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Comparative study of enzymatic and chemical denaturation of wheat gluten and their cellulosic nanocomposites

By

Nahla A. El-Wakil
Cellulose & Paper Dept.
National Research Center
Cairo, Egypt

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Protein-Based nanocomposites for Food Packaging

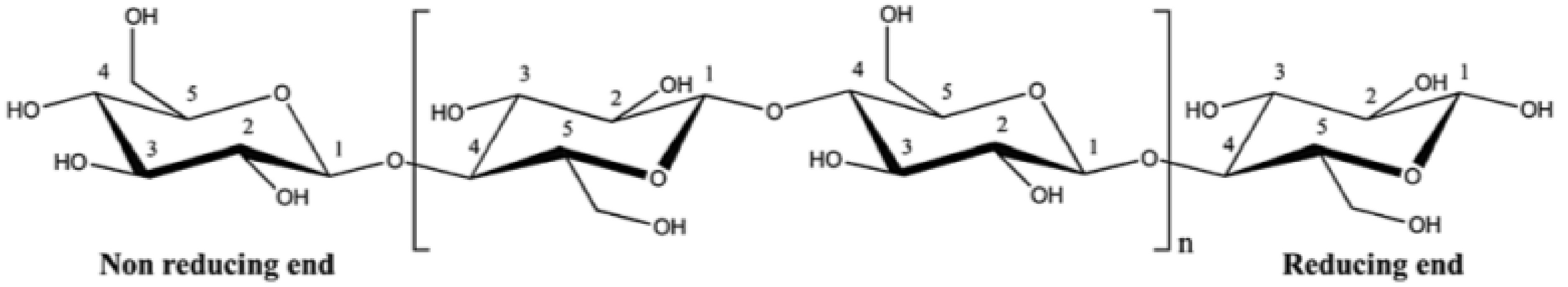
Academy of Scientific Research and Technology, Egypt & Campus France

Objective

The purpose is to examine the role of nanocellulose (CNC and MFC) as a reinforcing agent on the chemically and enzymatically denatured wheat gluten films.

Introduction

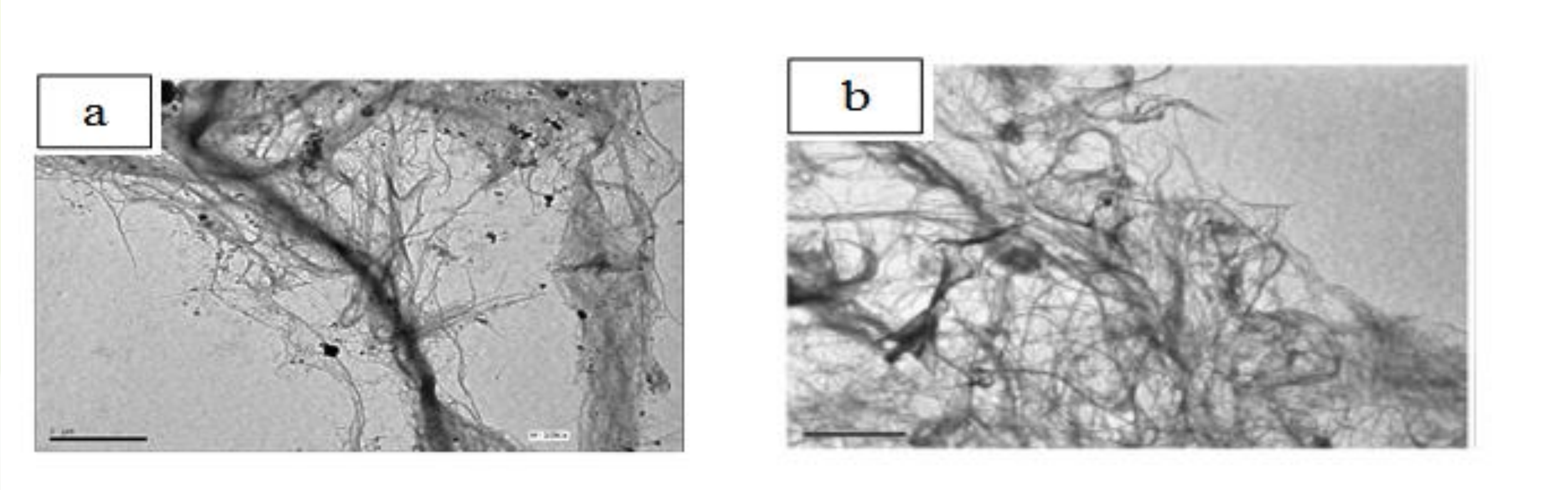
Cellulose



Chemical structure of cellulose (Klemm. et al., 2009)

