Project overview

MEAT & LIVESTOCK AUSTRALIA

Novel soaker pad development to improve red meat quality

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Brief summary

The aim of this PhD project (as part of Monash GRIP cohort) is to develop sustainable superabsorbent composite which can efficiently absorb drip loss from red meat packaging. Superabsorbent polymers (SAPs) are hydrophilic networks capable of absorbing a large volume of water. SAPs are commonly used in disposable diapers, feminine napkins, soil for agriculture and horticulture, gel actuators, water blocking tapes, drug delivery systems and absorbent pads. Most commercial SAPs are made of sodium-based polymers (mainly sodium polyacrylate), which are not biodegradable. This lack of sustainability has driven us towards the development of sustainable superabsorbent from renewable source and making a final product which is completely biodegradable and efficient enough to absorb the drip loss from red meat.

Objectives

Numbered list below:

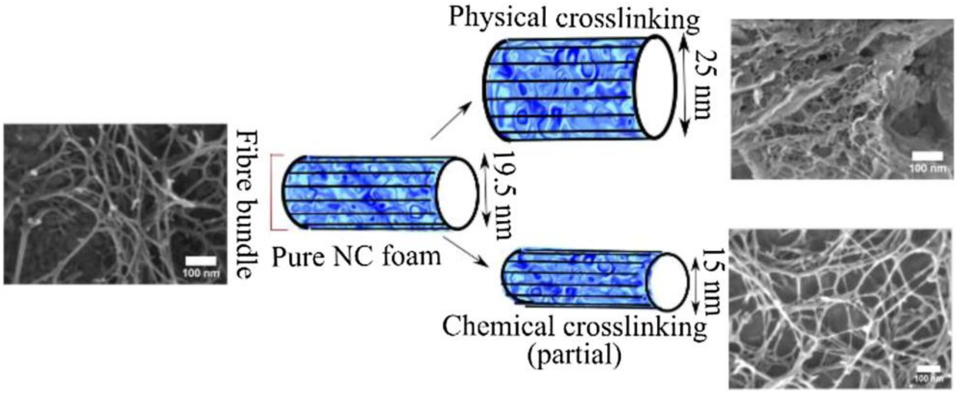
1. Develop sustainable superabsorbent and quantify mechanical property.
2. Correlate swelling mechanism with crosslinking type.
3. Quantify absorption kinetics with surface charge and ionic strength.
4. Quantify product biodegradability under accelerated condition.

Project outcomes

Outcome one

The mechanical strength of hydrogel and cryogel made from carboxylated nanocellulose fibres can be modulated by crosslinking and blending. Adding a crosslinker to carboxylated cellulose nanofibre (CNF) increases the mechanical strength of the hydrogels made from it. Blending cellulose nano crystal (CNC) to a suspension of carboxylated cellulose nanofibres increases the mechanical strength of its cryogels. Nanocellulose hydrogels are produced by oxidizing Bleached Eucalyptus Kraft (BEK) pulp followed by high pressure mechanical treatment. Polyethyleneimine (PEI) and hexamethylenediamine (HMDA) were crosslinked with NC hydrogels. Cellulose crystals (CNC/MCC) were blended with TEMPO oxidised fibre to control the gel properties with crosslinked samples. NC cryogels were prepared from these hydrogels by two steps process of freezing and lyophlisation. The mechanical properties of nanocellulose hydrogel and cryogel were modulated by controlling the type and density of crosslinking as well as blending with nano/micro fibres. Chemical crosslinking (HMDA) increases the hydrogel elastic moduli (G’) but not the cryogel compressive strength significantly. SAXS reveals the HMDA crosslinked hydrogel to be structurally homogeneous. Physically crosslinked hydrogel also increases the hydrogel elastic moduli but decreases the elastic compressive moduli. Blending carboxylated cellulose fibre suspension with CNC significantly increases the compressive strength of cryogel. NC gel exhibits tuneable mechanical strength and absorption capacity depending on crosslinking/blending making it suitable for use in personal care products and baby diapers, as an agricultural water retention aid, and in biosensor applications.

