Effect of Atmospheric Cold Plasma Treatment on Functional Properties of Modified Cassava (*Manihot Esculenta)* Starch

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Abstract

Cold plasma is a growing non-thermal food processing technique that shows great potential in the modification of starch. The working principle of the cold plasma includes using partial ionized positive and negative ions, charged particles in the form of electrons and photons, and gas-containing molecules, free radicals. The cassava plant roots are used to make tapioca starch, which has a starch concentration ranging from 15% to 33%. This research aimed to evaluate the influence of high voltages of cold plasma (10, 15, 20 kV for 5, 10, and 15 min) and its associated changes on the functional properties of tapioca starch when compared with the control (0 kV) sample. The amylose content of treated tapioca starch was decreased during cold plasma treatment. The water-binding capacity, solubility and swelling power of treated starch samples increased. The freeze-thawing stability of treated starch improves as amylose leaching rises after treatment. Based on the findings of this research, the use of cold plasma treatment for the production of modified cassava (*Manihot Esculenta*) starch may be advantageous with a distinct improvement in its functional properties.

Keywords: Atmospheric Cold Plasma, Functional Properties, Cassava (*Manihot Esculenta*) Starch, Starch Modification.

Effect of Atmospheric Cold Plasma Treatment on Functional Properties of Modified Cassava Starch

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Introduction (cassava and significance of starch)

- Cassava (*Manihot esculenta* Crantz.), also called tapioca, is a perennial woody shrub in the Euphorbiaceae family with tuberous roots.

- Cassava is highly tolerant to drought and harsh climatic conditions, and is admirably productive on poor soils and marginal lands.

- These agronomic traits make cassava a reliable crop for food security and various applications.

- Starch, a polysaccharide generated by plant tissues as the primary storage carbohydrate, is a highly adaptable raw material with several uses.

- The roots of the cassava plant has a starch content ranging from 15% to 33%.

Need for Starch Modification

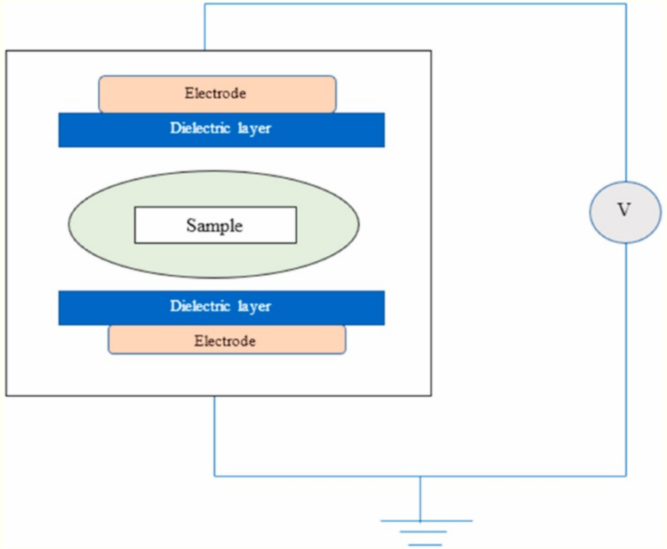
- Starch is the primary comprises of two major polysaccharides: amylose and amylopectin.
- Starch is utilized as a gelling, thickening, stabilizing, and flavour encapsulating agent in the baking, brewing, and confectionery industries.
- In its native state, starch is highly unreactive, insoluble, and retrogrades easily.
- Native starch has many disadvantages like poor solubility, poor shear and thermal stability, poor physical and functional properties.
- Therefore, starches must be modified to enhance their solubility, textural properties, and heat tolerance for diverse industrial applications.
- Starch can be modified using physical, chemical, and biological means.
- Physical methods can either be thermal (heat moisture treatment, spray drying, pre-gelatinization, etc.) or non-thermal (cold plasma technology, pulsed electric field, ultrasonication, high hydrostatic pressure, etc.) and have proven to be successful in modifying starches.

