Synthesis of Water-induced Cellulose-based Shape Memory Material from Pineapple Leaves

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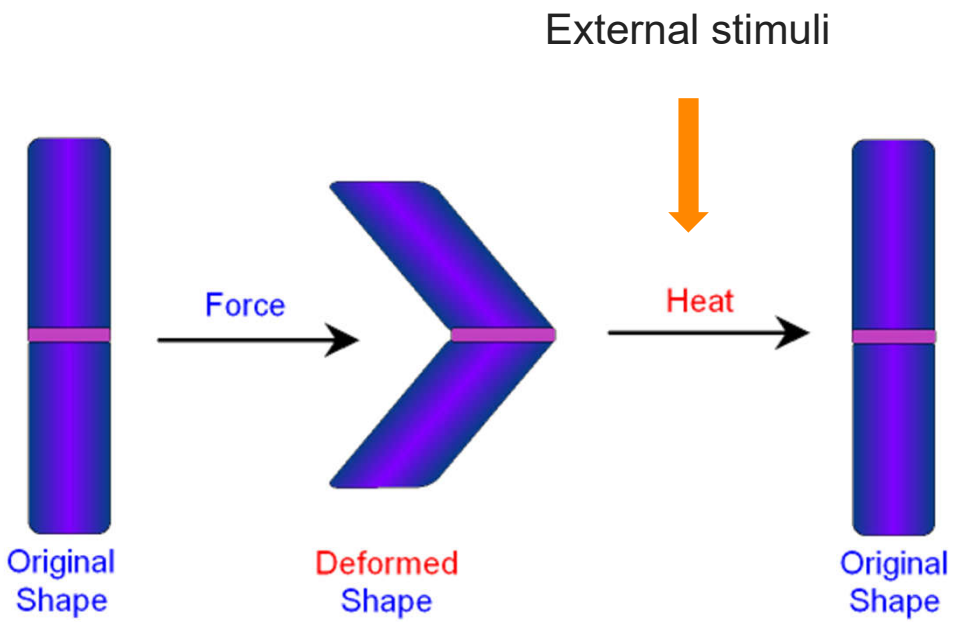
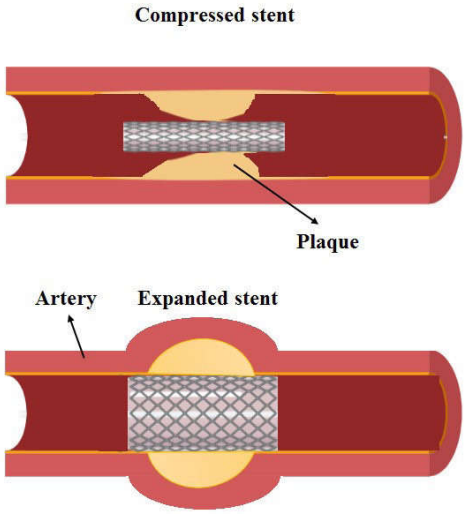
Shape memory materials



What Is Shape Memory?
(N. Seema,2018)



Self-expanding stents based on shape memory alloys and shape memory polymers (M. Ali,2020)

Waste from pineapple leaves

Thailand's Pineapple Situation: 2021 Outlook
(GCF International,2021)

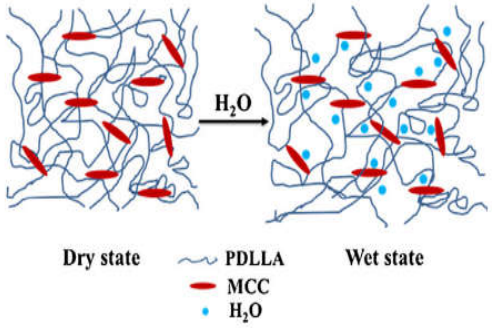
- During harvesting and manufacturing, pineapple leaves are discarded.
- However, pineapple leaf is an abundantly available potential source of cellulose.

Products per year

> **1.5** million tons

Research paper

From mechanisms of shape memory materials



CMC : Can be synthesized from abundant pineapple leaves.

PEG : Be a cross linkage agent that can improve water absorption

CA : Reduce **overmuch** water absorption.

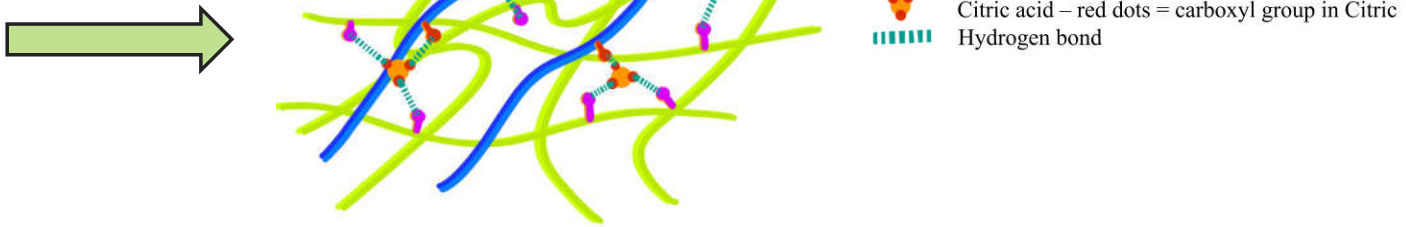
Liu, Y., Li, Y., Chen, H., Yang, G., Zheng, X., & Zhou, S. (2014). Water-induced shape-memory poly(d,l-lactide)/ microcrystalline cellulose composites. Carbohydrate Polymers, 104, 101–108.

Objective

- To synthesize water-induced cellulose-based shape memory materials from pineapple leaves with the best proportion of CMC : PEG : CA

(IJB_INNSPUB, 2019: Online)

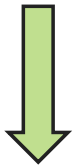
Pineapple leaves waste



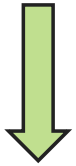
Shape memory material

Methodology

Part I : Preparation of cellulose from pineapple leaves



Part II : Synthesis of shape memory materials

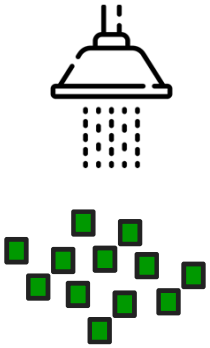


Part III: Shape recovery behavior of materials and physical properties test

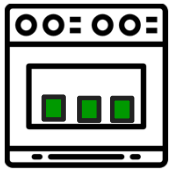
Part I : Preparation of cellulose from pineapple leaves

Pineapple leaves preparation

Pineapple leaves waste



Wash and cut pineapple leaves into small pieces

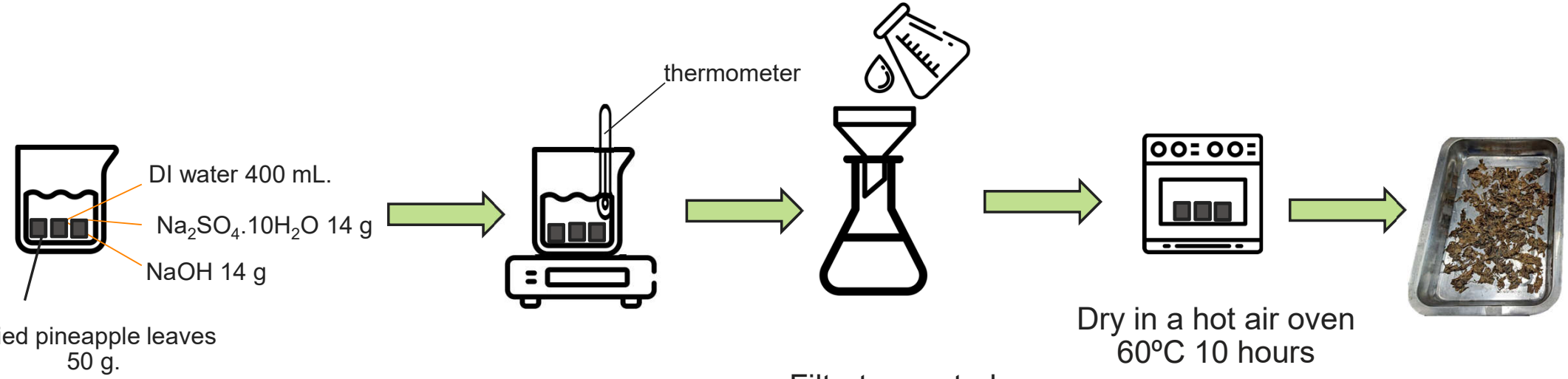


Dry in a hot air oven 60ºC 4 hours

Dried pineapple leaves

Part I : Preparation of cellulose from pineapple leaves

Alkali treatment for isolation cellulose



Dried pineapple leaves
50 g.

