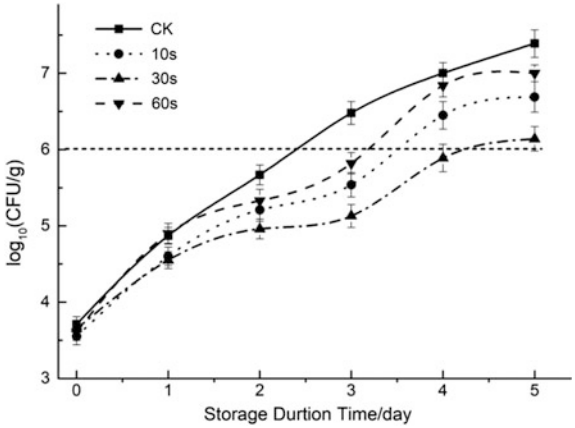

Fig. 3. Effects of plasma exposure duration time on the sterilization rate of cold meat surface with discharge power of 400 W and gas flow of 40 L/min

3.2 TVB-N Effects

TVB-N reflects the freshness level of cold fresh pork, and is an important indicator for evaluating the corruption and deterioration degree of meat products. The main principle of TVB-N value is to assess the freshness by measuring the alkaline nitrogenous volatile substances such as ammonia and amines produced by protein decomposition under the action of endogenous enzymes or bacteria. As shown in Fig. 4, the initial value of TVB-N of untreated samples is 4.97 mg/100 g, which gradually increased to about 11.09 mg/100 g with the storage time. TVB-N value of the treated samples was increased to 9.24 mg/100 g (day 5) with the storage time, which was lower than the original value, indicating that the cold fresh meat was still in a relatively fresh state. Since high level of TVB-N in cold fresh meat may be related to bacteria and endogenous enzymes to produce alkaline nitrogen compounds. After plasma treatment of cold fresh pork, TVB-N values has a relatively enormous reduction. In addition to the microbial inactivation of surface of cold fresh pork, TVB-N reduction is related to endogenous enzymes activity of cold fresh pork, which suggested the plasma treatment can inhibit the activity of endogenous enzymes in the cold fresh pork. Lackmann et al. has investigated the capabilities of nonthermal atmospheric-pressure plasmas to inactivate RNA, and found that direct plasma treatment with a DBD source caused permanent inactivation of RNA and continued plasma exposure led to over-oxidation of structural disulfide bonds. Ke et al. [15] has studied the effects of non-thermal plasma on horseradish peroxidase, and found that activity together with the contents of heme and iron in horseradish peroxidase decreased dramatically and on comitantly upon plasma treatment, since hydrogen peroxide from plasma broke the heme prosthetic group into fluorescent products, mainly dipyrroles and their derivatives [16]. Therefore, the inactivation of enzyme activity in the fresh meat may be the dominant factor to keep the storage circle, as its kinetic mechanism will be further instigated in next work.

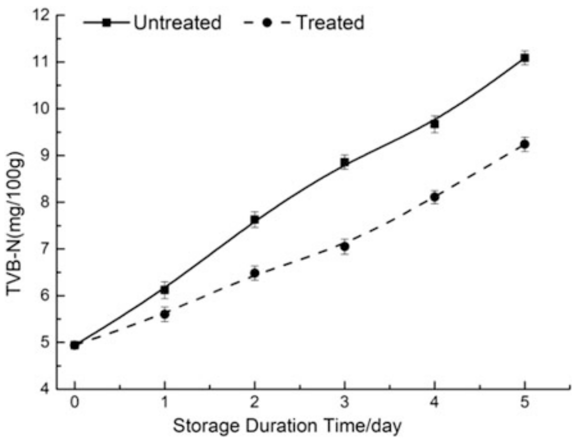

Fig. 4. Effect of atmospheric plasma treatment on TVB-N value of cold fresh pork

3.3 pH Effects

The pH value of pork is used as the detection index of meat products. The pH range of 5.8–6.2 is generally high in freshness, the range of 6.3–6.6 is secondary fresh pork, and the above 6.7 is rotten pork. The samples used in this study have high freshness, as shown in Fig. 5. As the storage time increases, the pH value gradually increases, indicating a decline in freshness. This is because some of the proteins inside cold fresh pork were broken down by bacterial enzymes into ammonia and amines, contributing to the increasing trend of pH. The freshness of the plasma treated samples showed the same change trend, and the pH value of the treated samples remained somewhat lower than that of the untreated samples. This further proved that plasma treatment was beneficial to inhibit the proliferation of bacteria on the surface of cold fresh pork and the decomposition of some proteins inside, and thus prolonged the storage and preservation period of cold fresh pork.

