Bio-polymers in the World of Plasma: Effects of Cold Plasma on Seed Surface

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INTRODUCTION:

Seeds can be considered as natural biopolymers. They are an essential source of nutrients for agriculture and food production. However, to gain optimal yield of important crops, many use pesticides and agrochemicals before, during, or/and after harvesting of crops. This represents a global threat to the environment, as its wide and common use can cause the resistance of pests to these chemicals and harmful effects on soil and the surrounding environment.

The non-thermal or "cold" plasma has been successfully used for treatment of various types of polymers and has recently shown great potential also in the field of agriculture. Many researchers have reported changes in hydrophilic properties of seed surface, increased water uptake and altered surface morphology, which was correlated with selective etching of biopolymer matrix. Moreover, plasma treated seeds were showed improved growth and possible resistance to abiotic stress such as drought and salinity.

The objective of our experiment is to identify surface changes after cold plasma treatment, and the influence of changed seed morphology and chemistry. Different plasma treatments were applied on seeds of two winter wheat varieties. We examined chemical composition of seed coat with X-ray photoelectron spectroscopy (XPS) and changes in hydrophilic properties of seed surface.

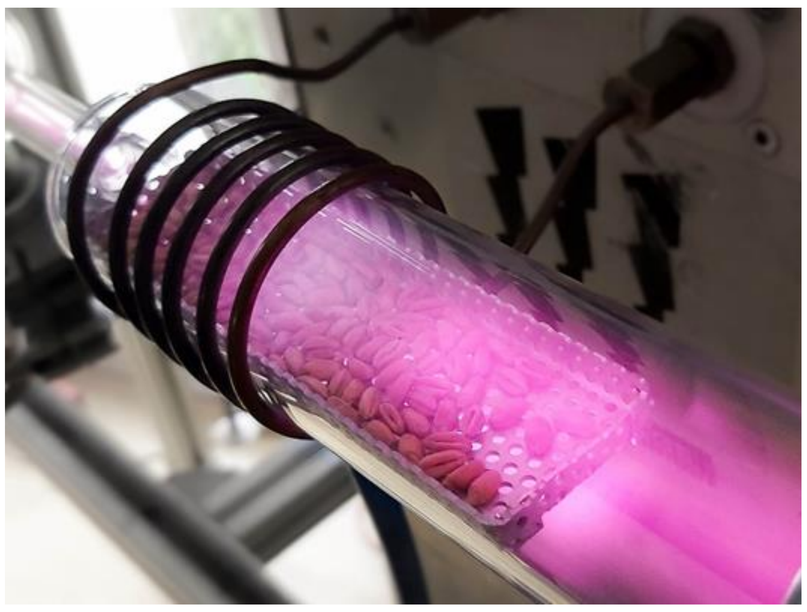


Figure 1: Wheat seeds in during treatment with direct plasma mode (glow region).

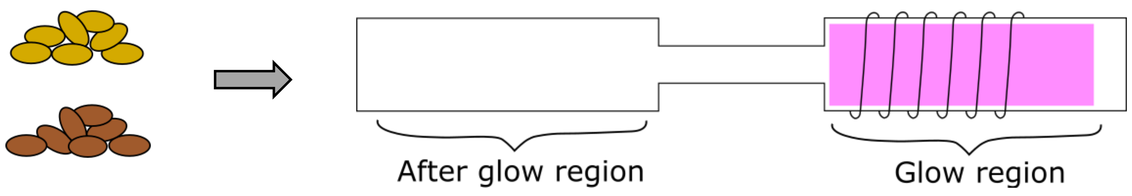
METHODS:

Seed material:

Seeds of two winter wheat (*Triticum aestivum*) varieties.

Plasma treatment:

- Low pressure oxygen RF plasma
- Direct treatment (glow region) for 10, 30 and 90 s
- Indirect treatment (after glow region) for 30, 90 and 180 s



XPS analysis:
Investigation of changes in chemical composition of seed surface.

