Modification of Keratin with Chitosan for Water Remediation

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Introduction

- Nowadays, green methods of purifying contaminated water has become a crucial goal, as clean drinking water becomes a scarcer resource.
- By using readily available biodegradable materials, we can produce membranes that adsorb heavy metals from water, with little risk that the process of doing so would cause further harm.
- In Canada, every year, over 100 000 tons of chicken feathers are burned or landfilled, which either worsens air quality or contaminates underground water. Instead of waste, these feathers can serve a beneficial purpose.
- Proteins such as keratin, combined with other biodegradable chemicals such as chitosan, can provide the physical and chemical properties necessary to form a membrane for water remediation.

Purpose

The purpose of this study was to create a biodegradable hybrid membrane out of the biopolymers keratin and chitosan, that will adsorb heavy metals from water.

Methodology

Lipid Removal
- Lipids are removed from chicken feathers with hexane using Soxhlet apparatus (process is repeated 3-4 times)

Bond Breaking
- Disulfide bonds in keratin are broken with the addition of ethylenediaminetetraacetic acid, tris hydroxymethyl aminomethane, urea, sodium sulfide, and water
- Solution is heated to 70°C and stirred for 48hrs

Adding Chitosan
- Solution equally divided into 75mL portions. 1%, 3%, 5%, 7% chitosan added and stirred overnight without heat

Centrifuge
- Solutions are separated into 40mL portions, and centrifuged 3 times
- Water soluble particles are cleaned out

Compress
- Experimented making membranes with a carver press
- Temperature, pressure, and time were adjusted until the correct conditions were found

Testing
- Thermogravimetric Analysis (TGA)
- Fourier Transform Infrared (FTIR)
- Differential Scanning Calorimetry (DSC)

