Additive Manufacture of Edible Cellulose Structures

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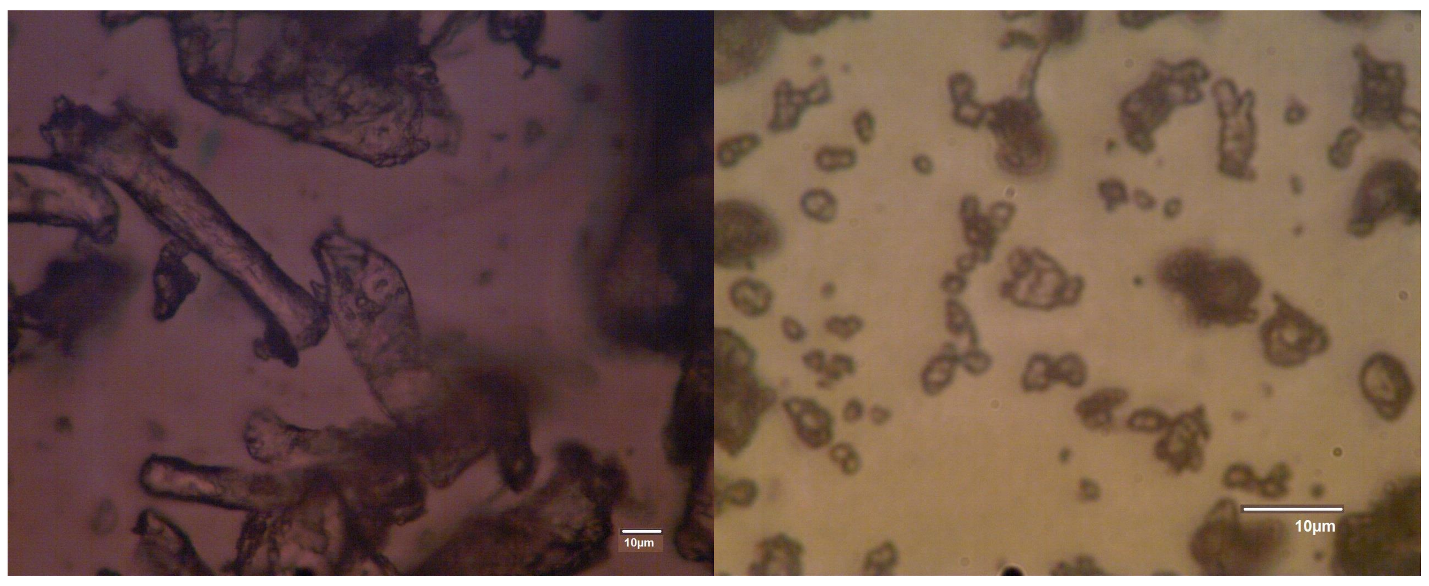
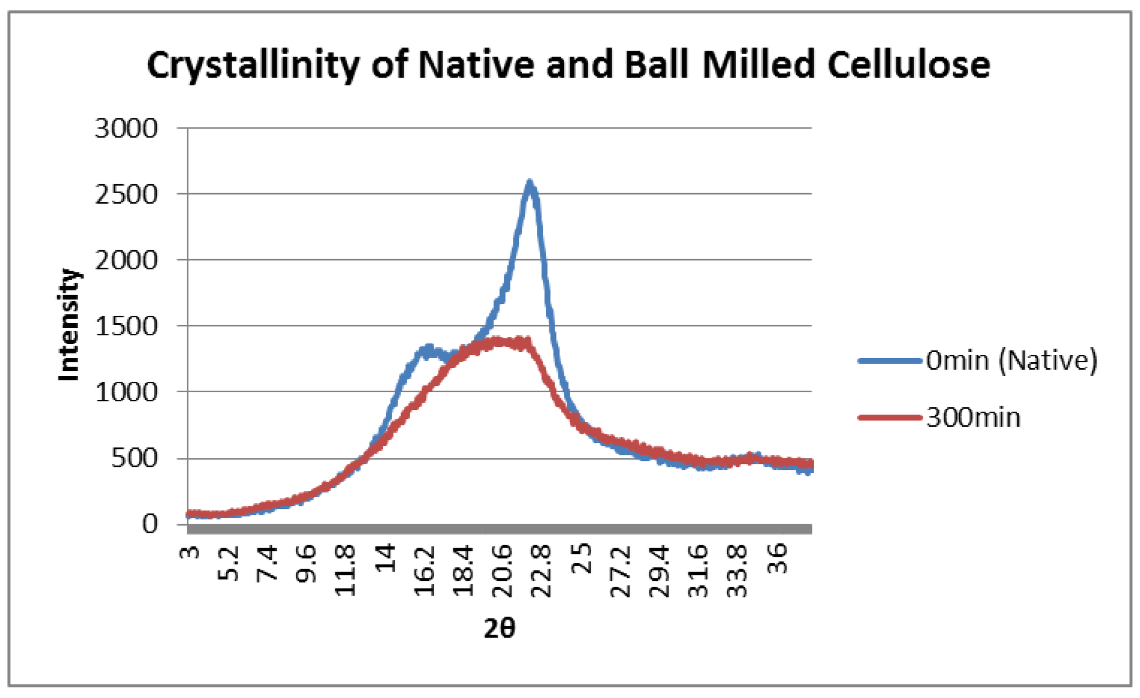
Introduction : Additive Manufacture describes processes involving the joining of materials to make objects from 3D model data, usually layer upon layer rather than subtractive or formative technologies$_1$. Its application to food products to date has mostly involved low pressure extrusion processes of pastes or molten solids – relying on the ingredient's ability to solidify in the printed atmosphere or post-printing cooking processes to bind layers and hold structure$_2$. AM in food has so far been used to create interesting, complex geometries not possible by conventional manufacturing but has much more potential than this.