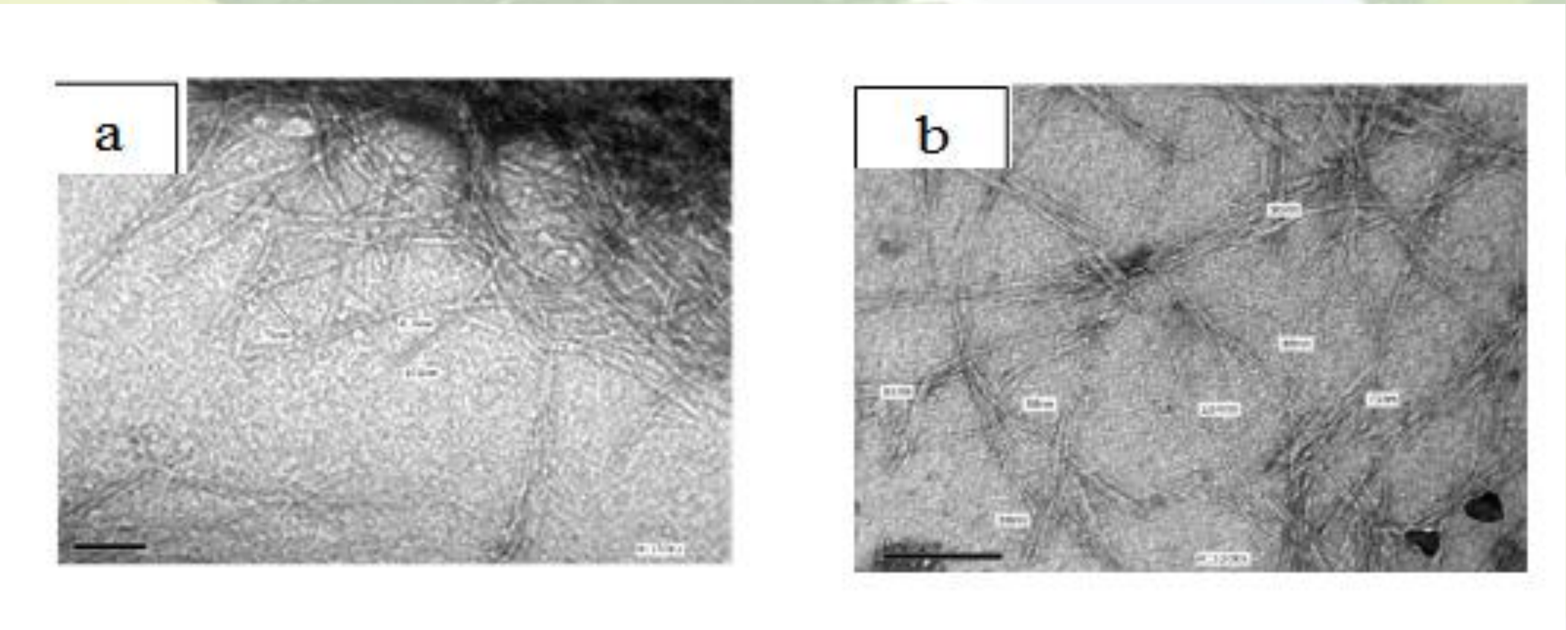
Nanocellulose

Microfibrillated cellulose



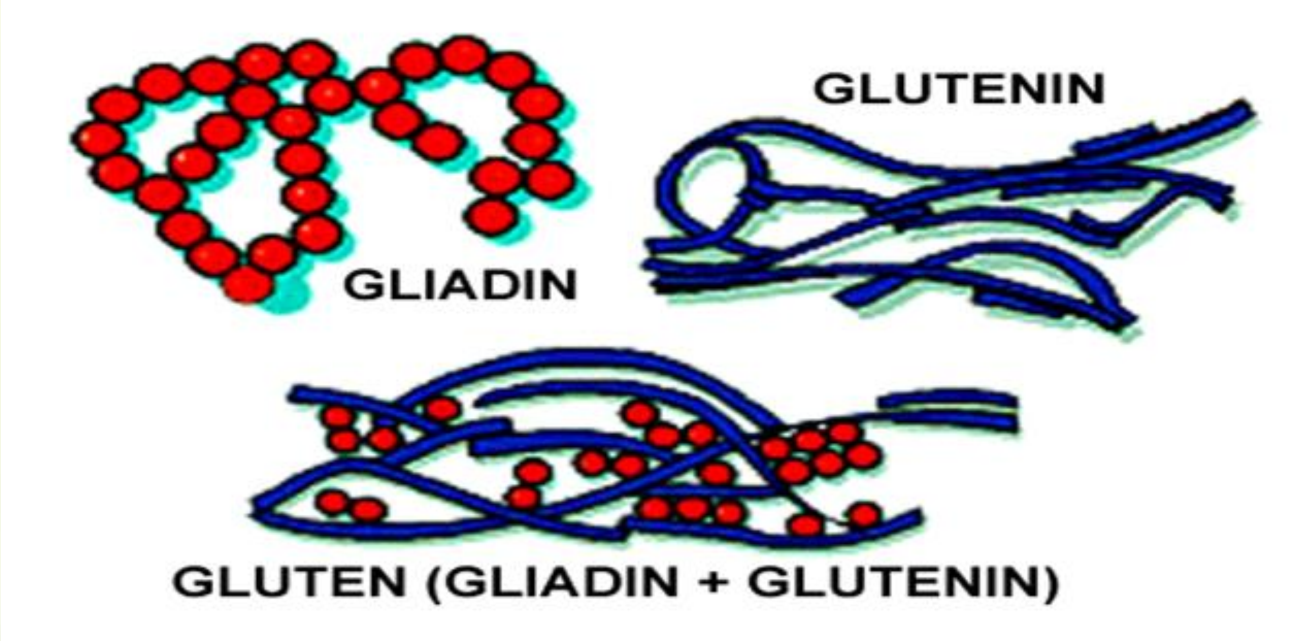
TEM of nanofibers isolated from rice straw (a) and bagasse (b) (Hassan et al., 2010 & 2012)

Cellulose nanocrystals



The nanostructure of (a) bagasse and rice straw (b) (Hassan et al., 2009)

Wheat gluten



The structure of wheat gluten