Fig 1. Methods used to make and test a membrane

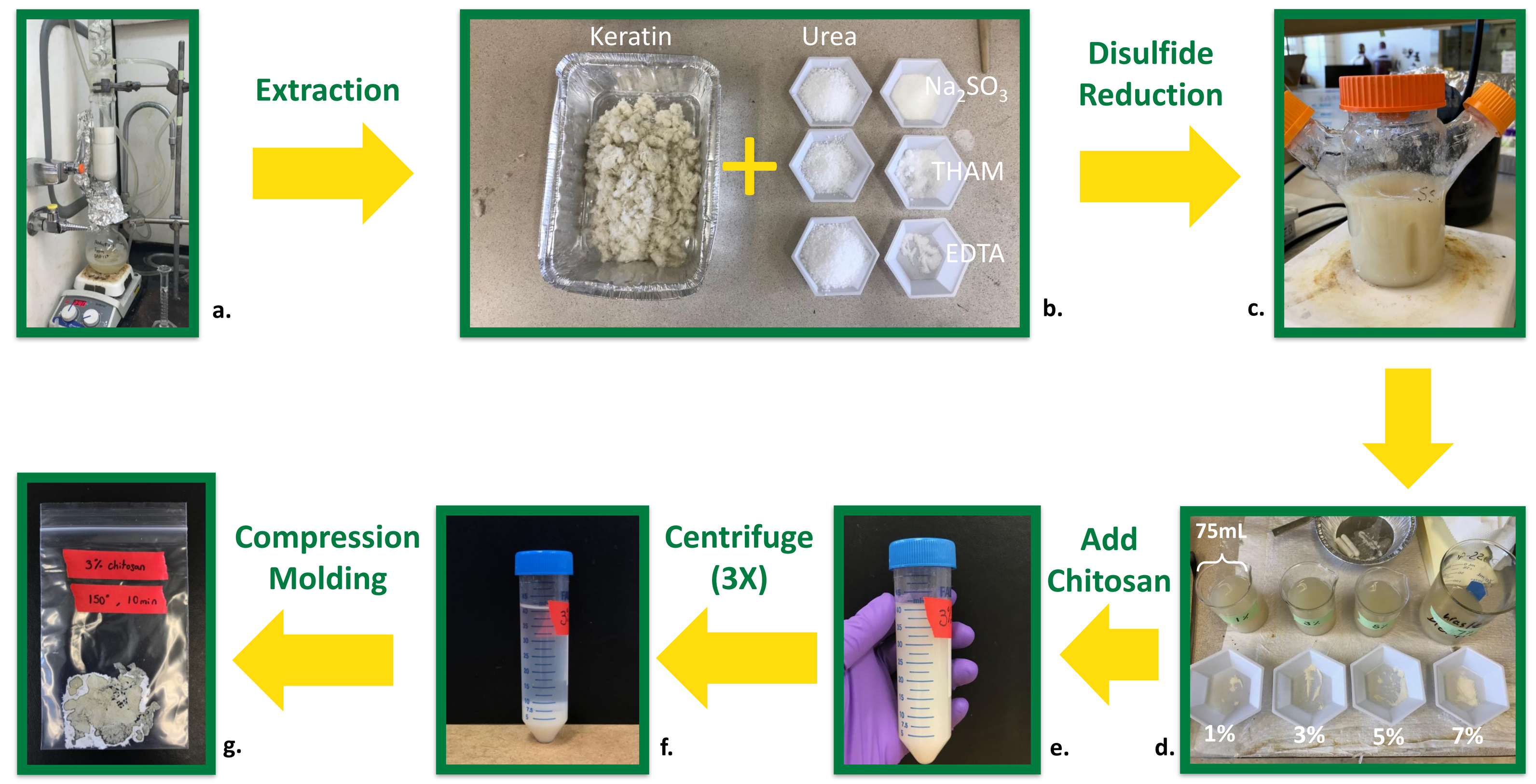

Fig 2. a) Soxhlet Apparatus **b)** Keratin from feathers and chemicals used to break down disulfide bonds. **c)** Bond breaking **d)** Adding chitosan **e)** Solution before centrifuge **f)** Solution after centrifuge **g)** Keratin/chitosan membrane

Bonding
- Chitosan bonds to Keratin by electrostatic attraction
- Partial positive groups of the keratin amino acids attract partial negative groups of chitosan [Fig 3].

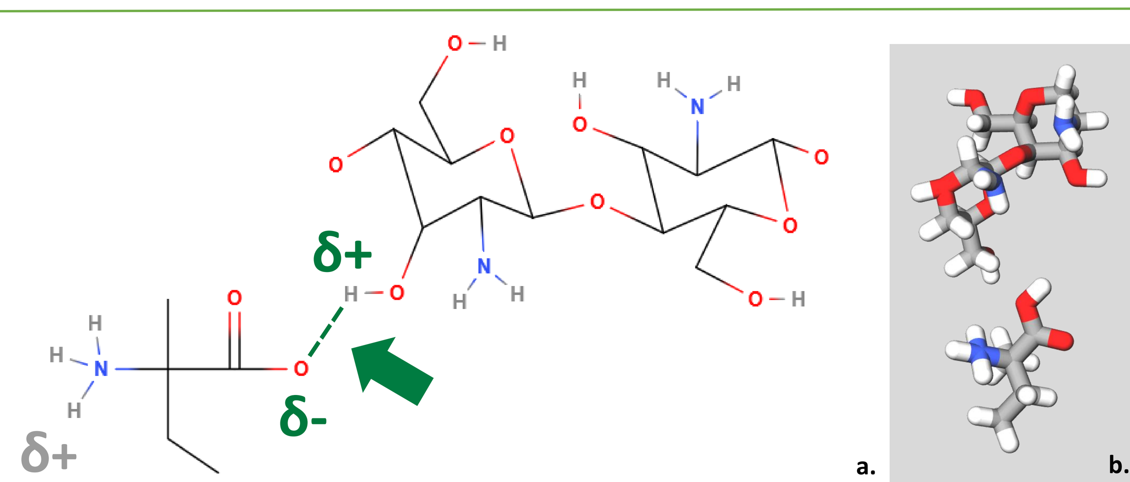

Fig 3a. Partial negative charge on keratin amino acid group (left), and partial positive part of chitosan molecule (right) [1]. **Fig 3b.** 3D chitosan (top) and keratin (bottom) [1].

Results

Conditions for Compression Molding

Chitosan %	Temp (°C)	Pressure (psi)	Time (min)	Result
7%	170	3500	10	Incomplete
5%	170	5000	15	Burned
5%	155	5000	15	Burned
3%	**150**	**5000**	**10**	**Starting to form**
3%	155	5000	10 (+10)	Incomplete
1%	155	5000	10	Incomplete

Fig 4. 6 out of 15+ total experiments performed on carver press. 3% chitosan at 150°C, 5000psi, and 10min was used for testing.