Materials and Method

- Cellulose powder (22µm particle size, 27% crystallinity)
- Polysaccharides
  - Locust Bean Gum (LBG)
  - Konjac Glucomannan (KGM)
  - OSA Modified Starch (OSA)
  - Maltodextrin DP≈20 (MD6)
  - Oat β-Glucan (OBG)

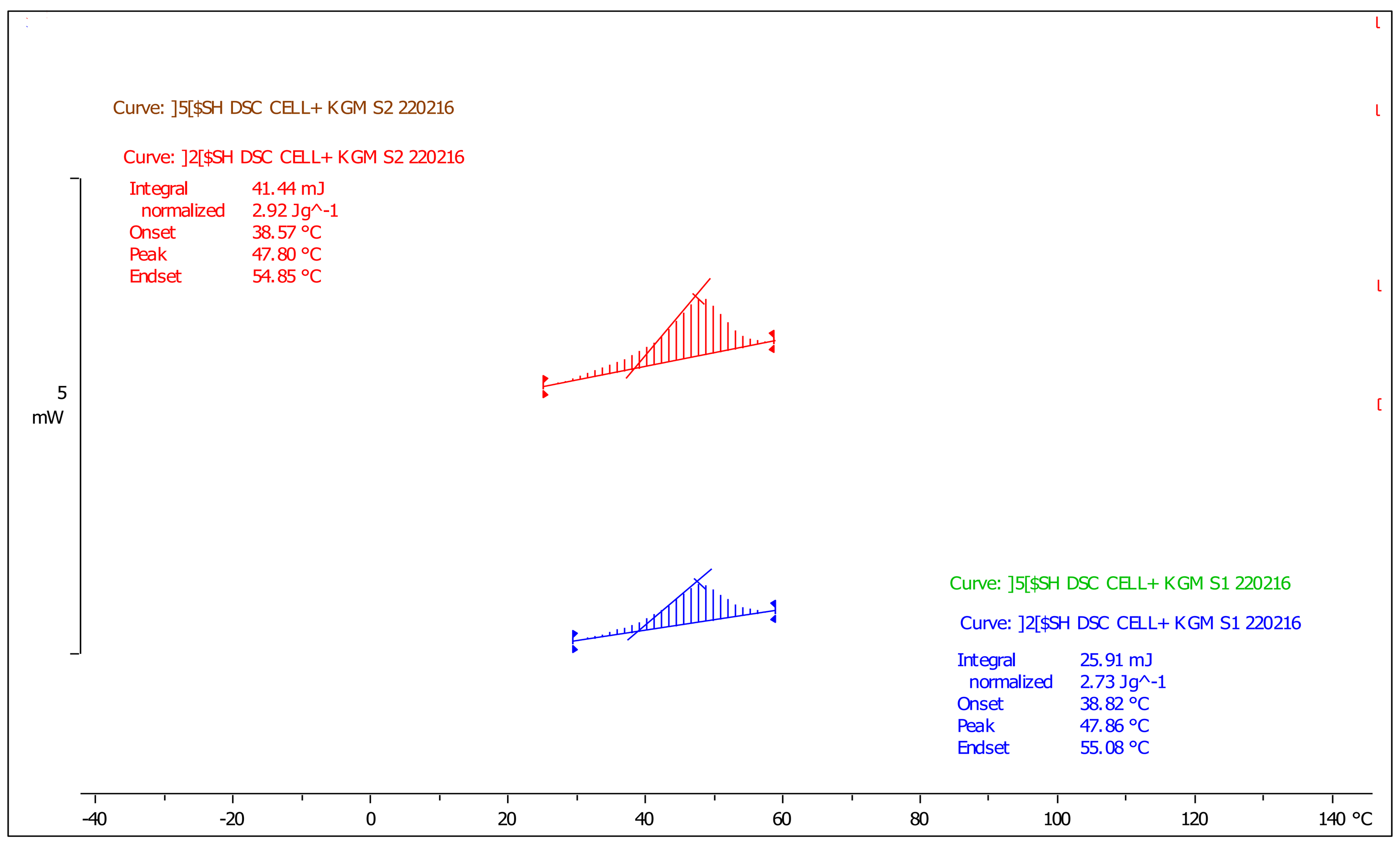


Left : Native Cellulose, Right : Ball Milled Cellulose, Below : X-Ray Diffractogram Illustrating loss of crystallinity through ball milling.



- Cellulose mixed with polysaccharides in 1:1 ratio then ball milled at 800rpm for 300min to form a fully amorphous powder
- Samples dried over P_2O_5 then equilibrated to different Relative Humidity (RH%) over saturated salt solutions