Prepare mixture of pineapple leaves and reagents

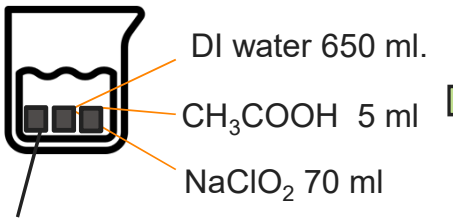
Heat the mixture
70ºC 4 hours

Filtrate reacted pineapple leaves with vacuum filter
&
wash with DI water

Dry in a hot air oven
60ºC 10 hours

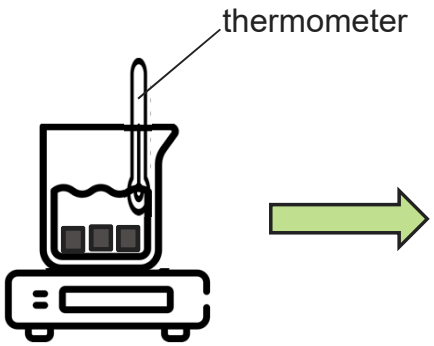
Part I : Preparation of cellulose from pineapple leaves

Bleaching cellulose

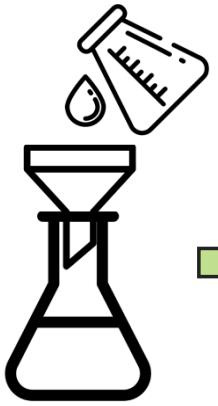


Dried pineapple leaves
50 g.

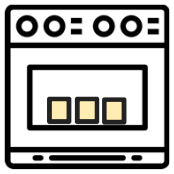
Prepare mixture of pineapple leaves and reagents



Heat the mixture
80ºC 3 hours



Filtrate bleached cellulose with vacuum filter
&
wash with DI water

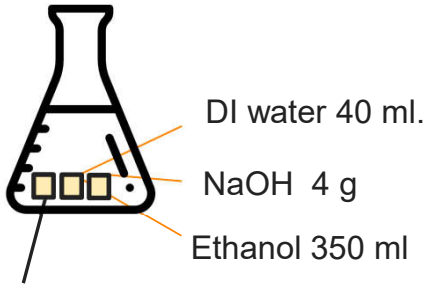


Dry in a hot air oven
60ºC 10 hours

Cellulose

Part I : Preparation of cellulose from pineapple leaves

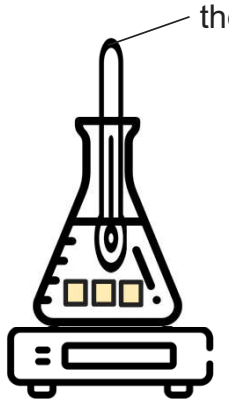
CMC preparation from cellulose



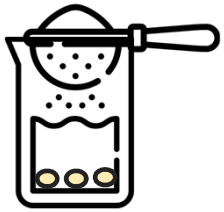
Bleached pineapple leaves
12 g.

Prepare mixture of bleached pineapple leaves and reagents

Shake on a shaker
30 minutes



Heat the mixture
70ºC 3 hours



Filtrate large solids from mixtures and fine sediments

Part I : Preparation of cellulose from pineapple leaves

CMC preparation from cellulose

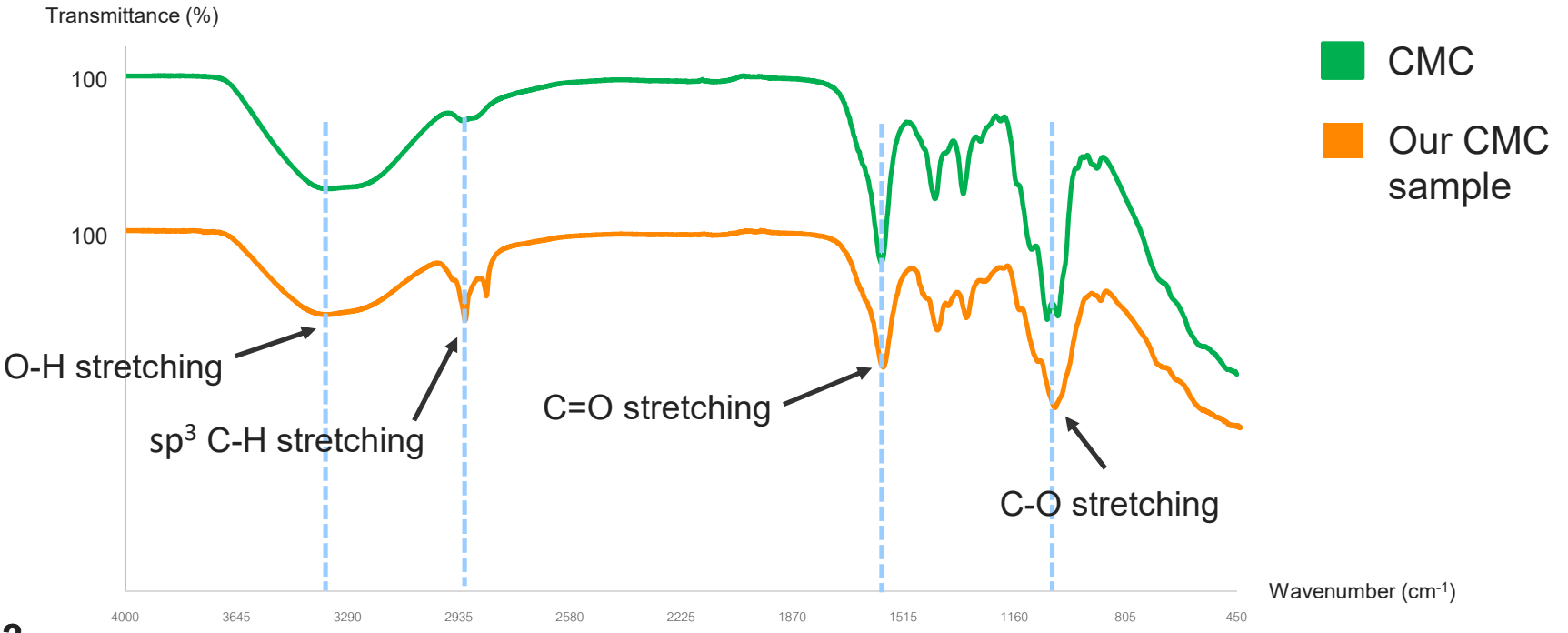
Filtrate the CMC sediments with a vacuum filter
&
wash with DI water

Dry in a hot air oven 60ºC 10 hours

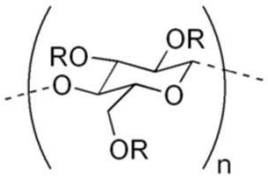
Carboxymethyl Cellulose (CMC)