Cold Plasma Treatment

- Cold plasma (also known as non-thermal plasma) is a partially ionized gas produced by applying sufficient energy to a neutral gas at low or atmospheric pressure

- When the energy is applied, the free electrons naturally present in the gas pick up the energy faster than the ions. The accelerated electrons then transfer the energy to heavier gas molecules through elastic and inelastic collisions. As a result of these collisions, the gas goes through several phase reactions-ionization, excitation, and dissociation to produce several reactive species (reactive oxygen species and reactive nitrogen species), new electrons, ions, and free radicals

- The extremely high temperatures are not suitable for treating thermally sensitive materials like starches, which is why cold plasma is a more appropriate method for starch modification and other food applications



Starch modification using to cold plasma

- Starch may be modified by cold plasma in ways like cross linking, depolymerization, plasma etching, functional group incorporation.
- The mechanism of modification mainly depends on the type of feed gas used and treatment time.
- Free radicals and energetic electrons generated helps in cross linking in between the polymeric chains of starch molecules
- The bombardment of high energetic ions of plasma causes depolymerization of amylose and amylopectin side chains of starch molecules resulting in smaller fragments.
- Plasma-generated reactive species causes surface etching and volatilization.

Review of Literature

Types of modification	Modification condition	Parameters evaluated	Findings	Reference
Oxidation	Chemical: sodium chloride (0.5–5% w/v) Temperature: 30 °C Time: 60 min	Syneresis (%)	Syneresis increased on modification; starch treated with 5% sodium chloride had the highest value	Trinh and Dang (2019)
		Solubility	Solubility increased on modification with the salt conten	
Phosphorylation	Chemical: STPP (5%), STMP (2%) Starch: 10 g pH: 9 Temperature: 45 °C Time: 1 h	Swelling power	Initial swelling power, 47.67% increased to 56.43 (STPP) and 52.28% (STMP)	Sugih et al. (2019)
		Solubility (%)	Solubility increased from 19.01, to 28.67 and 47.65% for STPP and STMP, respectively	
Oxidation	Chemical: Ozone Temperature: 30–50 °C pH: 7, 8, 9 and 10	Swelling power (%)	Modified starch had the lowest swelling power at pH 10	Pudjihastuti et al. (2018)
		Solubility	Solubility increased with modification Ph	
Hydrolysis	Chemical: lactic acid Starch suspension: 50% Time: 25 min	Swelling power (g/g)	Swelling power increased from 13.21 to 15.02 and 14.23% after oven and sun drying, respectively	Sumardiono et al. (2019)
		Solubility (%)	Solubility increased from 13.45% to 16.75 and 16.94% after oven and sun drying, respectively	
Esterification	Chemical: citric acid (10, 20, 30, 40%) starch suspension:45% Temperature: 50 °C Time: 24 h	Syneresis (%)	Modified starch had lower syneresis (%) than native starch	Mei et al. (2015)
		Solubility	Solubility reduced on modification; but increased with temperature	

Starch modification using cold plasma

Starch type	Operating conditions	Key findings	Reference
Maize	Power: 75 W Time: 1, 5, and 10 min Gas: Atmospheric air Dielectric material: quartz	Decrease in relative degree of crystallinity, molecular weight and viscosity	Bie et al. (2016b)
Banana	Power: 60–167 W Dielectric material used: Quartz	Alteration in crystalline structure Increased solubility Decreased swelling power	Yan et al. (2020)
Waxy maize starch and normal maize starch	Power: 750 W Frequency: 25 kHz Distance from probe to sample: 14 mm Time: 1–7 min	Etching on the surface of starch granules Increase in water binding capacity Decrease in relative crystallinity	Zhou et al. (2019)
Maize	Power: 750 W Frequency 25 kHz Time: 2min	Decreases in swelling power Increases in solubility Increases in resistant starch content Increases in relative crystallinity Increase in gelatinization temperatures in normal maize while a decrease was observed in waxy maize	Yan et al. (2020)