Denaturation of protein

- Heat denaturation
- Chemical denaturation
- Enzymatic denaturation

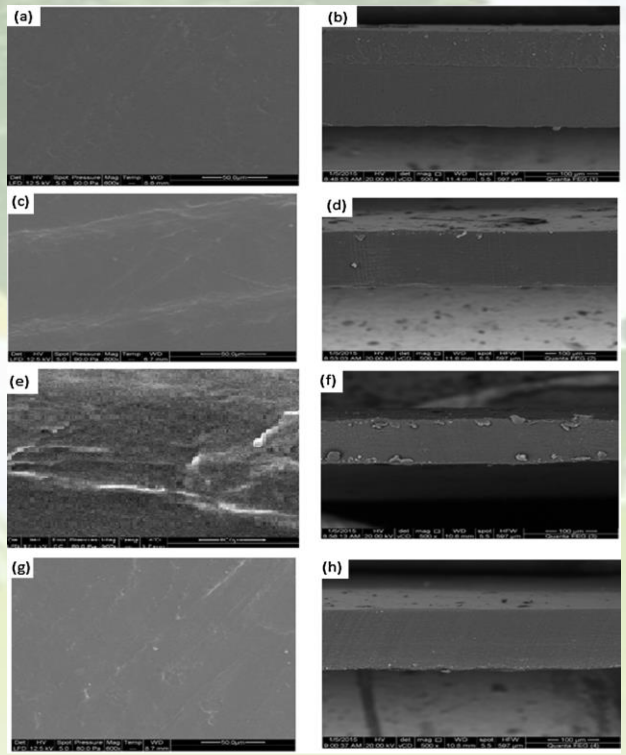
Chemical denaturation of wheat gluten

Development of wheat gluten/nanocellulose/titanium dioxidenanocomposites for active food packaging. Nahla A. El-Wakil, Enas A. Hassan, Ragab E. Abou-Zeid, Alain Dufresne. Carbohydrate Polymers 124(2015) 337–346.