Part I : Preparation of cellulose from pineapple leaves

Carboxymethyl cellulose (CMC) Characterization by FTIR

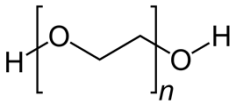


Part II : Synthesis of shape memory materials

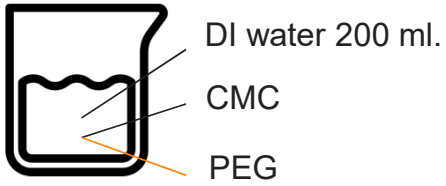


CMC

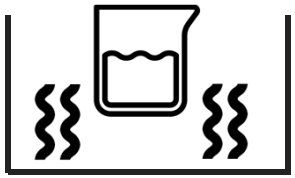
+



PEG

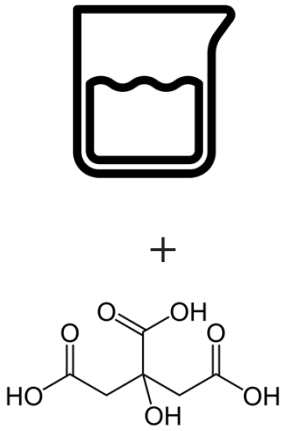


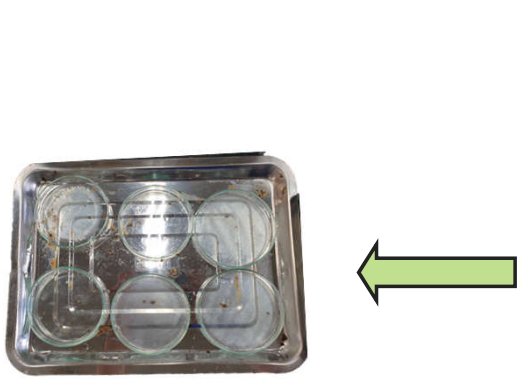
Mix CMC and PEG in different proportions



Sonicate in an ultrasonic bath 45-60 minutes

Part II : Synthesis of shape memory materials

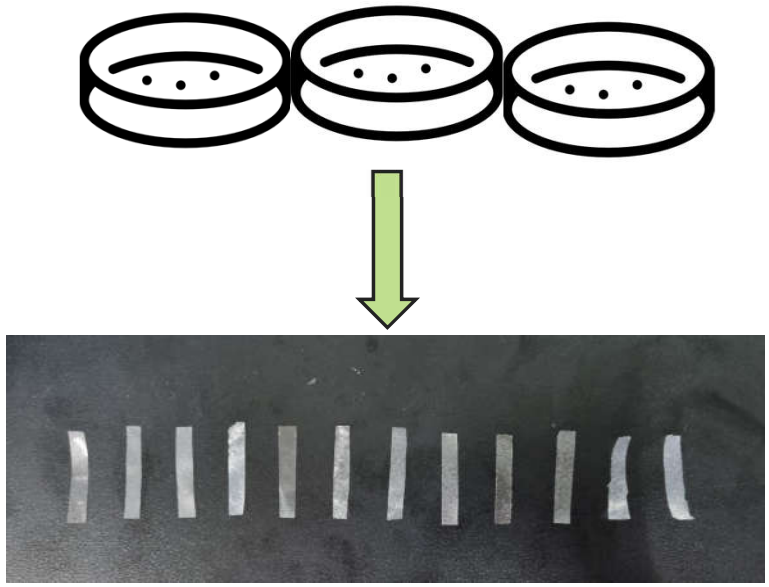




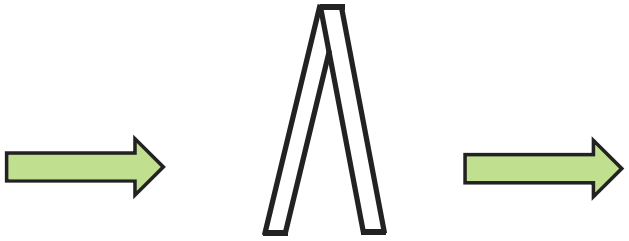
The proportions of materials in each sample (%w/w)

sample	CMC	PEG	CA
1	100	0	0
2	90	10	0
3	80	20	0
4	70	30	0
5	90	0	10
6	80	10	10
7	70	20	10
8	60	30	10
9	80	0	20
10	70	10	20
11	60	20	20
12	50	30	20

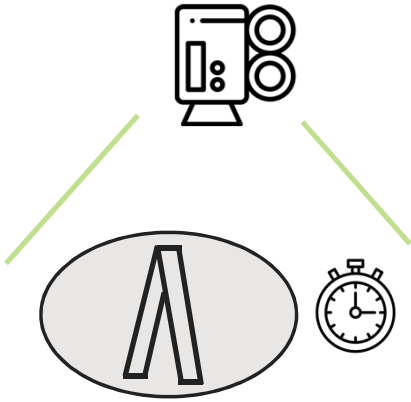
Part III: Shape recovery behavior of materials test



Cut the materials with
5 mm. x 30 mm.
&
Weigh its mass and
measure its volume



Fold the materials up
in the half

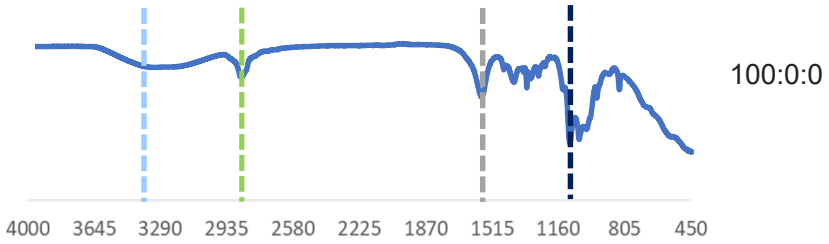


Take videos material
deformation in water
by a camera
&
Weigh its mass and
measure its volume

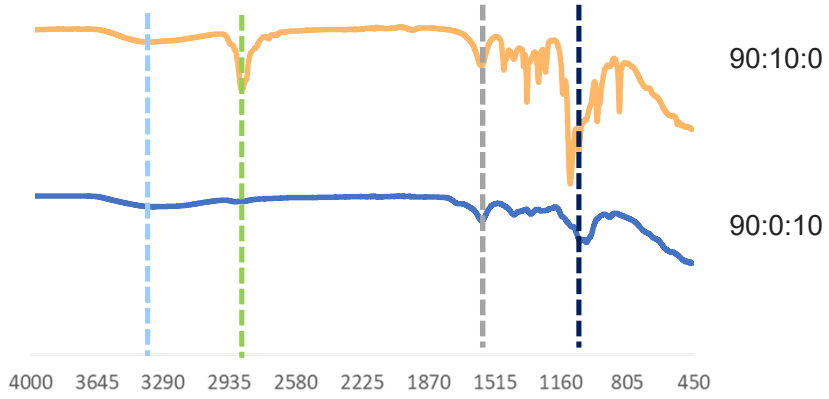
Part III: Tensile modulus and elongation at break test

Use Universal testing machine (UTM)
to test the 12 different ratios of materials.