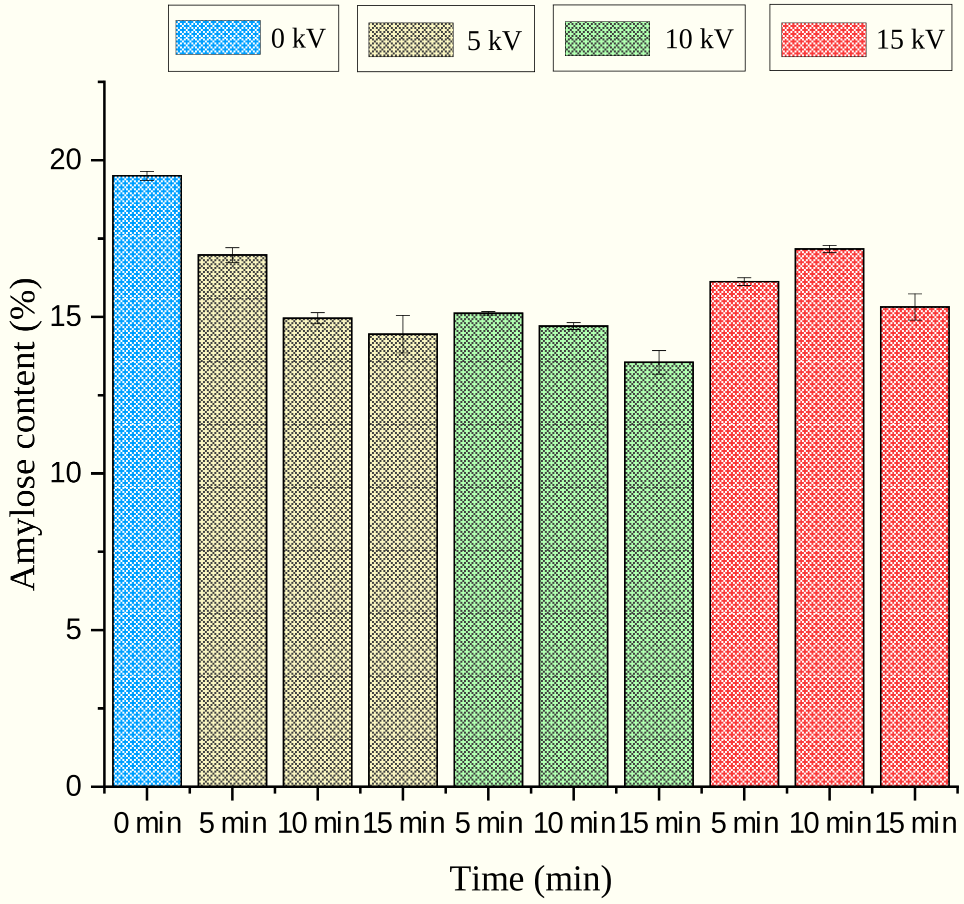
Materials and Methods

- **Treatment condition** : Starch was treated with dielectric barrier plasma at room temperature (~25 °C) and atmospheric air using different high voltages for plasma generation (5, 10 and 15 kV) for 5, 10, 15 min.

- **Amylose Content Determination :** Using spectrophotometric method.
- **Water Holding Capacity (WHC) :** Determined by gravimetric method
- **Solubility and Swelling power :** Determined by gravimetric method
- **Syneresis:** It is an important indicator of the tendency of starch to retrograde. Determined by freezing and thawing .

