

Sterilization of granular materials in a low pressure plasma circulating fluidized bed reactor

Extended abstract for poster presentation

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The objective of our research project is to sterilize powders and granular materials for pharmaceutical and food applications (e.g. wheat grains) in a non-thermal plasma. The application of conventional thermal or chemical sterilization methods for this purpose is often limited, since many products are sensitive to heat, moisture and a variety of chemicals. Radiation sterilization is a rather novel method to sterilize products, however, it is not accepted without reserve among consumers, especially in the case of gamma irradiation. A promising alternative to these methods is plasma sterilization. The sterilizing effect of a plasma treatment was successfully demonstrated in numerous research activities (mostly on flat substrates, inoculated vials or medical devices) [1]. In general, it is agreed that the synergetic combination of UV inactivation, photodesorption resulting from UV photons and the etching by reactive species is responsible for the effective destruction of microorganisms [2].

In a first study, we focused on the inactivation of spores on grains of wheat. Therefore, we used a low pressure and low temperature plasma to meet the thermal limits of food processing. In order to obtain a sufficiently high treatment time and high plasma particle interaction we followed a multipass approach by using a circulating fluidized bed reactor (CFBR, see Figure 1).

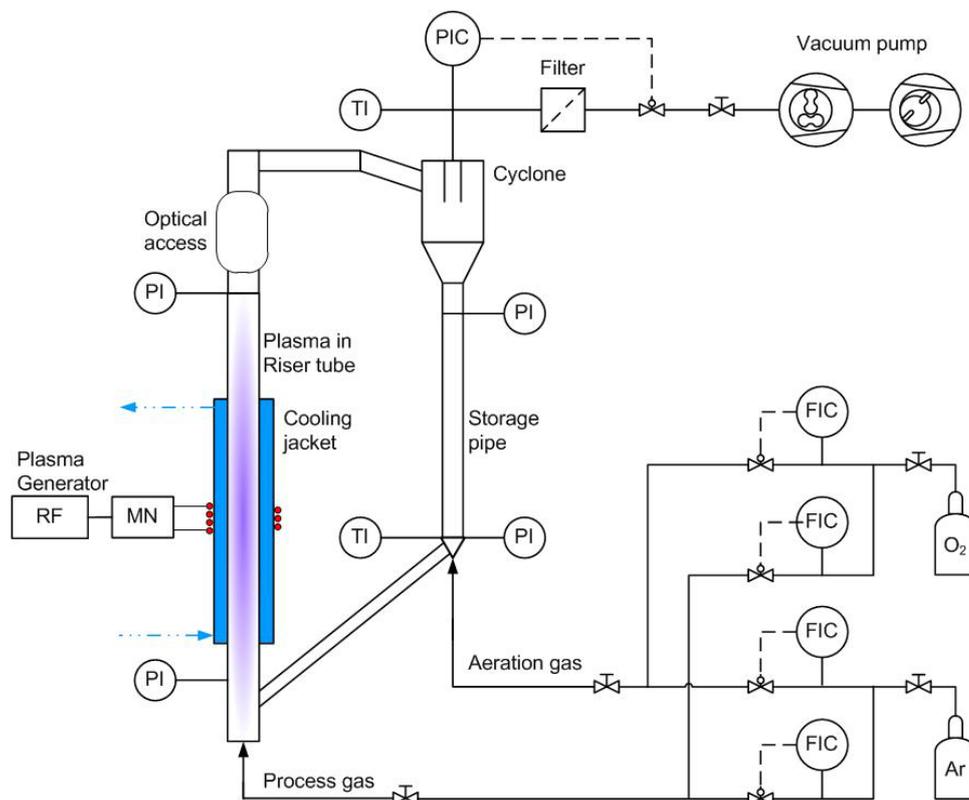


Figure 1: Process flow diagram of low pressure plasma circulating fluidized bed reactor

A non-thermal, inductively coupled plasma is ignited in the water-cooled riser tube of the CFBR. Particles are lifted by the process gas mixture through the riser tube and sterilized in the reactive plasma zone. In the cyclone these particles are separated from the gas flow and collected in a storage tube from where they are repeatedly conveyed to the treatment zone by an aeration gas flow. With these multiple circulations we can realize an adequate cumulative treatment time and at the same time limit the thermal load from the plasma onto the particles to short treatment periods. The low pressure level in the system is maintained by a double-stage vacuum pump.

We successfully managed to combine the high gas flow which is required to lift the granular materials in the riser tube with the low pressure ($p < 20$ mbar) which is essential to ignite and sustain a stable and homogeneous discharge. We observed that the emission intensity in the visible wavelength range and the axial extension of the emitting plasma zone in the riser tube depends on the process parameters, mainly energy input and gas composition. The intensity and axial extension increases when augmenting the energy input and lowering the oxygen gas dosage. A higher power input increases the electron and ion concentration and thus the amount of excited species [3]. A reduced oxygen concentration decreases the quenching effect, where the molecular oxygen causes additional collisional energy losses due to the excitation of vibrational and rotational energy levels, molecular dissociation and negative ion formation [4].