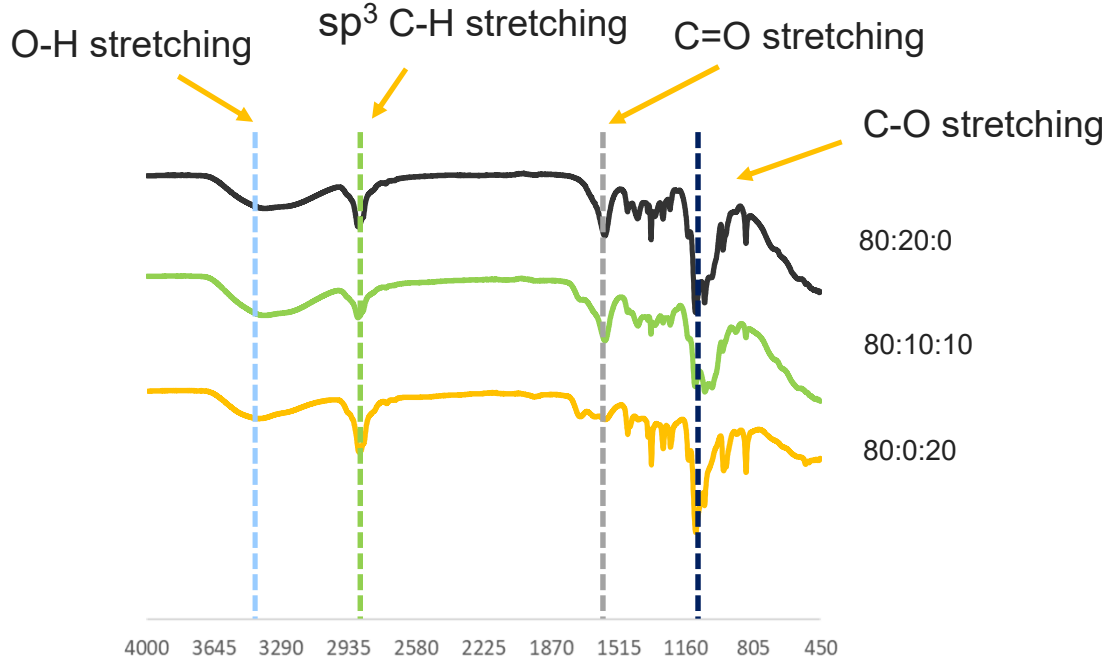
Materials characterization by FTIR



100 %w/w CMC concentration

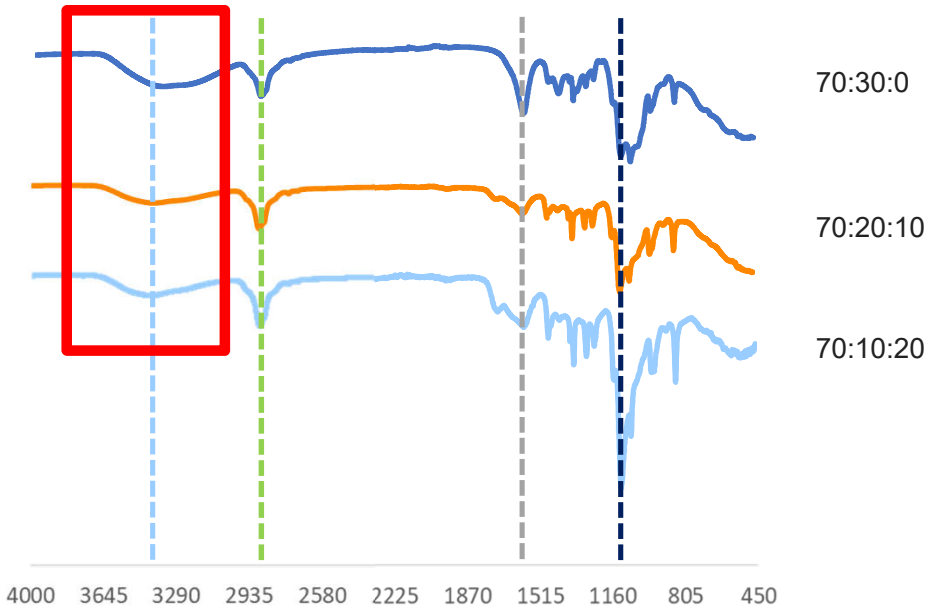


90 %w/w CMC concentration

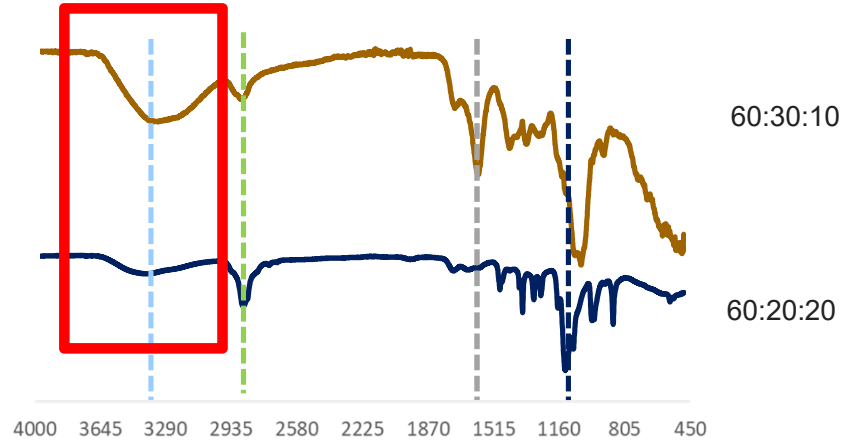


80 %w/w CMC concentration

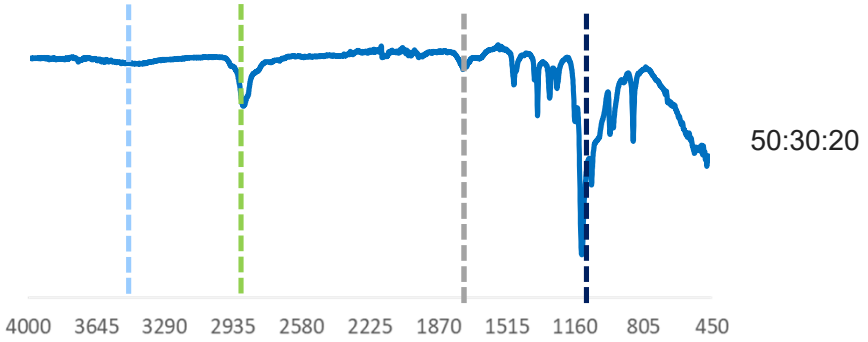
Materials characterization by FTIR



70 %w/w CMC concentration



