PGX Technology

- ✓ The PGX Technology is a novel processing technology based on Pressurized Gas eXpanded liquids (PGX) that can:
  - ➢ **Dry** aqueous solutions or dispersions of polymers derived from agricultural and/or forestry feedstocks, such as polysaccharides, gums, biopolymers at mild processing conditions (40ºC).
  - ➢ **Purify** biopolymers by removing contaminants, impurities and odours during the precipitation and drying process.
  - ➢ **Micronize** the polymer to a matrix consisting of highly porous fibrils or spherical particles having nano-scale features depending on polymer molecular structure.
  - ➢ **Functionalize** the polymer matrix by generating exfoliated nano-composites of various polymers forming fibers and/or spheres simply by mixing various aqueous polymer solutions/dispersions prior to PGX processing.
  - ➢ **Impregnate** the polymer matrix homogeneously with thermo-sensitive bioactives and/or hydrophobic modifiers to tune solubility of the final polymer bioactive matrix all in the same processing equipment at mild conditions (40ºC).
  - ➢ **Extract** valuable bioactives at mild conditions from fermentation slurries, while drying the residual biomass.

For additional information please contact Dr. Bernhard Seifried at bseifried@ceapro.com

PGX Technology – Key Features:

The PGX technology …

- … is suitable for processing highly viscous solutions of high molecular weight biopolymers (MW = 600 to 1500 kDa) and temperature sensitive bioactives.
- … utilizes a highly tune-able pressurized gas expanded liquid as drying fluid consisting of CO_2 and anhydrous ethanol, which are both recyclable natural food grade solvents "Generally Recognized As Safe " (GRAS).
- … eliminates issues related to surface (or interfacial) tension leading to agglomeration of biopolymers during conventional drying technologies.
- … generates highly porous morphologies similar to those obtained by freeze drying at a fraction of the required time and cost.
- … utilizes a spray chamber in which the polymer matrix is formed in fractions of seconds out of the aqueous solutions leading to short drying times and small drying equipment.
- … facilitates process intensification allowing high throughput equipment on a small footprint.
- … is scale-able and has been successfully scaled-up from lab scale to pilot plant scale capable of processing 300 kg/hr of aqueous solution/slurry.
- … is a highly tuneable process that can produce a highly porous, preservative free, sterile polymer matrix, consisting of powders, fibers, granules or nano-scale spherical particle composites.
- … is capable of producing a wide variety of morphologies with fine nano-scale structures including fibrils and spheres, with large specific surface areas, tuneable surface properties enabling dispersion and solubilisation.
- … can be used to impregnate or coat the polymer matrix with bioactives directly after the drying step to generate ingredients for functional foods, nutraceuticals, cosmetics or pharmaceutical delivery systems.

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PGX Technology – Applications 1:

- PGX Oat β-Glucan (BG):
  - linear polysaccharide, Molecular Weight (MW): 500-1500kDa

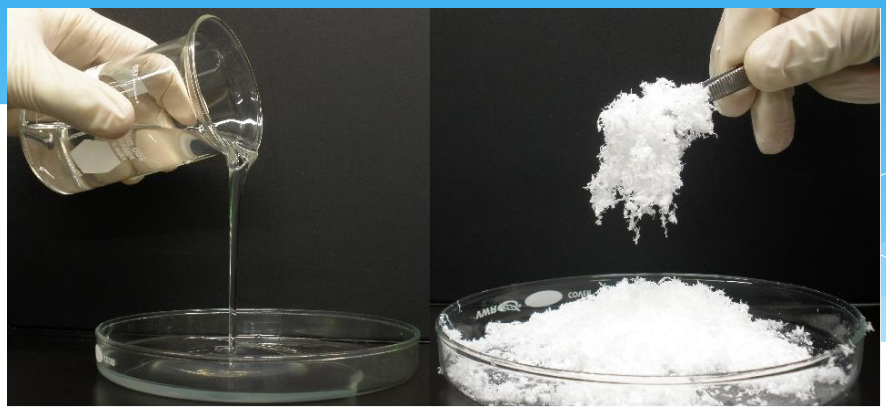

Figure 1. Highly viscous 1%wt BG solution shown (left) and fine PGX-BG microfibrils (right).

