Plant Based Nanotechnology for Drug Delivery of Antioxidant and Anti-inflammatory Therapies

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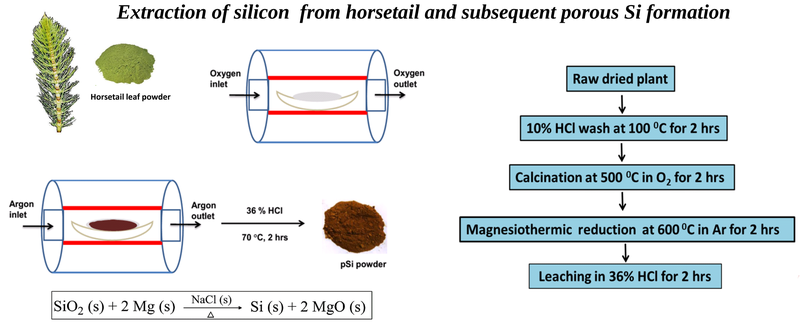
I. Introduction

Equisetum arvense (Horsetail) is a silicon accumulator plant serving as a source for a viable eco-friendly route for fabricating nanostructured porous silicon (pSi) drug delivery carriers; at the same time, if the selected plant leaf components contain medicinally-active species as well, then the single substance can provide not only the nanoscale high surface area drug delivery carrier (pSi), but the drug itself. With this idea in mind, porous silicon was fabricated from stems/fronds of the silicon accumulator plant *Equisetum arvense* and the anti-inflammatory activity of the leaf components (aqueous ethanol extract) of *Equisetum arvense* was tested using a luciferase assay. We evaluated the dose dependent activity of the extract to inhibit TNF (cell signaling protein (cytokine) involved in systemic inflammation) induced NF- kB (regulates the expression of cytokines) activation. Our long-term goal is to measure the anti-inflammatory activity of extract-loaded porous silicon particles in a sustained manner.

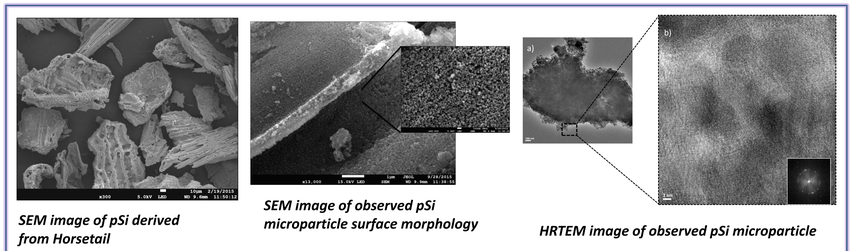
II. Fabrication of Porous Silicon (pSi)

Extraction of silicon from horsetail and subsequent porous Si formation



- Sodium chloride was added to the reaction mixture during magnesiothermic reaction to maintain porosity, as well as act as a thermal moderator

III. Characterization of Porous Silicon



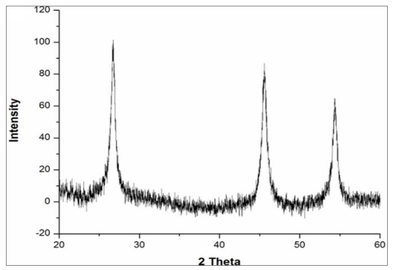
SEM image of pSi derived from Horsetail

SEM image of observed pSi microparticle surface morphology

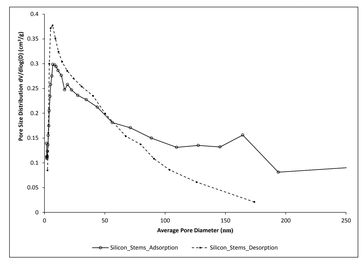
HRTEM image of observed pSi microparticle

- pSi particle size: 77.8 ± 45.7 µm
- TEM analysis shows the presence of numerous small Silicon nanocrystals embedded in an amorphous matrix

X-ray diffraction (XRD) pattern



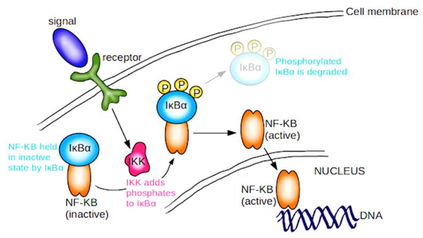
Brunauer–Emmett–Teller (BET)