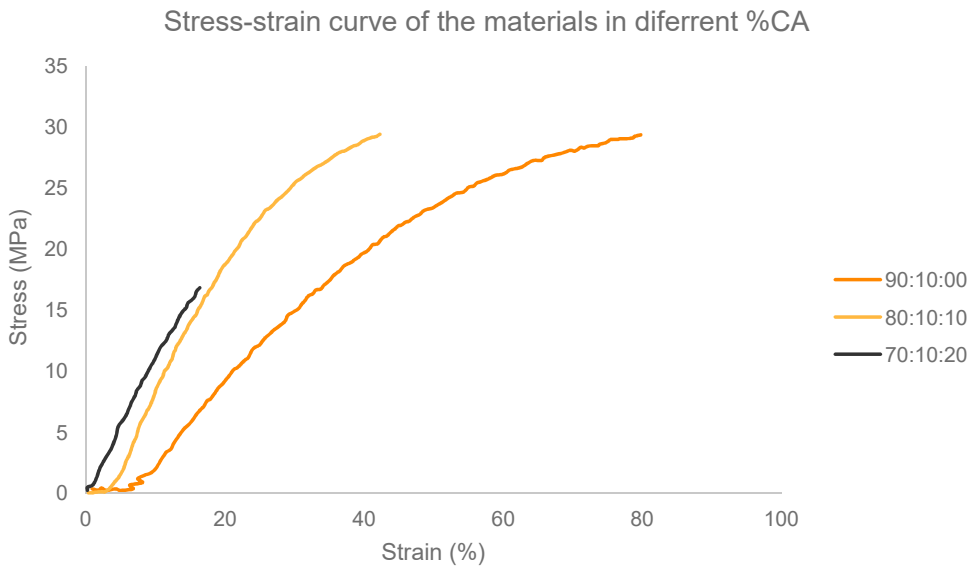
60 %w/w CMC concentration

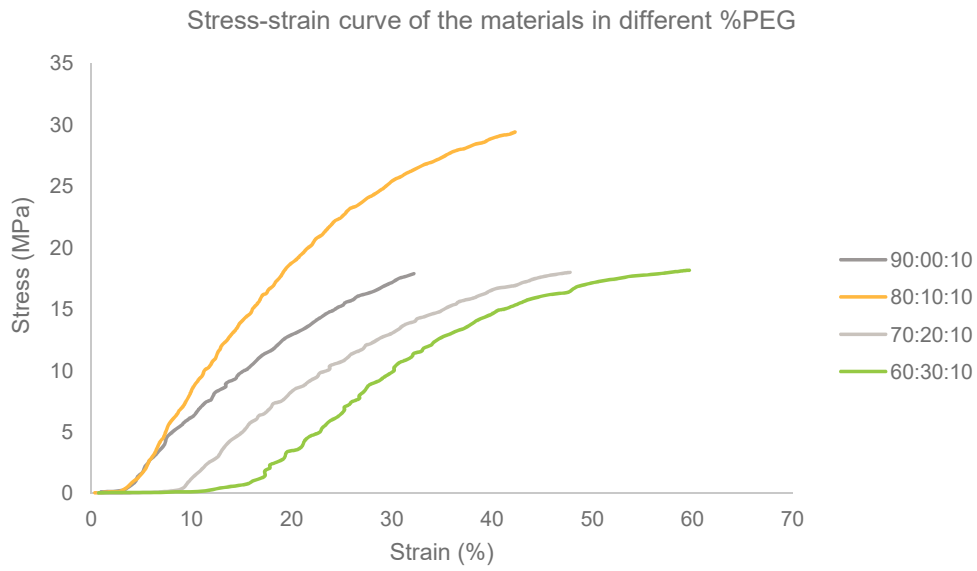


50 %w/w CMC concentration

Physical properties of materials

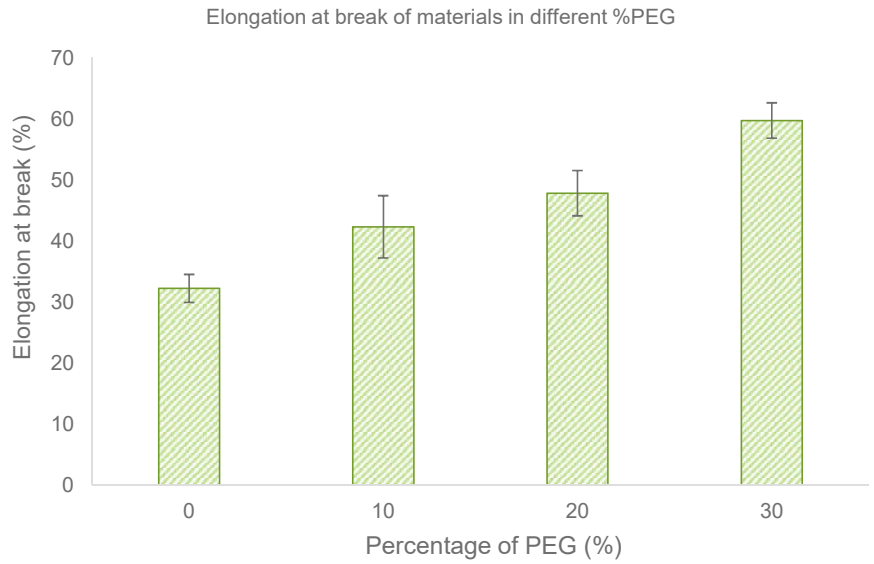
Stress-Strain

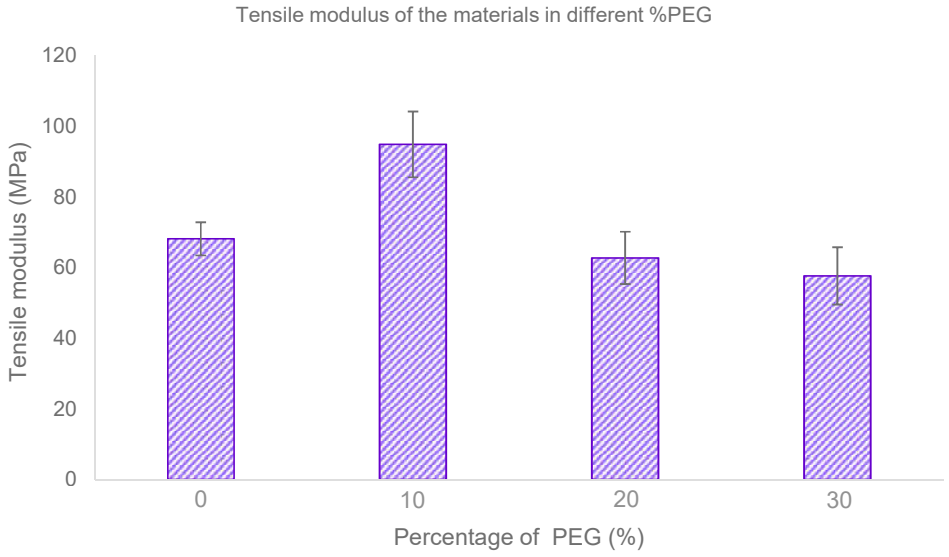




Physical properties of materials

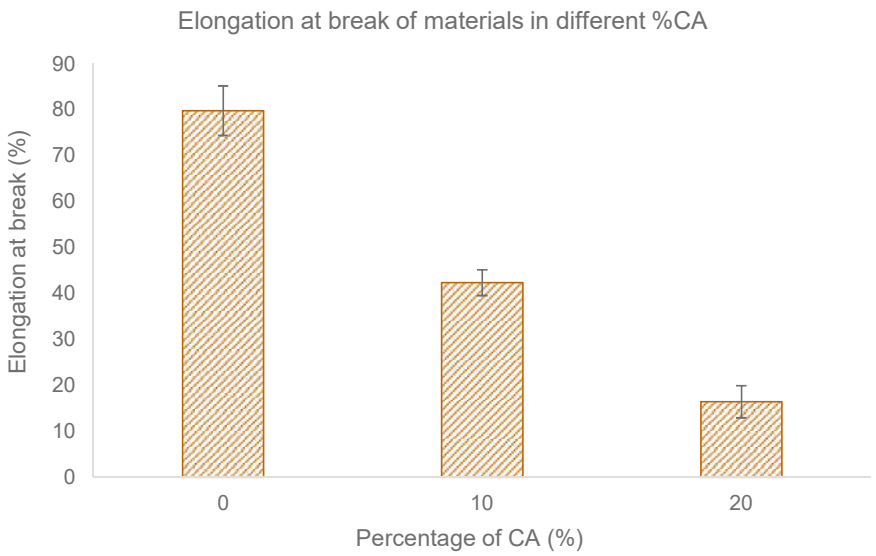
Effect of PEG