Thermogravimetric Analysis

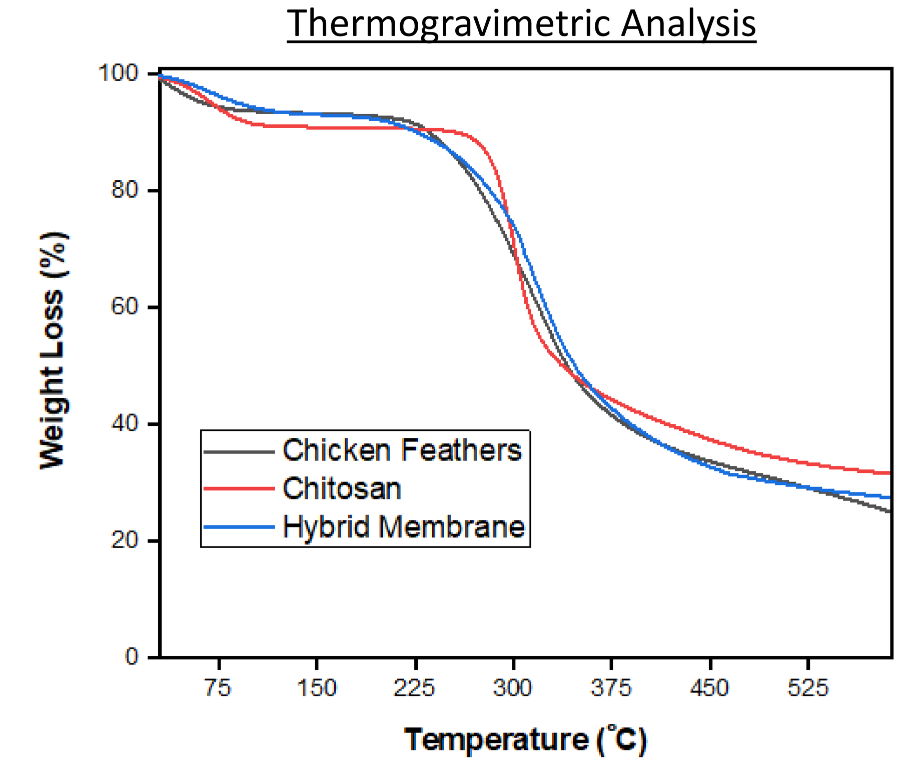

Fig 5. TGA analysis in nitrogen atmosphere – showing thermal capacity of the materials.

Fourier Transform Infrared

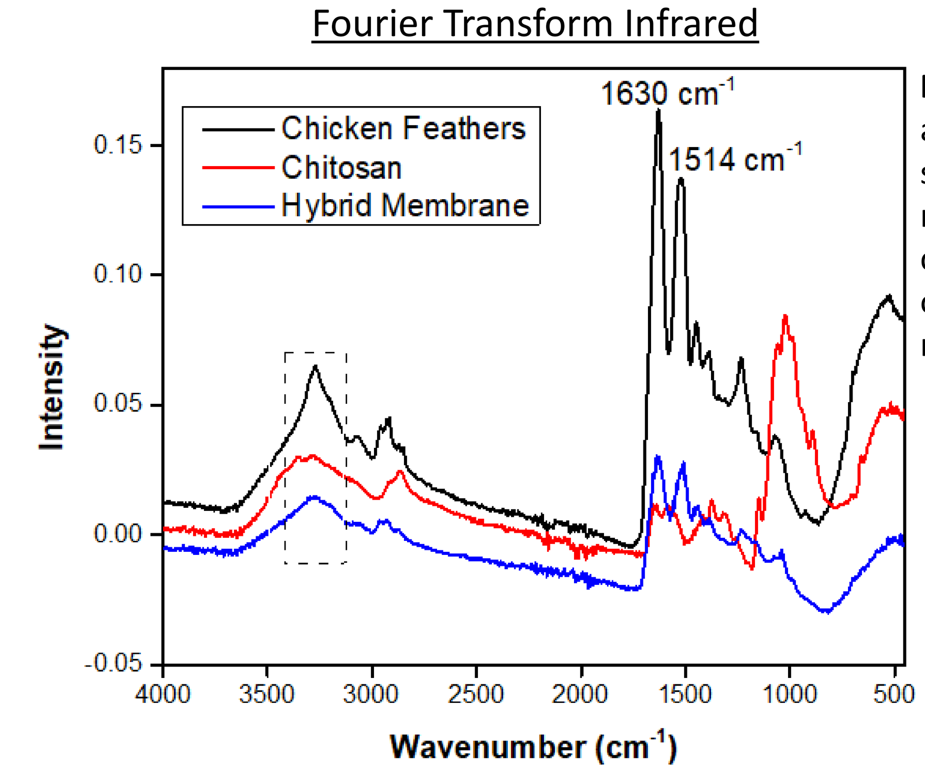

Fig 6. FTIR analysis – showing molecular composition of the materials.