In a first experimental investigation, we showed the general feasibility of our approach to effectively reduce microorganisms on a granular substrate and we investigated the effects of plasma power, processing time and gas composition on the sterilization efficacy. Figure 2 demonstrates the reduction of bacillus amyloliquefaciens spores on grains of wheat in the CFBR, operated with an argon/oxygen gas mixture for different energy inputs, gas compositions and treatment times. The number of colony-forming units (CFU) per gram of wheat grains is plotted over the number of passes through the reactive plasma zone (cycles), which is closely related to the effective treatment time.

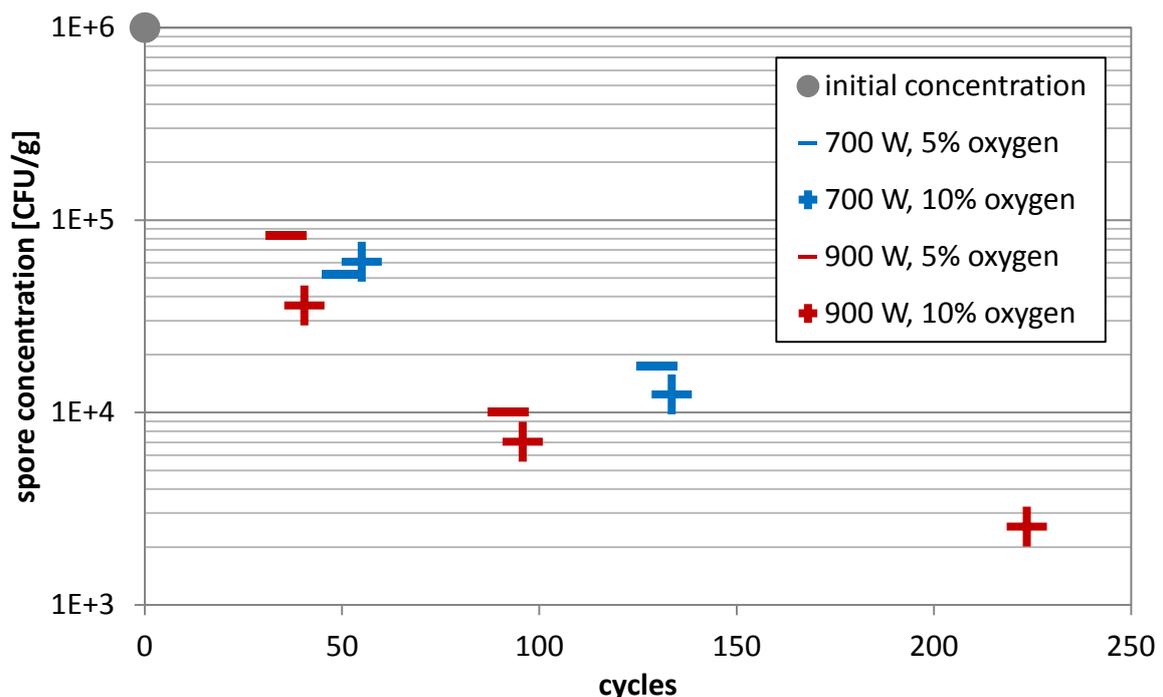


Figure 2: Reduction of bacillus amyloliquefaciens spores in CFBR as affected by treatment time (cycles), power input and oxygen concentration

We were able to reduce the contamination of bacillus amyloliquefaciens spores by more than 2 logarithmic units to below 1% of the initial spore concentration within less than 100 cycles by applying a plasma ignited with 900 W and 10% oxygen. As the treatment time for these conditions is approximately 0.25 seconds per cycle, the effective treatment time for this reduction is below 25 seconds. Furthermore, it can be seen that the reduction is fast within the first cycles of the treatment but then decelerates. Higher plasma power seems to support the reduction, where the main reasons are supposed to be the stronger plasma intensity and the higher axial extension of the reactive plasma zone as described before. The effect of the oxygen ratio is less explicit; the reductions for 5% and 10% oxygen and identical power inputs are in the same range. The plasma intensity and the axial extension were observed to be higher for the oxygen lean plasmas. Therefore, the inactivation efficacy of oxygen rich plasma must be higher to outweigh the effect of the plasma intensity and dimension. This effect can be attributed to the higher concentration of reactive oxygen species in the oxygen rich gas feed. Spectroscopic methods are applied to closer investigate the effects of reactive species and UV irradiation.

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