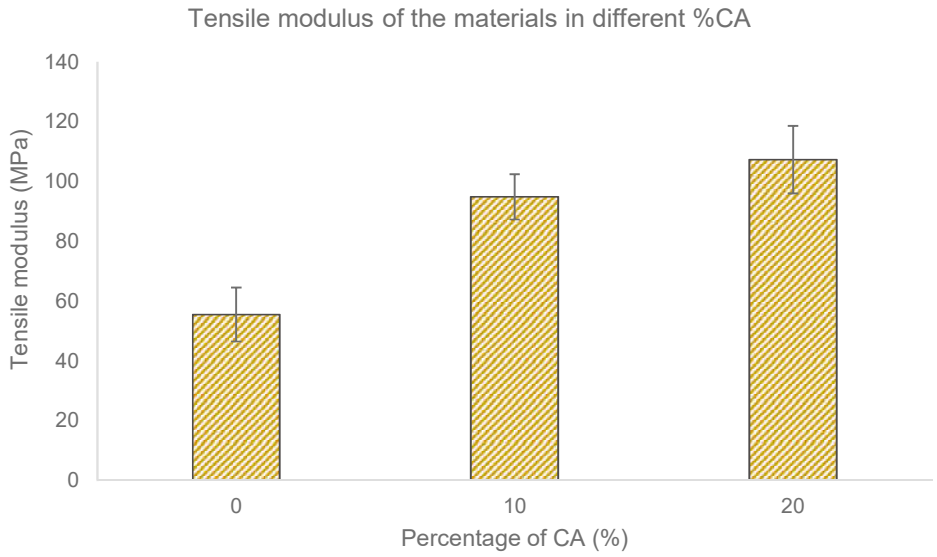




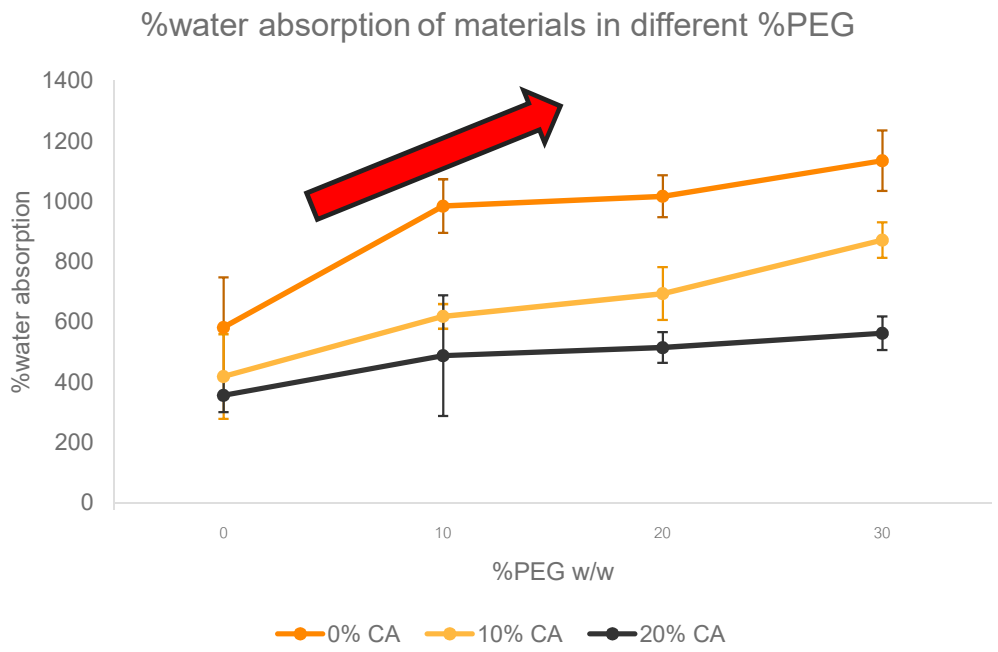
Physical properties of materials

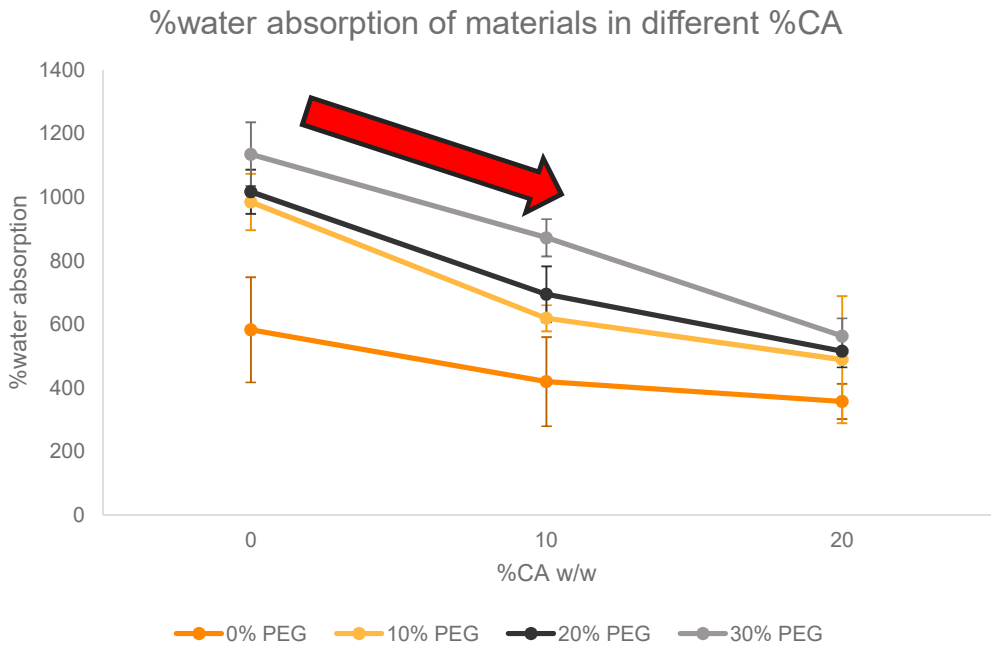
Effect of CA





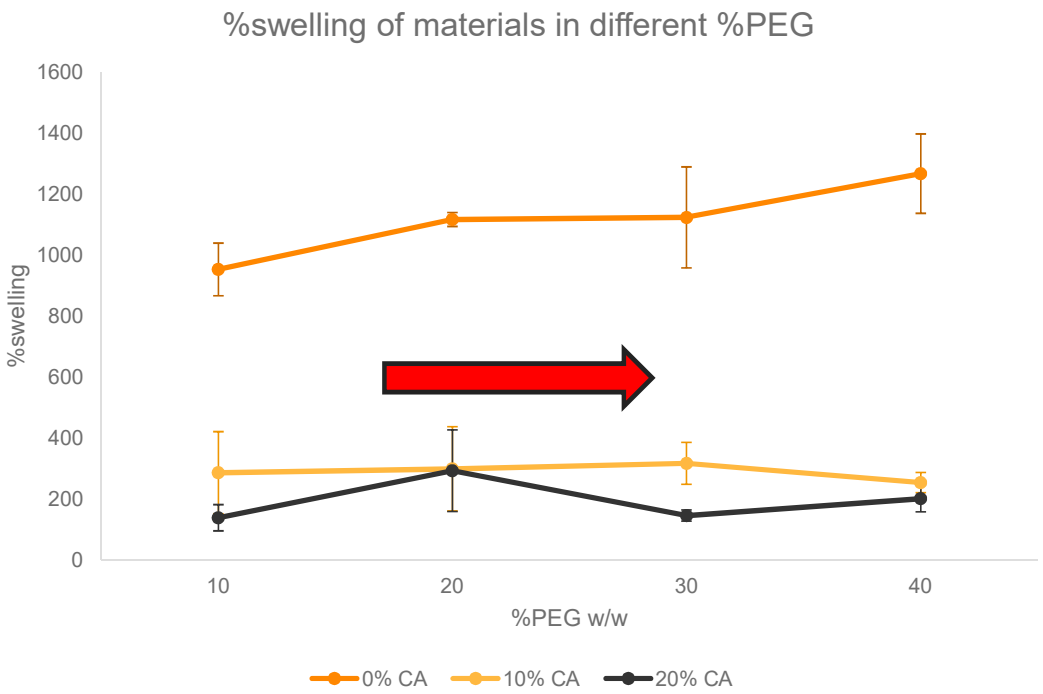
%Water absorption

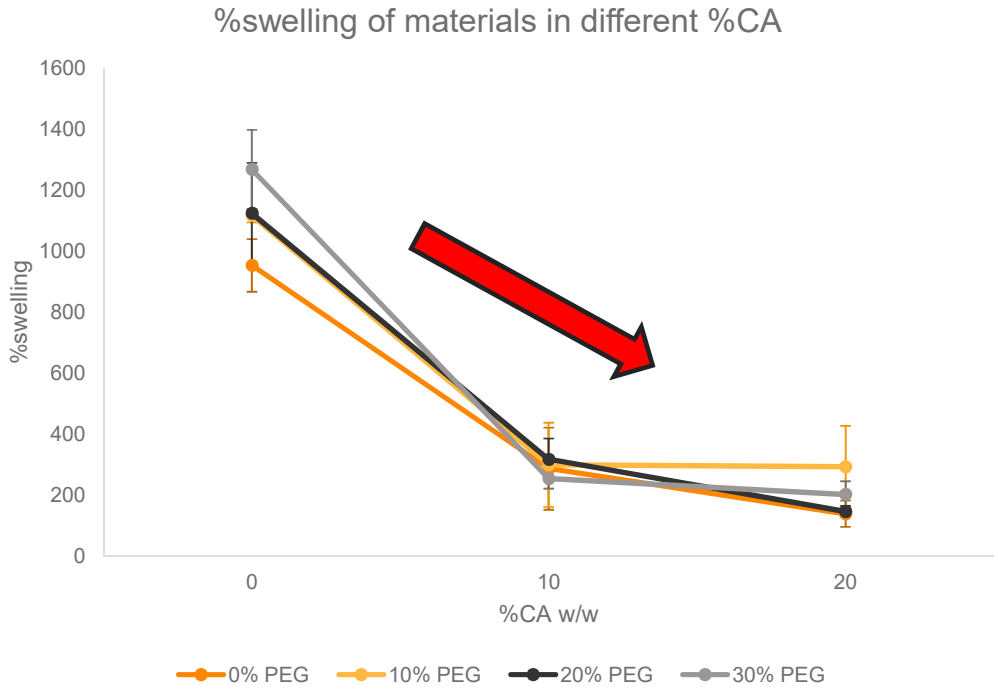




$$\%\ water\ absorption = \frac{M_f - M_i}{M_i} x100\%$$

%Swelling

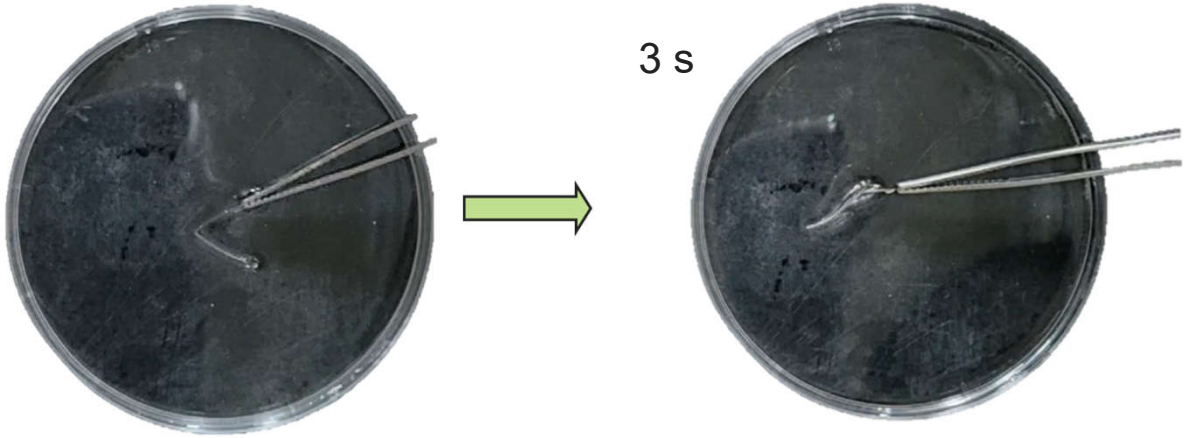




