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Original Article

# Application of corona electrical discharge plasma on modifying the physicochemical properties of banana starch indigenous to Taiwan

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ABSTRACT

Corona electrical discharge (CED) belongs to an atmospheric pressure cold plasma. In this study, raw banana starch (indigenous to Taiwan), which contained resistant starch and amylose at a level of 58.4 g/100 g and 14.5 g/100 g, respectively, was treated by CED at 30 kV/cm, 40 kV/cm, and 50 kV/cm for 3 minutes. After the CED treatment, starch analyses showed that there were no apparent changes in the resistant starch and amylose contents. Only surface and nonpenetrative damage caused by plasma etching at different voltage strengths were observed on the starch granules. The CED treatments reduced the total area of diffraction peak, gelatinization enthalpy (by −21% to −38%), and different pasting behaviors including peak viscosity, breakdown, final viscosity, and setback. The CED treatments were capable of increasing relative crystallinity and gelatinization temperature. This study revealed the potential of CED plasma technology as a tool to modify the characteristics of banana starch.



## 1. Introduction

Atmospheric pressure nonthermal plasmas (APNTPs), also termed "cold plasma," is a plasma that is only slightly ionized (<1%). This can be operated at room temperature (290–300 K) without any quenching, and using it can avoid thermal degradation of thermosensitive materials. It provides a variety of electrical discharges such as corona electrical discharge (CED), dielectric barrier discharges, atmospheric pressure plasma jet, and micro hollow cathode discharges [1]. Among all different applications of APNTPs, CED plasma is considered cost effective and relatively easy to operate [2].

APNTP has been applied in the food industry for various purposes, including decontamination of raw agricultural products (e.g., apple, lettuce, almond, mangoes, and melon), egg surface, and food system (e.g., cooked meat and cheese) [3]. APNTP is different from traditional thermal pasteurization. It could inactivate microbial enzymes and reduce the degradation of functional components in foods.

Some studies have shown that APNTP could affect the crystallinity of the solid starch granules [4] and improve

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dough strength [5,6]. APNTP-treated flour was found to have an increased stability, strength, deformation energy (W), and index of swelling [7]. Prolonged treatment time and higher applied voltage could improve viscosity and elastic modulus of wheat flour [6].

Native raw banana starch is rich in resistant starch. This makes it a good candidate to confer health benefits such as preventing postprandial blood sugar from rising rapidly. However, restriction of swelling and other physicochemical properties in resistant starch might also make the raw banana starch unfavorable for applications in moisture holding, thickening, and gel forming. Our recent research efforts have also revealed the potential of applying CED plasma technology as an alternative physical approach to modify the property of banana starch indigenous to Taiwan.

In this study, Taiwan's native banana starch was treated with CED plasma at different electrical field strengths. The aim was to improve the physicochemical properties and characteristics of banana starch by CED, and thus to increase its economic potential and industrial applications. Changes in α-amylose and resistant starch contents were determined. The effects of CED plasma at different conditions on the physical functionality including morphological characterization, X-ray diffraction (XRD), thermal analysis, and pasting behavior of treated starch were also investigated.

## 2. Materials and methods

### 2.1. *Materials*

Green banana (Pei Chiao, AAA) was purchased from a local market in Wufeng, Taichung (Taiwan). The Taiwan's native banana starch was extracted according to the methods described by Aparicio-Saguilán et al [8] immediately after harvest.

### 2.2. *CED treatments*

Native banana starch suspension was prepared by mixing native banana starch in deionized water at a ratio of 1:3 (w/w) for 4 hours at 25°C. With reference to the methods described by Han et al [9], the suspension was treated with the CED system (TBA-HT3, YUSING Co., Ltd., Shizuoka, Japan) under a current intensity of 60 A at 30 kV/cm, 40 kV/cm, and 50 kV/cm for 3 minutes. A schematic diagram of the experimental setup is shown in Figure 1. After the CED treatments, the samples were immediately vacuum filtered and dried in an oven at 40°C for 24 hours. Dried starch samples were kept in a refrigerator at about 4°C before analysis.

### 2.3. *Determination of amylose and resistant starch contents*

Amylose content as a percentage of total starch was analyzed using the amylose/amylopectin assay kit manufactured by Megazyme International Ireland Ltd. (Bray, Ireland). Resistant starch content in the banana starch sample was measured using the resistant starch assay kit developed by Megazyme International Ireland Ltd. (Bray, Ireland).

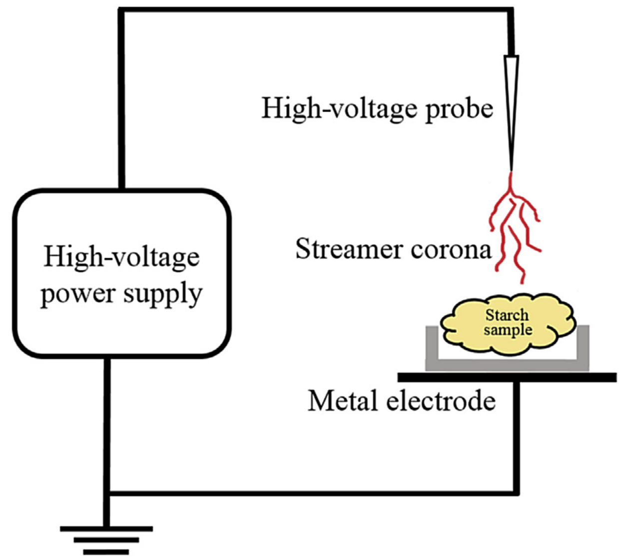


**Figure 1 – Schematic diagram of the experimental setup using corona electrical discharge plasma as a tool to modify starch characteristics.**

### 2.4. *Morphological characterization*

The morphology and birefringence patterns of banana starch samples were examined using a tabletop scanning electron microscope (SEM; TM-1000, Hitachi, Tokyo, Japan) and Nikon microscope (Optiphot 2-Pol, Nikon, Tokyo, Japan). Before SEM observation, samples were fixed on a specimen holder using double-face tape and sputter coated with gold (at 2 mbar for 3 minutes).

### 2.5. *X-ray diffraction*

The relative degree of crystallinity of banana starch samples was investigated by XRD (PW3040; Philips, Amsterdam, the Netherlands) operated at 40 kV and 30 mA with copper as a target. The diffracted intensity was measured from 4° to 60° as a function of 2$\theta$, with a step angle of 0.013° at a scan rate of 1°/min. Percent crystallinity was calculated as the percentage of peak area in the total diffraction area.

### 2.6. *Thermal analysis*

The gelatinization properties of native and CED-treated banana starch samples were analyzed with a differential scanning calorimeter (DSC; Model Q20, TA Instruments, New Castle, DE, USA). Starch samples were sealed in an aluminum pan and mixed with deionized water at a ratio of 1:3 (w/w). After stabilization at 30°C for 5 minutes, the samples were further heated to 150°C at a rate of 10°C/min. The onset, peak, and conclusion temperatures ($T_o$, $T_p$, and $T_c$, respectively) together with gelatinization enthalpy ($\Delta H_{gel}$) were quantified.

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