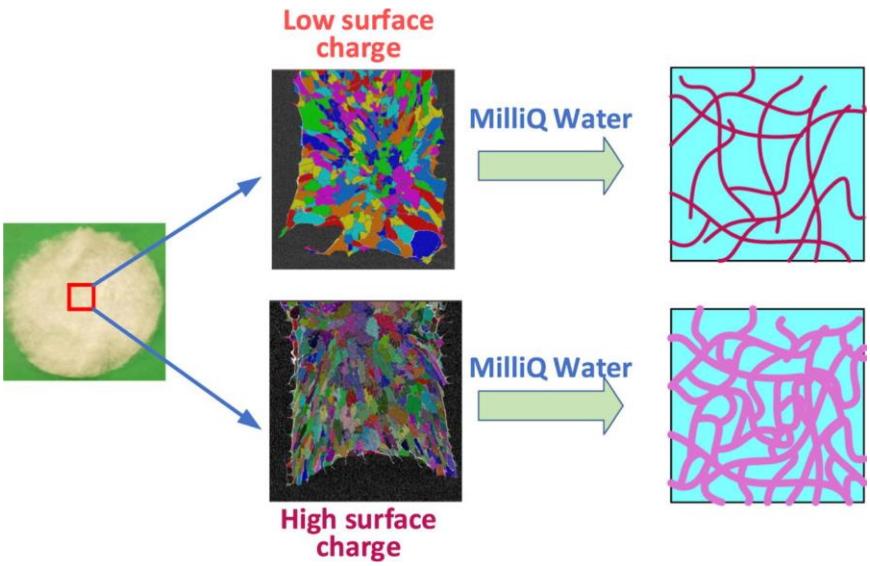
Outcome two



The water absorption capacity of nanocellulose (NC) foam is tailored by crosslinking with polyethyleneimine (PEI) and hexamethylenediamine (HMDA). The interaction of amine groups in PEI and HMDA with the carboxylic groups (COO−) of NC affects the foam structure which reduces its swelling capacity. Functionalised NC foams were prepared by TEMPO (2,2,6,6,-tetramethylpiperidine-1-oxyl) oxidation of bleached pulp, followed by fibrillation into a hydrogel, adding a crosslinker and freeze drying the hydrogel into a foam. The structure of the NC foam characterised by rheology, SANS (Small Angle Neutron Scattering), SAXS (Small Angle X-ray Scattering) and cryo-SEM (cryo-Scanning Electron Microscopy) was related to absorption and swelling properties. The NC foam has the highest water absorption capacity at 132 g water/g foam. PEI-NC foam has a water absorption capacity of 71 g water/g foam, which further decreases to 47 g water/g foam for the HMDA-NC foam. Small angle scattering reveals the elementary fibril of NC is 3–5 nm thick and forms fibre bundles. In water, these bundles swell differently for the different types of foam which affects the water absorption capacity of the network. The structural analysis of the foam was related to the swelling capacity. The structure of NC foam can be engineered for specific applications for biomedical, agriculture or food industries.

This chapter has been published in Journal of Colloid and interface science (Hossain, Laila, et al. "Structure and swelling of cross-linked nanocellulose foams." Journal of colloid and interface science 568 (2020): 234-244.)

Outcome three



The absorption capacity and kinetics of nanocellulose foams are controlled by the surface charge of the fibres, which affects swelling and determine the porosity and structure of the network. Absorption kinetics were quantified at time scales ranging from fractions of a second to minutes. The mass absorption rate as well as the area profile for the liquid stains were simultaneously measured. The absorption profile followed a three-stage mechanism: wicking, transition and fibre swelling. Absorption of fluids differing in ionic strength revealed the critical role played by electrostatic forces. Nanocellulose foam absorption capacity is 25% higher for water than for 0.9 wt% NaCl solution. The absorption kinetics of nanocellulose foam are also tuneable by modulating the surface charge. High surface charge nanocellulose foams have slower absorption in water than their low surface charged analogues. This behaviour is driven by the lower pore sizes developed in high surface charge foams, as determined by X-ray CT. Small Angle X-ray Scattering revealed structural homogeneity of high surface charge foams upon absorption of water due to high fibrillation and fibre swelling.

This chapter has been published in Journal of Colloid and interface science (Hossain, Laila, et al. "Absorption kinetics of nanocellulose foams: Effect of ionic strength and surface charge." Journal of Colloid and Interface Science (2021).)

Outcome four

The objective of this chapter is to quantify the effect of crosslinked superabsorbent in accelerated biodegradation conditions. Cellulase enzyme has been used to accelerate the biodegradation rate. The variables considered are: substrate concentration, enzyme concentration and types of crosslinking. Extent of biodegradation is analysed by CO_2 evolution and glucose left in the sample container by hydrolysis in day 2, 4 and 6. After day 6, around 90% of sample degradation is achieved for chemically crosslinked sample whereas original NC sample showed only 32% degradation over the time. These results suggest that there is enzyme inhibition for original NC sample, however, the chemical crosslinked samples accelerated the enzyme activity.

Related Resources

Laila Hossain Thesis - https://figshare.com/articles/thesis/ENGINEERING_SUSTAINABLE_NANOCELLULOSE_SUPERABSORBENTS_CHARACTERIZATION_AND_APPLICATION/19082705

Benefits to industry

- Developed sustainable efficient superabsorbent.
- Characterisation of different types of superabsorbent revealed that absorbent composite of different absorption kinetics can be prepared depending on final application (such as for meat packaging, fruit packaging etc).
- Consumer survey about the new product indicated positive feedback which encourages the industry to take further step to lunch the product.
- The developed superabsorbent can not only be used in meat packaging, it can also be used for other food packaging or baby diaper which expands the market and opens the scope of collaboration.

Future research and recommendations

- Test the developed superabsorbent composites in real scenario and find out the best performant superabsorbent.
- Compare shelf life of meat when using the sustainable superabsorbent with the commercial superabsorbent.
- Cost analysis for large scale production and how to minimise the cost.