$$\% \; swelling = \frac{V_f - V_i}{V_i} x100\%$$

Shape recovery of materials

0 s



3 s

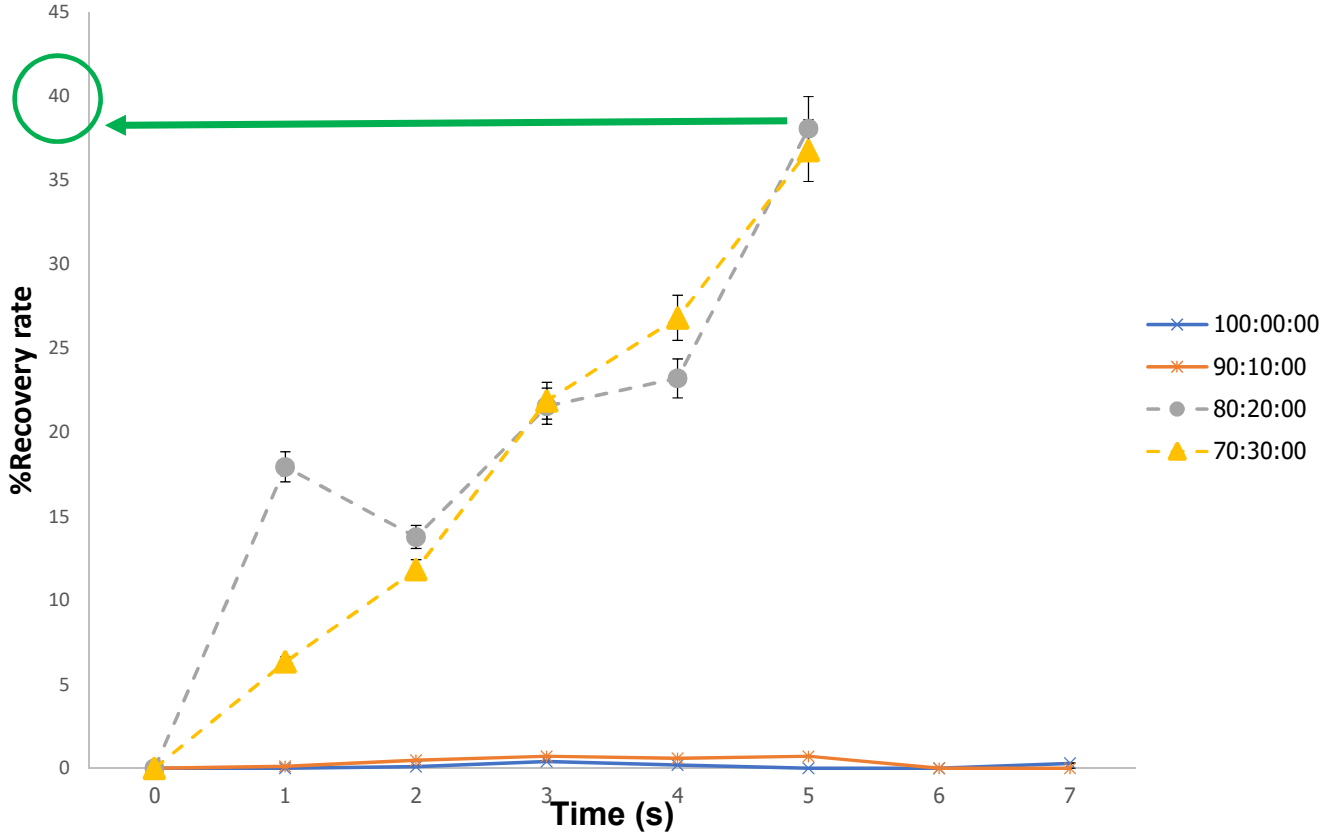
The picture example of experiment

$$R_r = \left(\frac{\theta_f - \theta_{\mathrm{i}}}{180^0 - \theta_{\mathrm{i}}}\right) x100\%$$

θ_{i} is the initial angle
θ_f is the final angle
R_r is the percentage of shape recovery