Results

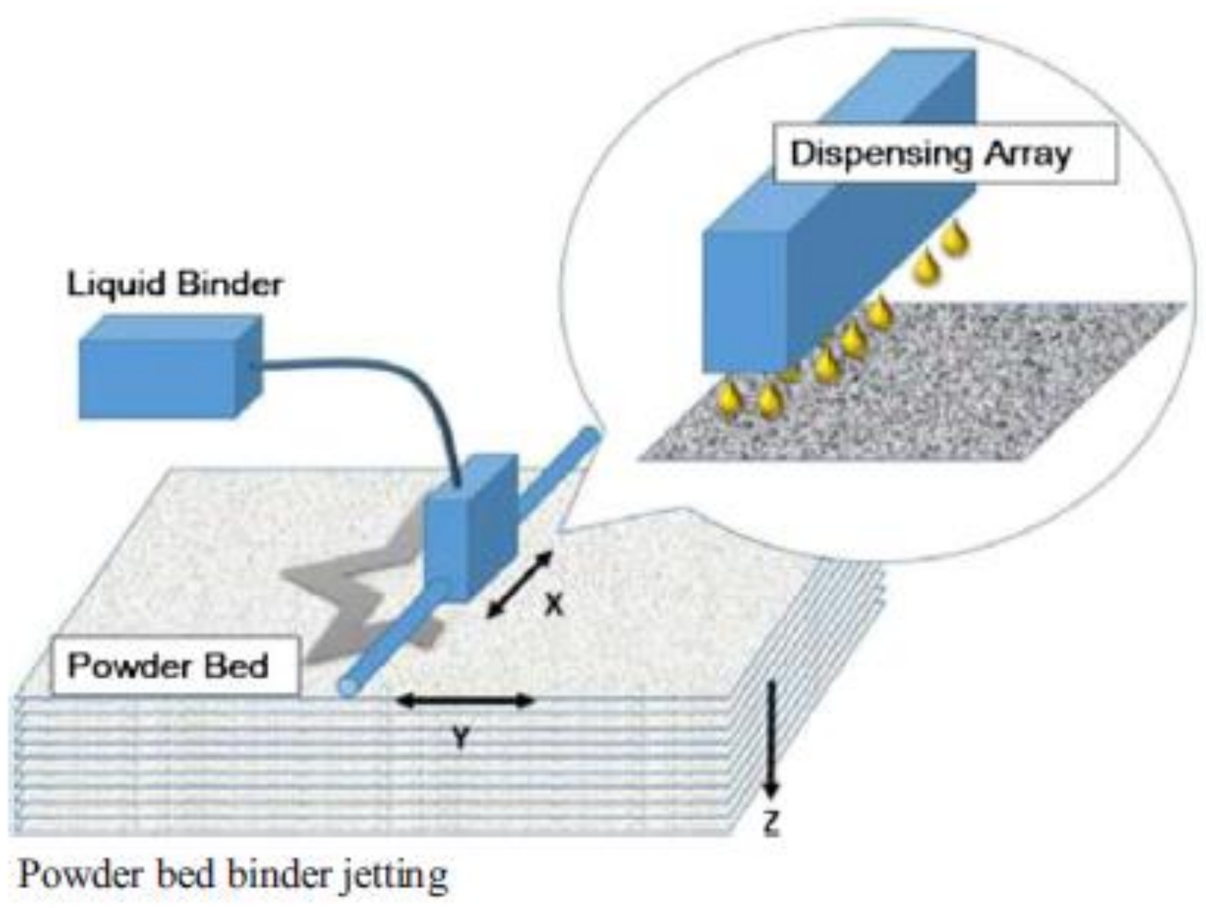


Above : DSC scan of co-ball milled cellulose-KGM mixture showing traces of first heat and reheat of samples in duplicate

- Analysis using thermal methods such as Differential Scanning Calorimetry (DSC) and Dynamic Vapour Sorption (DVS) give insight into recrystallisation kinetics of the amorphous powder.
- Recrystallisation of Cellulose-KGM mixture equilibrated at 75%RH (sample 13% moisture) on the first DSC heat is shown to the left, masked phenomenon spanning 38-55°C.
- Peak on second reheat ≈0°C indicative of water release from amorphous structure on recrystallisation.
- Consistent with observed weight loss on DVS at 90%RH at 25°C indicative of recrystallisation.

Future Work and Application :

- Further testing to confirm recrystallisation theory observed in DSC and DVS through application of controlled heat and analysis with X-Ray Diffraction to determine crystallinity
- Application to binder jet 3D printing (seen on right) using controlled heat and moisture to recrystallise into 3D structures based on a computer design
- Designer particles and controlled structure ingredients for food products



Powder bed binder jetting

References : 1) ASTM International, 2013. F2792-12a - Standard Terminology for Additive Manufacturing Technologies. Rapid Manufacturing Association, pp.10–12. Available at: http://www.ciri.org.nz/nzrma/technologies.html.
2) Lipton, J.I. et al., 2015. Additive Manufacturing for the Food Industry - A review. Trends in Food Science & Technology, 43(1), pp.114–123. Available at: http://www.sciencedirect.com/science/article/pii/S092422441500045X.

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