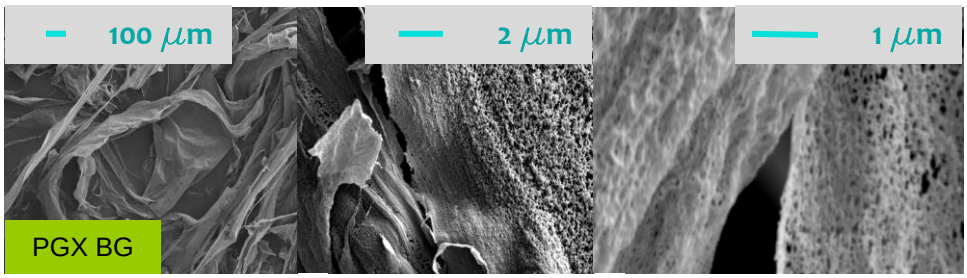

Figure 2. SEM images of porous BG microfibrils having nano-scale pores formed by PGX processing (zooming in from left to right, shown with scale bars).

Figure 3. Powder and granules of BG with particle size ranging from <100 µm to 2mm.

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PGX Technology – Applications 2:

- PGX Gum Arabic (GA):
  - complex mixture of glycoproteins and polysaccharides.
  - MW: >600 kDa

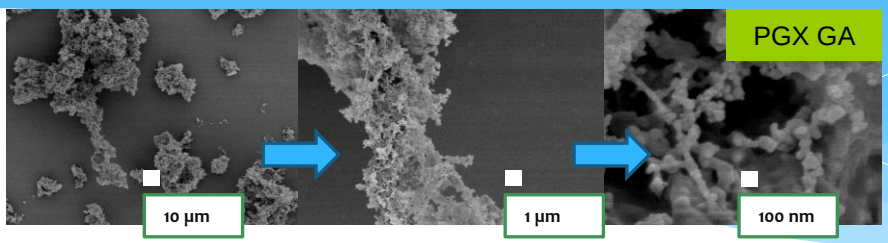
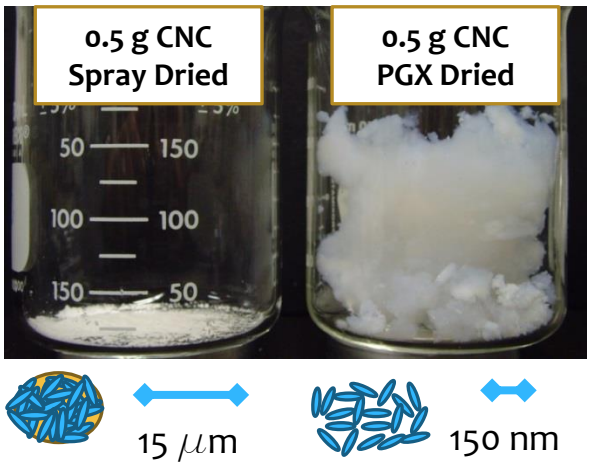


Figure 4. SEM images of gum arabic nanoparticle network formed by PGX process (same particle magnified from left to right, with scale bars shown).

- PGX-Cellulose Nanocrystals (CNC): PGX-CNC Aerogels
  - Cellulose nanocrystals of approximately 150 nm length and 20 nm diameter.
  - Bulk Density: 6 kg/m^3
  - Porosity: >99.5%
  - Specific Surface Area: > 200 m^2/gram



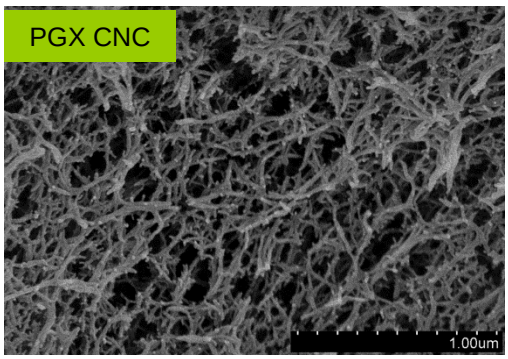


Figure 5. LEFT: Comparison between conventional spray dried (SD) CNC (left) forming compact agglomerated particles and PGX dried CNC aerogel (right). The photos show the same mass of CNC in both beakers. **RIGHT:** SEM image of the PGX CNC aerogel open-porous structure.

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PGX Technology – Applications 3:

- PGX Corn Starch (CS):
  - Mixture of linear Amylose (25%) and branched Amylopectin (75%)
  - Amylose MW: 30-600 kDa
  - Amylopectin MW: 50.000 – 500.000 kDa
  - Bulk density: <80 kg/m³

Figure 6. Corn starch before (left) and after PGX processing (right), showing the same mass of corn starch in both containers.