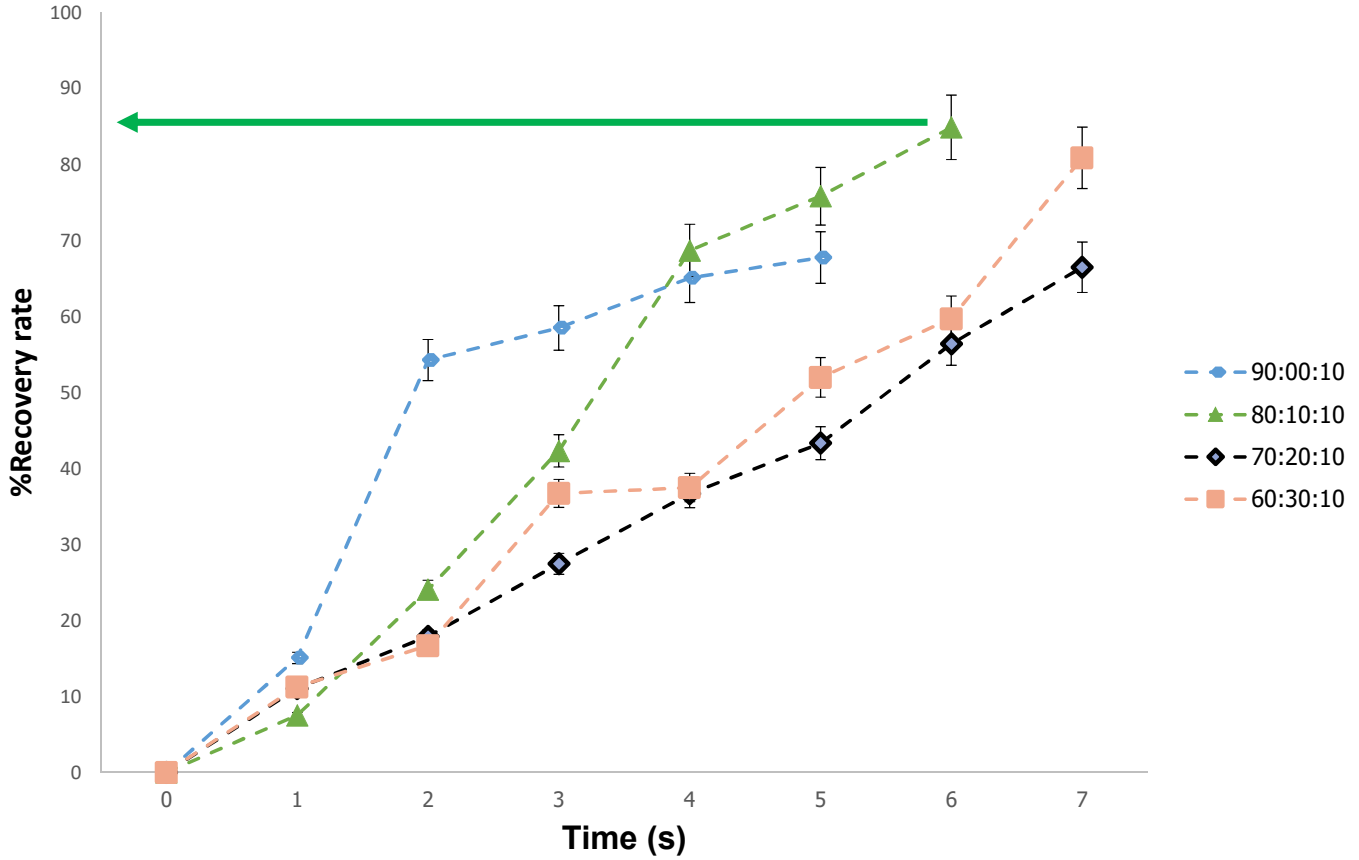
Results : Shape recovery behavior

%Recovery rate at 0%w/w CA concentration



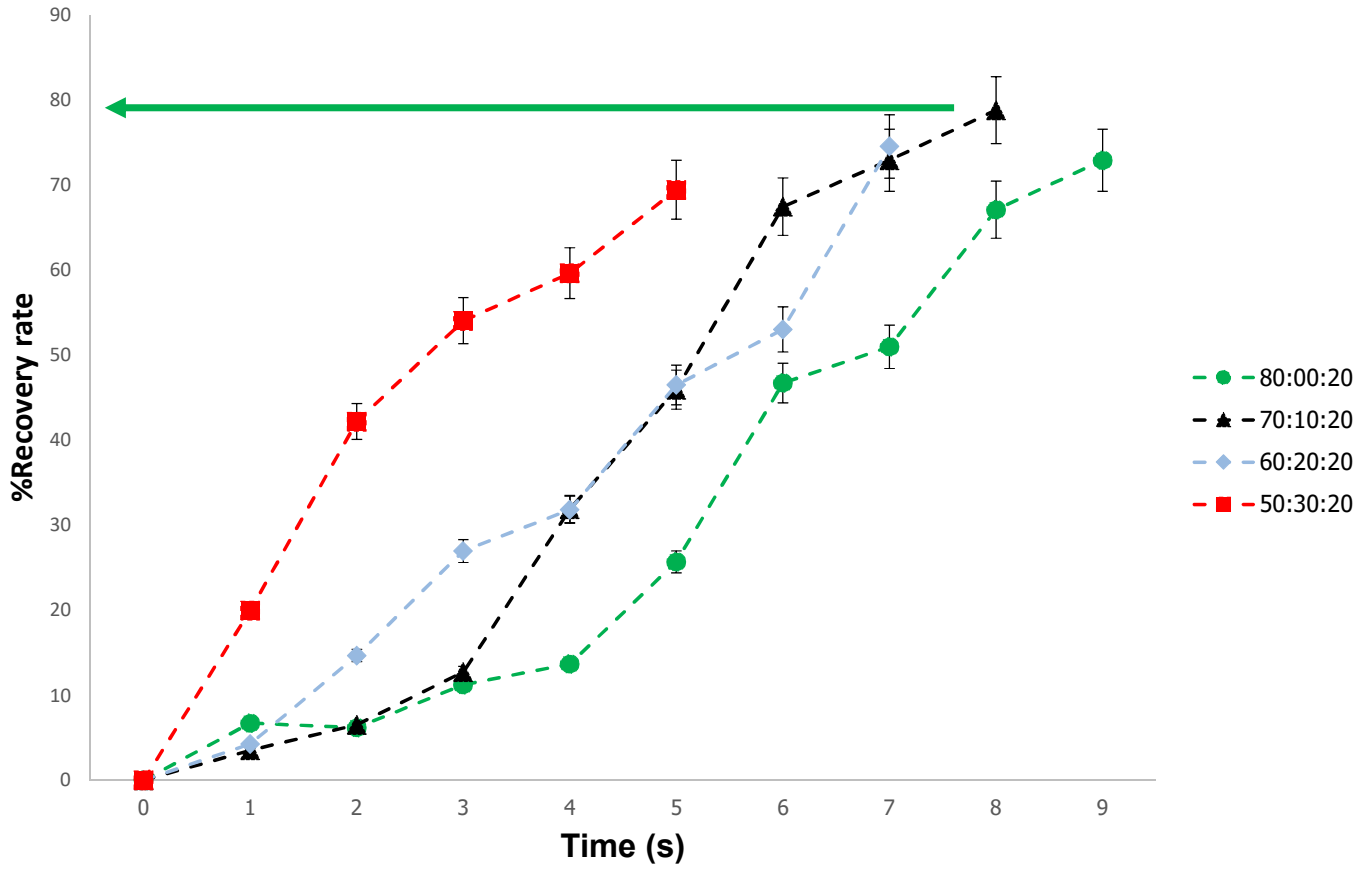
Results : Shape recovery behavior

%Recovery rate at 10%w/w CA concentration



Results : Shape recovery behavior

%Recovery rate at 20%w/w CA concentration



Conclusion

- The best ratio of CMC:PEG:CA is 80:10:10 with the recovery rate 84.84% in 6 seconds.

- CA has the ability to decrease water absorption and swelling of the materials, but PEG has only the ability to increase water absorption.

- CA improves tensile modulus, but decrease elongation at break of the materials. In contrast, PEG increases elongation at break of the materials ,but it don’t have predictable trends of tensile modulus.

Reference

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THANK YOU