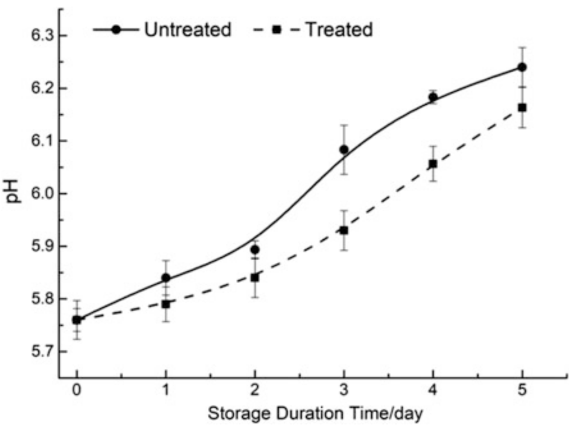

Fig. 5. Change trend of pH value as a function of storage duration time with untreated and treated samples

3.4 Juice Loss Rate Effects

Juice loss rate is an important index to evaluate the quality of cold fresh pork, reflecting the water retention of cold fresh pork, which will accelerate protein denaturation rate and muscle fiber structure changes. As shown in Fig. 6, the juice loss rate of cold fresh pork increased with the extension of storage period. After storage time of 5 days, the untreated group reached 3.42% with comparison of 2.56% for the treated group. The experimental results showed that low-temperature plasma treatment could not accelerate the increase of surface moisture of cold fresh pork, but was beneficial to reduce the rate of juice loss, which might be due to the fact that charged particles, groups and active substances generated during low-temperature plasma treatment could promote the ability of cold fresh meat to bind water molecules. The rate of juice loss was related to protein decomposition and muscle fiber structure changes during storage. It can be seen that low-temperature plasma treatment had no negative impact on the water holding capacity of cold fresh pork, indicating that the cold sterilization technology had certain advantages in the storage and preservation of fresh food.

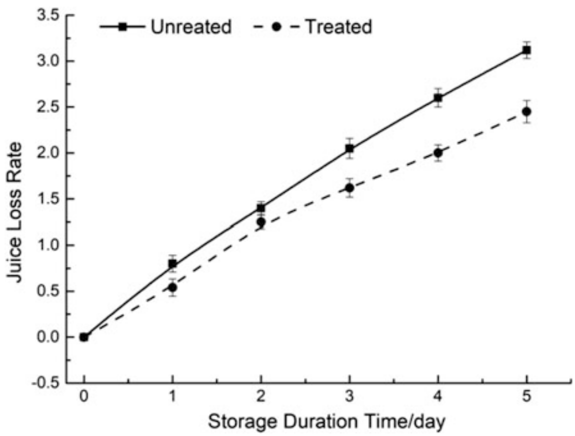

Fig. 6. Trend rate of juice loss rate as a function of storage duration time with untreated and treated samples

4 Conclusions

In this study, the surface of cold fresh pork was treated with atmospheric plasma discharge technology, and the results showed that atmospheric plasma treatment could effectively inhibit the growth of microorganisms in the surface of cold fresh meat, which was conducive to maintain the quality of cold fresh meat and extend the storage period. The discharge power and treatment time were obtained and optimized as follows: the treatment power was 450 W, and the treatment time was 30 s, when the total number of colonies on the surface of cold fresh pork was decreased the most, that was 2 log values. The quality test showed that the pH value and TVB-N value of cold fresh meat were decreased to a certain degrees under plasma treatment, which inhibited the activity of endogenous enzymes to some extent, since the treated samples were still in the first-order freshness range when stored for five days. At the same time, the juice loss rate of the samples was reduced after treatment, which was beneficial to the storage and preservation of cold fresh pork. Therefore, it can be deduced that atmospheric plasma technology can significantly inhibit the growth of microorganisms on the surface of cold fresh pork, and has no negative impact on the quality of pork. The results of this study also indicated that atmospheric plasma technology, as a new cold sterilization technology, has the characteristics of green and pollution-free for food storage, and has great application potential.

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