Result and Discussion

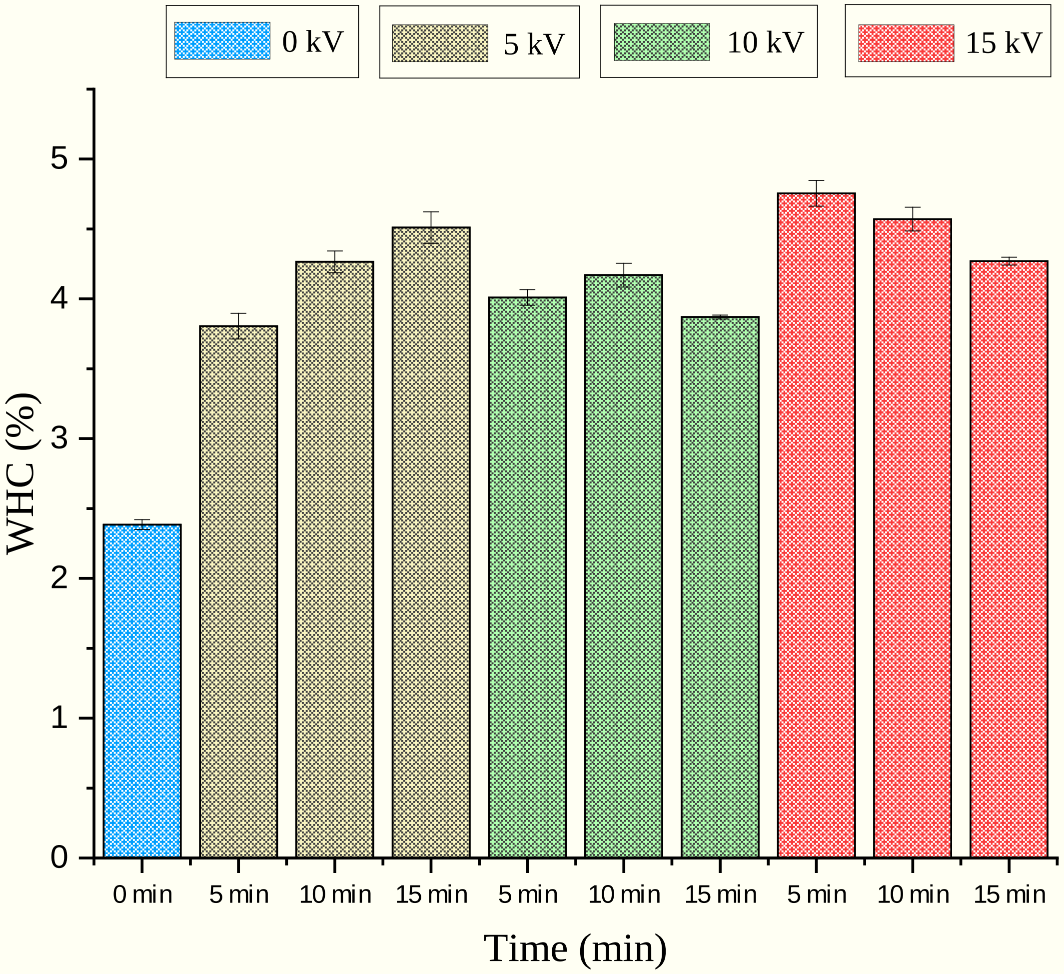
- **Amylose Content Determination:**



•The reduction of the amylose content can be explained by the formation of simple sugars (as glucose), resulted from the interaction between plasma reactive species and glycosidic linkage.

•Although the increase of the plasma voltage causes an increase of the concentration of reducing sugars , higher voltages can favor the appearance of new bounds, increasing the complexation of starch molecules.

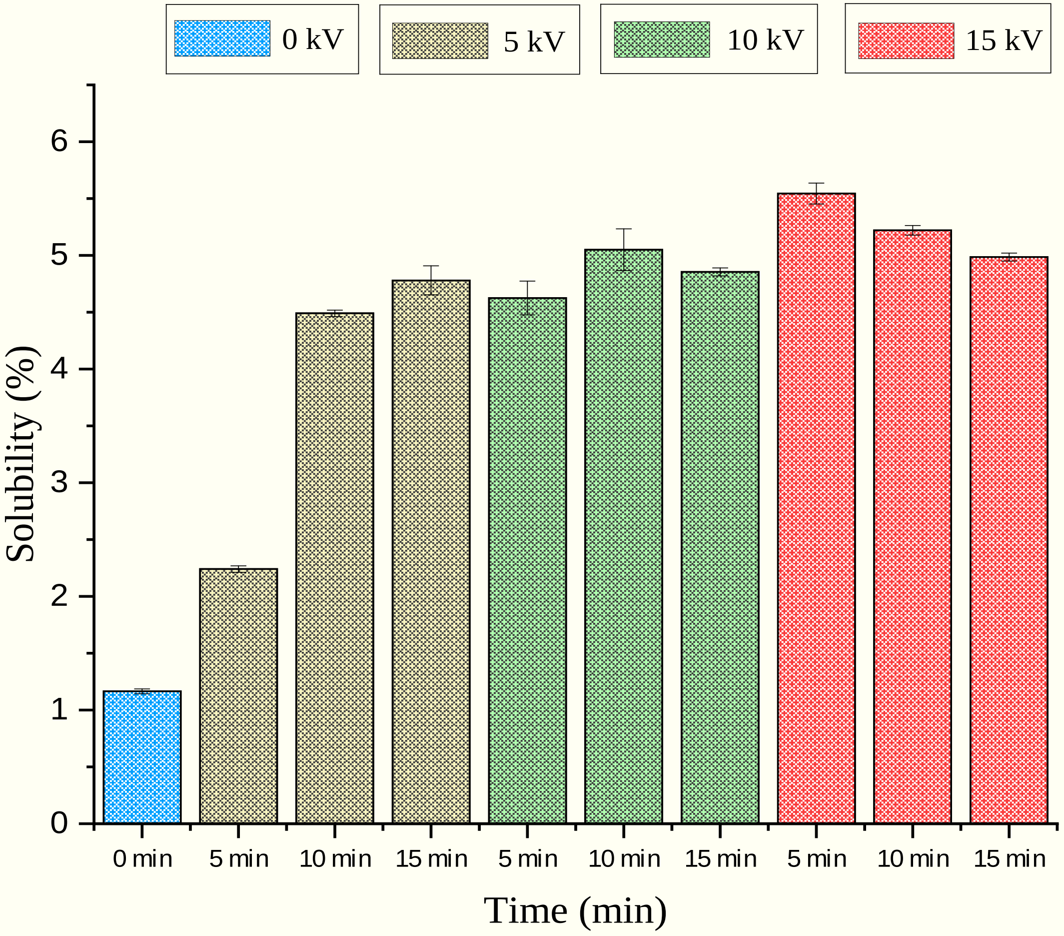
- **Water Holding Capacity (WHC):**



•The increases in water holding capacity can be attributed by increasing hydrophilic nature due to incorporation of OH groups.