Differential Scanning Calorimetry

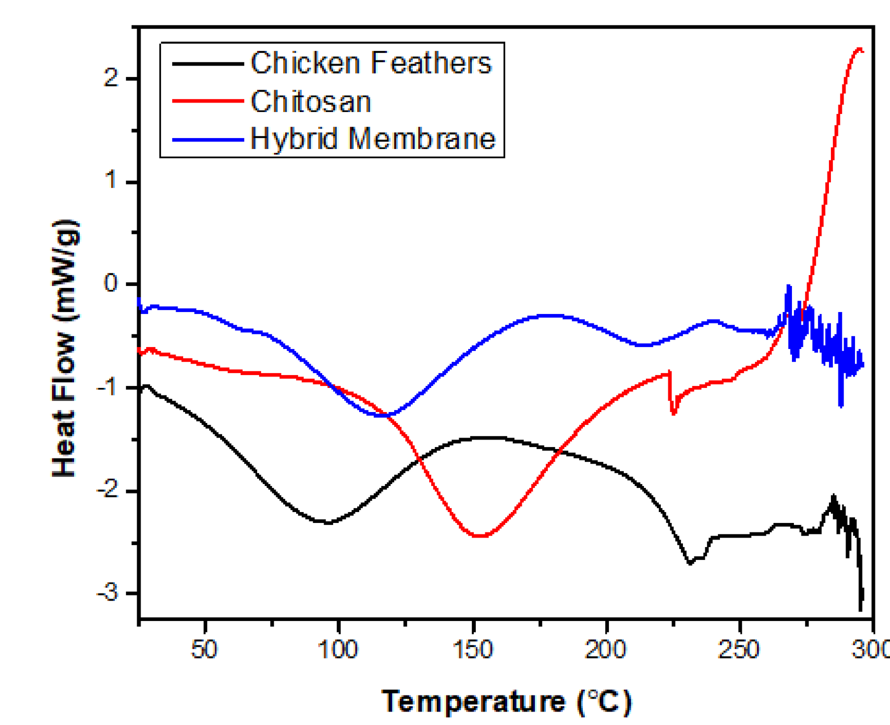

Fig 7. DSC of materials – comparing heat flow in response to temperature.

Expected Outcomes

- Low cost membrane
- Biodegradable and reusable
- Metals (cations) will be adsorbed by electrophilic functional groups on the keratin/chitosan membrane by means of dative bonding
- Metals with a higher positive charge or electronegativity will react more efficiently with the membrane

Conclusions

- When compressing, membranes may not have formed due to a high temperature [Fig 4]. If there was more time for this project, a lower temperature and longer time in the carver press could be tested.
- Evidence from TGA [Fig 5] suggests:
  1. Moisture loss occurs at 100°C
  2. The 2nd decreasing curve shows the decomposition of keratin's secondary structure, the decomposition of polysaccharides into monosaccharides within chitosan, and the separation of keratin and chitosan within the membrane
  3. At the end of the graph, the hybrid membrane has retained more weight than keratin, and therefore has an increased thermal stability, proving its properties and structure has been improved
- Evidence from FTIR [Fig 6] suggests:
  1. Certain wavenumbers correspond to certain bonds
  2. The hybrid membrane contains less of the same groups than keratin, due to its less intense peaks
  3. Dotted lines outline hydroxyl (OH^-) stretching, at 1630cm^{-1} there is Carbonyl stretching, and at 1514cm^{-1} stretching occurs in the amide region
- Evidence from DSC [Fig 7] suggests:
  1. Moisture loss occurs between 100°C and 150°C
  2. The curve after 255°C corresponds to melting temperature
  3. After melting, degradation occurs

Acknowledgements

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Literature cited:
[1] image created in molview.org