Moisture content in seeds:
Inspecting the effects of plasma treatment on moisture content in seeds.

Water contact angle measurements:
Measuring the changes in hydrophilic properties of the seed surface.

Water uptake of seeds:
Inspecting if changed chemical surface and hydrophilic properties affect water uptake of seeds.

RESULTS:

- XPS analysis of seed surface revealed that plasma treatment causes a decrease in C, and increase in O (Figure 2) and N content compared to control. In contrast with untreated seeds, plasma treated (direct and indirect) seeds also displayed signals for K and Ca elements. Similar results were found in both winter wheat varieties.

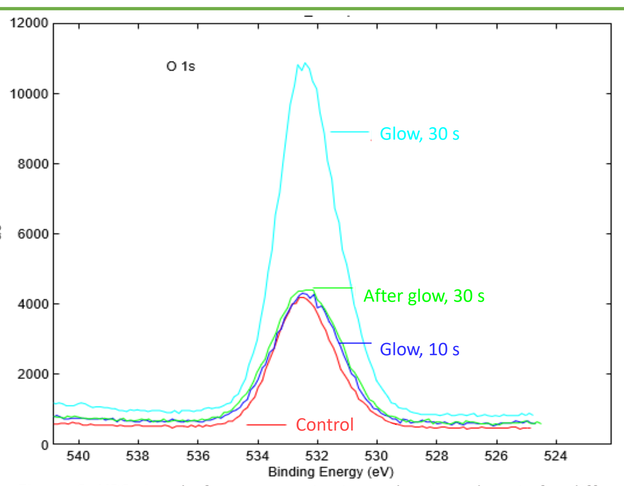


Figure 2: XPS signal of oxygen content on wheat seed coats for different plasma treatments.

Element signals (atomic %)	Control	Glow 10 s	Glow 30 s	After glow 30 s
C1s	88,4	77,2	65,7	76,4
O1s	10,2	18,9	27,5	19,7
N1s	1,5	2,2	5,3	1,9
K2p	/	0,5	0,3	0,7
Ca2p	/	0,4	0,3	0,5

Table 1: XPS results of elemental composition in atomic % of wheat seed coat for different plasma treatments: control (untreated seeds), direct exposure to plasma (in glow region) for 10 and 30 s, and indirect exposure to plasma (in after glow region) for 30 s.

- Vacuum conditions alone (without plasma treatment) cause a decrease in MC. Plasma treatment decreased moisture (MC) in seeds of both winter wheat varieties. Longer exposures to plasma treatment (direct and indirect) cause greater decrease in MC compared to shorter exposures to plasma. Ingenio wheat variety had lower MC than Bernstein.
- Vacuum conditions do not affect water contact angle (WCA) of seed coat. Plasma treatment, on the other hand, decreases WCA by half, and longer treatments (90 s in direct mode or 180 s in indirect mode) the value of WCA decreased to one third of the control values in both winter wheat varieties. Indirect plasma treatment of seeds for 90 s had slightly higher WCA than direct plasma treatment for 90 s. This could be attributed to less aggressive properties of indirect plasma treatment and thus a smaller decrease in WCA.
- Plasma treatment caused an increase in the water uptake of seeds compared to control. There was no difference between plasma treatments. Bernstein wheat variety had smaller water uptake in both control and plasma treated seeds, compared to Ingenio wheat variety.

CONCLUSIONS:

- Vacuum conditions and plasma treatment decrease moisture content in seeds.
- XPS and WCA analysis showed that there is no statistically significant difference between the two wheat varieties.
- Plasma treatment changed the chemical composition of seed surface and increased hydrophilic properties of seed coat.
- Changes in chemical composition and hydrophilic properties affected the water uptake of seeds. With more hydrophilic surface, water enters the seed easier than in untreated seed where surface is more hydrophobic.
- The two wheat varieties have different characteristics regarding moisture content and the dynamics of water uptake. Nevertheless, we found no significant difference in chemical composition of seed coat between them before or after plasma treatment.