•Plasma etching increases effective surface area and hydrophilicity of starch granules, this resulted in increase in the water holding capacity compared to untreated samples

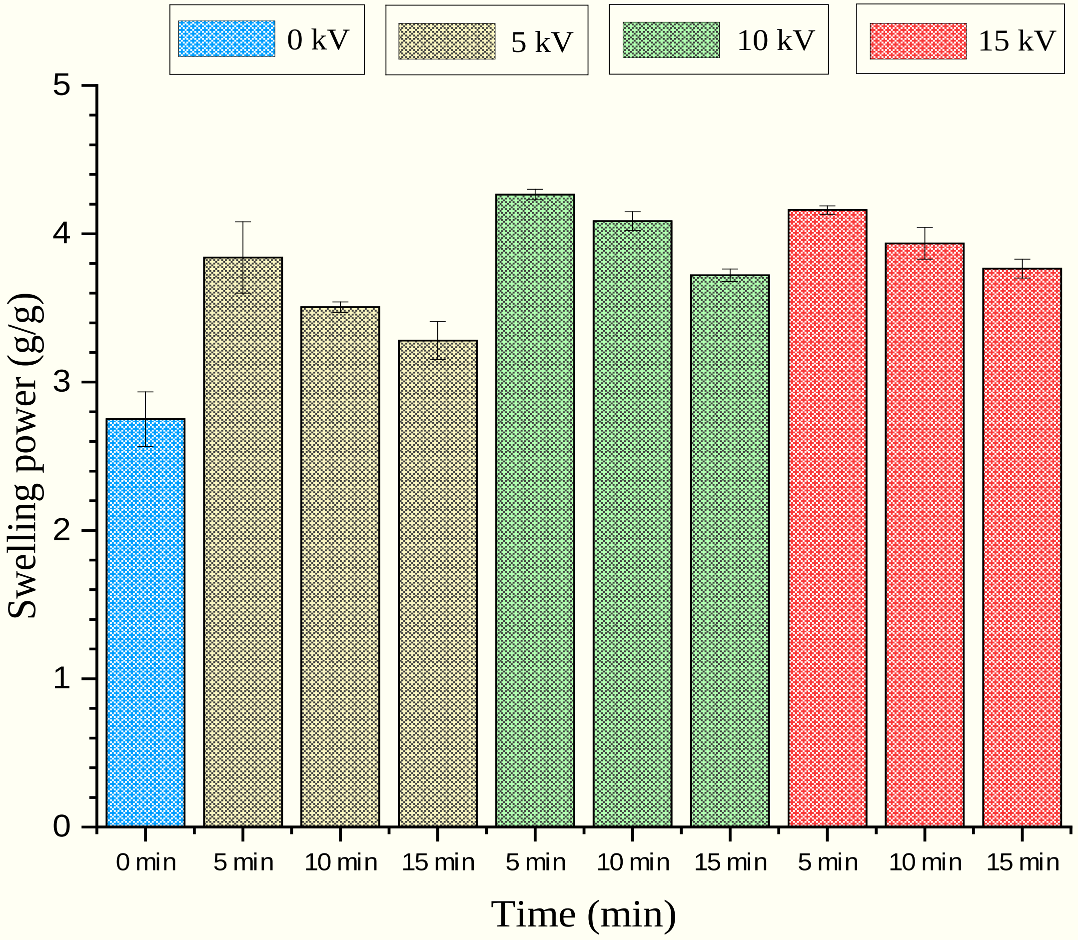
- **Solubility:**



- The increases in solubilty is attributed due to partial breakdown or depolymerization of starch which might lead to formation of smaller fragment.

- Solubility of the cassava starch also increases due to the higher amylose leaching.