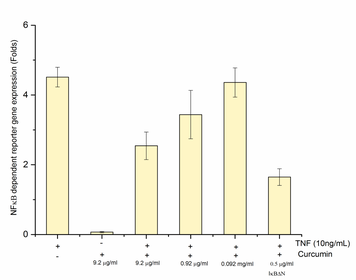
- Presence of crystalline silicon is evident from XRD analysis showing peaks associated with the cubic Si (111), (220), and (311) reflections
- Energy dispersive X-ray analysis shows >99% purity with no residual Mg phases detected
- BET data shows the plant derived pSi has surface area of 171 m2/g, a pore volume of 0.43 ml/g, and average pore diameter of 9.8 nm

IV. Anti-inflammatory activity

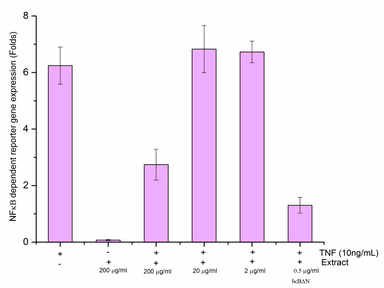
NF- kB Signaling Pathway



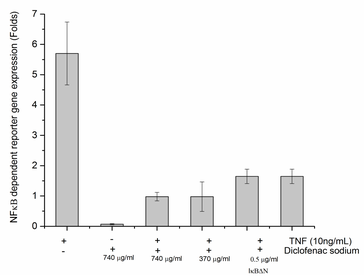
NF- kB activation-Curcumin



NF- kB activation-Extract



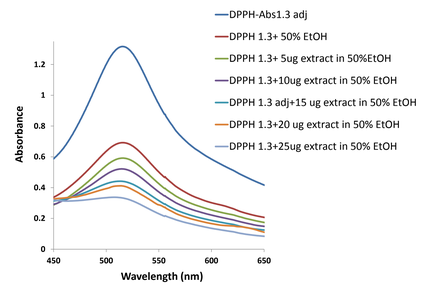
NF- kB activation-Diclofenac

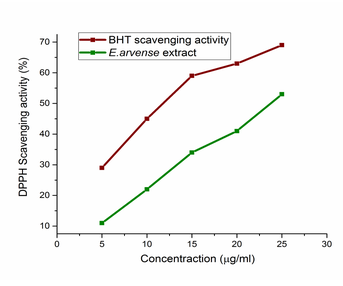


- The ground leaves of *E. arvense* were extracted with 50% ethanol and tested for it's anti-inflammatory activity
- We observed inhibition of TNF-induced NF- kB activation by two known anti-inflammatory compounds (Diclofenac and Curcumin)
- *E.arvense* leaf extract at a dose of 200 µg/ml showed inhibition of NF- kB activation

V. Antioxidant activity of extract

Evaluation of antioxidant activity by DPPH radical scavenging

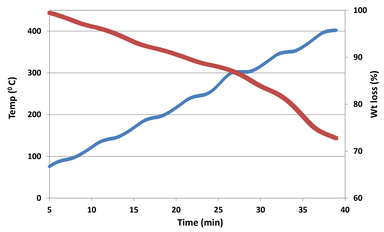




- When plant antioxidants reacted with DPPH (1, 1diphenyl-2-picryl hydrazyl), and is reduced to the DPPHH (1, 1diphenyl-2-picryl hydrazine) and as consequence the absorbance's decreased
- IC_{50} values obtained for a known antioxidant BHT (butylated hydroxy toluene) and ethanolic *E.arvense* extract were as 13 and 23 µg/ml respectively

VI. Extract Loaded into Porous Silicon

Thermogravimetric analysis (TGA) on extract loaded into pSi



- Extract (100 mg) was dissolved in a mixture of ethanol and DMSO
- pSi (10 mg) was soaked with the above extract solution for 1 hr
- The above mixture was heated at 70 °C for 30 min
- Excess extract was washed with 90% ethanol, and dried it in a vacuum oven for 2 days
- Total loading by weight 15% (TGA)

Conclusions

- We have demonstrated that a single plant can yield both drug and drug delivery carrier
- Initial studies on plant extract showed anti-inflammatory and antioxidant activities
- Our future goal is to measure the anti-inflammatory/antioxidant activity of extract-loaded porous silicon particles in a sustained manner