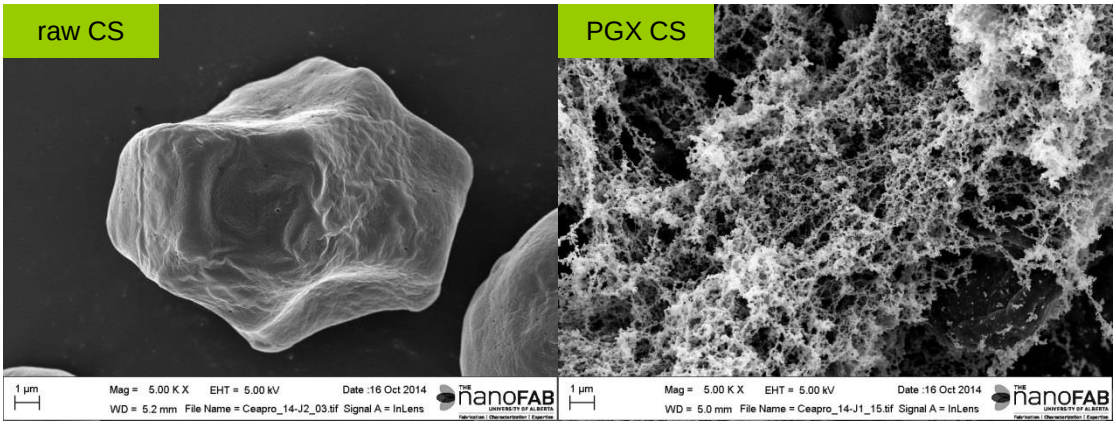

Figure 7. SEM images of corn starch before (left) and after PGX processing (right) under same magnification showing nano-scale structured starch network.

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PGX Technology – Applications 3:

- PGX-BG impregnated with CoQ10
  - PGX BG impregnated with CoQ10 using supercritical CO_2
    - at 40°C and about 200 bar.

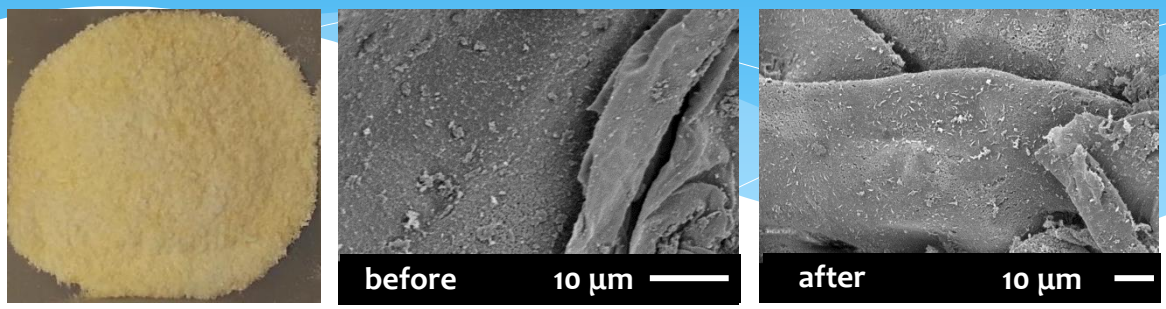

Figure 8. (Left) Photograph of PGX-BG homogeneously impregnated with Coenzyme Q10.
Figure 9. (Right) SEM images of PGX-BG before and after impregnation with CoQ10 showing no visible difference between BG and CoQ10 impregnated BG suggesting that the porous BG structure is not negatively affected by the impregnation step and that CoQ10 is deposited onto the matrix at submicron scale(#).

- PGX-GA impregnated with beta-carotene
  - GA nanoparticle agglomerate impregnated with beta-carotene

Figure 10. Gum Arabic nanoparticle composite particles impregnated with beta carotene.

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Sarah Mayner, Chadd Kiggins, Alexander Kendrick, Prof. Clark Colton, Prof. William Dalzell;
subject 10.27, Chemical Engineering Department, MIT, Cambridge, MA (2014).

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PGX Technology – Applications 4:

- With the PGX Technology highly purified, sterile, porous polymer nanomaterial can be generated for applications including:

- Cosmetics
- Pharmaceuticals
- Nutraceuticals
- Functional Foods
- etc…

The PGX Technology is an enabling technology for generating

- Highly porous water soluble bio-degradeable polymer carriers
- Exfoliated Bio-Nanocomposites
- Aerogels
- Purified bioactives

The PGX Technology will facilitate specific applications such as:

- Functional Food and Cosmetic Ingredients
- Drug Delivery
- Hydrogels
- Absorbants
- Biomedical Devices
- Wound Healing/Scaffolding
- Biocomposites, etc…

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