Cellulose as an Edible Ingredient for 3D Printing

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Presentation Overview

- Why use cellulose?
- Pre-processing to enable printing
- Application to Additive Manufacturing - Binder Jetting
What is Cellulose?

**Glucose** is the basic building block.

- **Hierarchical chain structure** for strength.
- **Hydrogen bonds** → tight packing → crystalline, rigid structure.
- **Plant cells**
- **Cell walls**
- **Cellulose microfibrils** in a plant cell wall
- **Cellulose molecules**

- **Abundant**
- **Natural**

≈10^{11}-10^{12} Tons synthesized annually by plants!

Image from: http://bio1151.nicerweb.com/Locked/media/ch05/cellulose.html
Cellulose in the Human Diet

- Impossible to estimate how much we consume daily
- No human enzyme to digest cellulose
- Not fermented by gut bacteria
  $\rightarrow 0 \text{ kcal g}^{-1}$
  $\rightarrow$ Dietary fibre without excess gas production

- Crystalline structure difficult to dissolve
- Often derivatised to partially/fully soluble materials
  $\rightarrow$ Native cellulose typically “bulking agent”
Ball Milling to Alter Properties

Native Cellulose Fibre
- Physical Size Reduction

Cellulose Ball Milled for 30min at 800rpm
- Decreased Molecular Chain Length
- Loss of Crystallinity

Recrystallisation to Structure

X-Ray Diffraction Data Showing Sample Crystallinity

- Thermal analysis of samples undertaken
- Control of moisture and temperature allows recrystallisation control
- Addition of structurally similar polysaccharides can introduce further interactions and control
  e.g. Locust Bean Gum (Galactomannan)
  Glucomannan
  Xanthan Gum
  β-Glucan (from Oat)

Intensity

200 arbitrary units

Native Cellulose (27%)
Recrystallised Sample (20%)
Cellulose Ball Milled 30min (<5%)
AM Process - Binder Jetting

- Powder building material
- Liquid binding material
- Layer by layer approach – 3D model split into 2D cross sections of a defined thickness
- Binder deposition nozzle diameter 21μm (10pL) or down to 10 μm (1pL)
- Potential for 24-bit colour printing

Sugar Structure: http://www.3dsystems.com/culinary
My Materials

Ink: Providing necessary moisture to induce recrystallisation with interacting polysaccharide

Powder: Ball Milled Cellulose with/without interacting polysaccharide

• Powder bed and ink temperature controlled
• Nozzle selected to provide desired moisture
• Not only simple particle adhesion
  → Recrystallisation induced will lead to a more robust structure
Future Work

• Ink development and analysis

• Combine powder and ink in process to develop a working model

• Modify polysaccharides in powder and ink to change structural properties and develop for food use

Drop watcher on Dimatix ink jet printer
Thank you for your attention, Any questions?

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