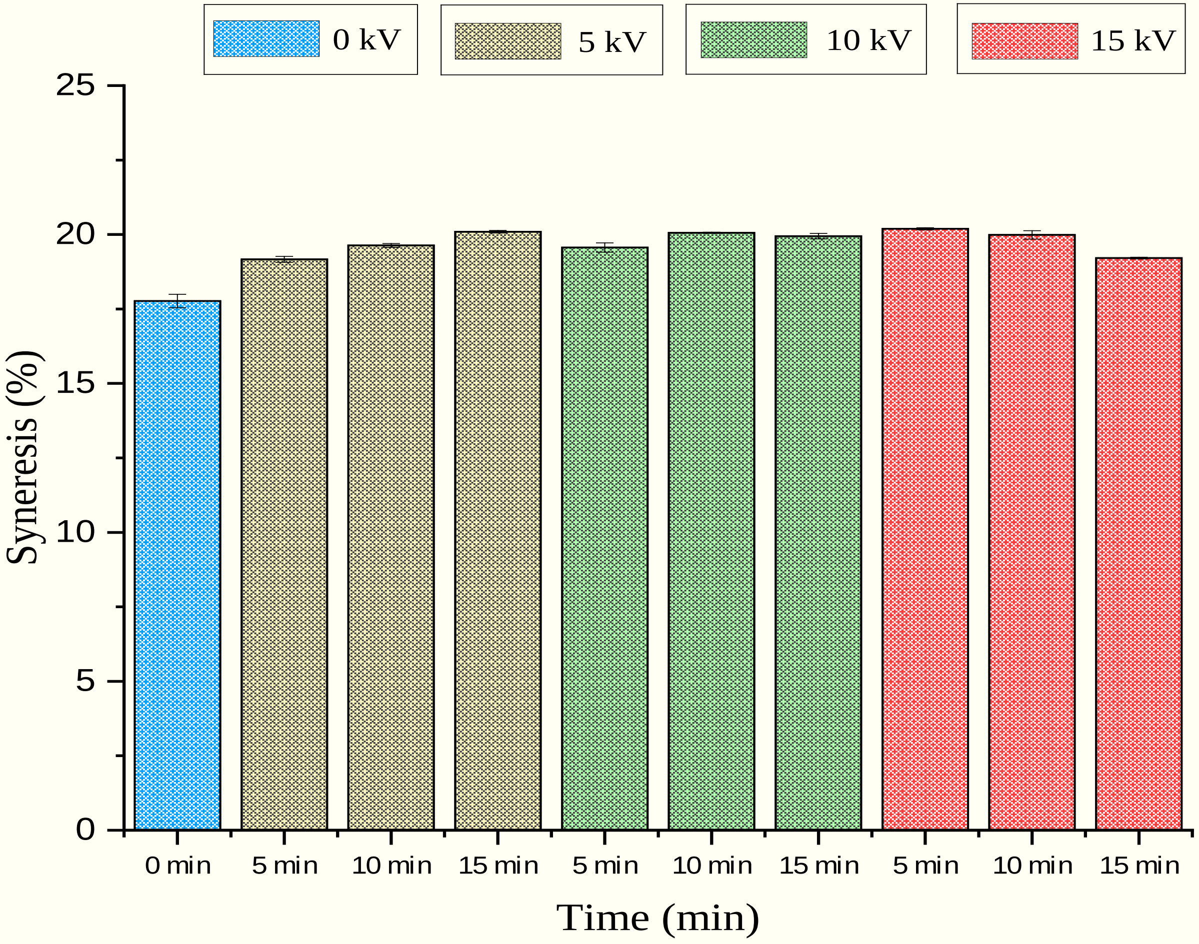
- **Swelling power :**



- The dense accumulation of amylose in the amorphous region, the integrity of the granule, and the strong interaction between the starch chains may be important factors that affect the swelling power.

- The easy leach out of simple sugars and smaller chain amylose fragments from the starch granules might have increased the swelling power.

- **Syneresis:**



- The increase in syneresis is attributed to the depolymerization of starch molecules due to cleavage of glycosidic bonds

- Higher syneresis of starch could be related to their weaker gel structure

Conclusion

- This study examines the application of non-thermal Atmospheric Cold Plasma (ACP) as a potential alternative to current chemical treatments for improving functionality of cassava starch.
- The process parameters like voltage and treatment time have an important role in modifying the properties of the starch.
- The amylose content of treated cassava starch was shown to decrease. There was increase in water binding capacity, solubility and swelling power of the treated starches.
- From the study it can be concluded that the plasma modified starch as an ingredient could be incorporated in the product formulation of various food products (e.g., frozen foods, sauces, baked goods).

Thank You