Charcterization

- Scanning electron microscopy (SEM)
- Water sensitivity
    - Contact angle
    - Water vapor uptake (WVU)
    - Water vapor permeability (WVP)
- Mechanical testing
    - Tensile strength and Young's modulus
- Antimicrobial activity

Scanning electron microscopy (SEM)



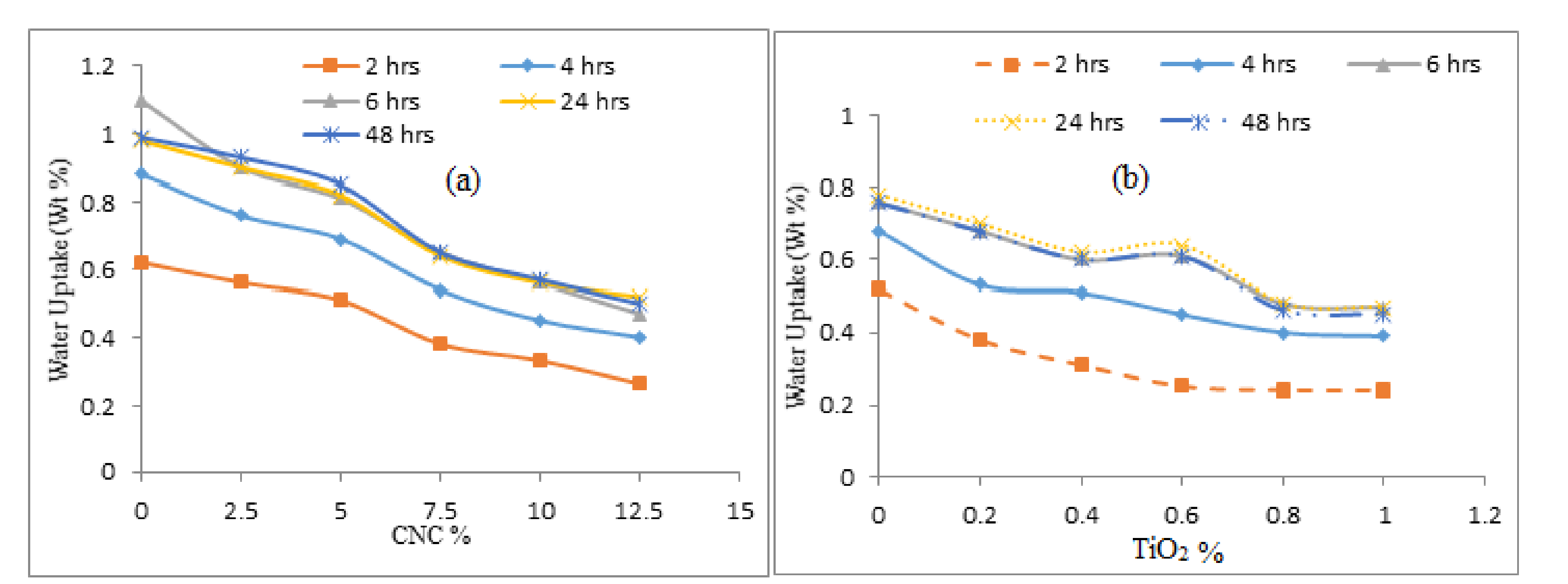
SEM micrographs of surfaces and cross sections of neat WG (a and b), WG/CNC 7.5% (c and d), WG/CNC 12.5% (e and f) and WG/CNC 7.5%/0.6%TiO_2(g and h).

Contact angle

Contact angle of WG, WG / CNC and WG/CNC/ TiO_2

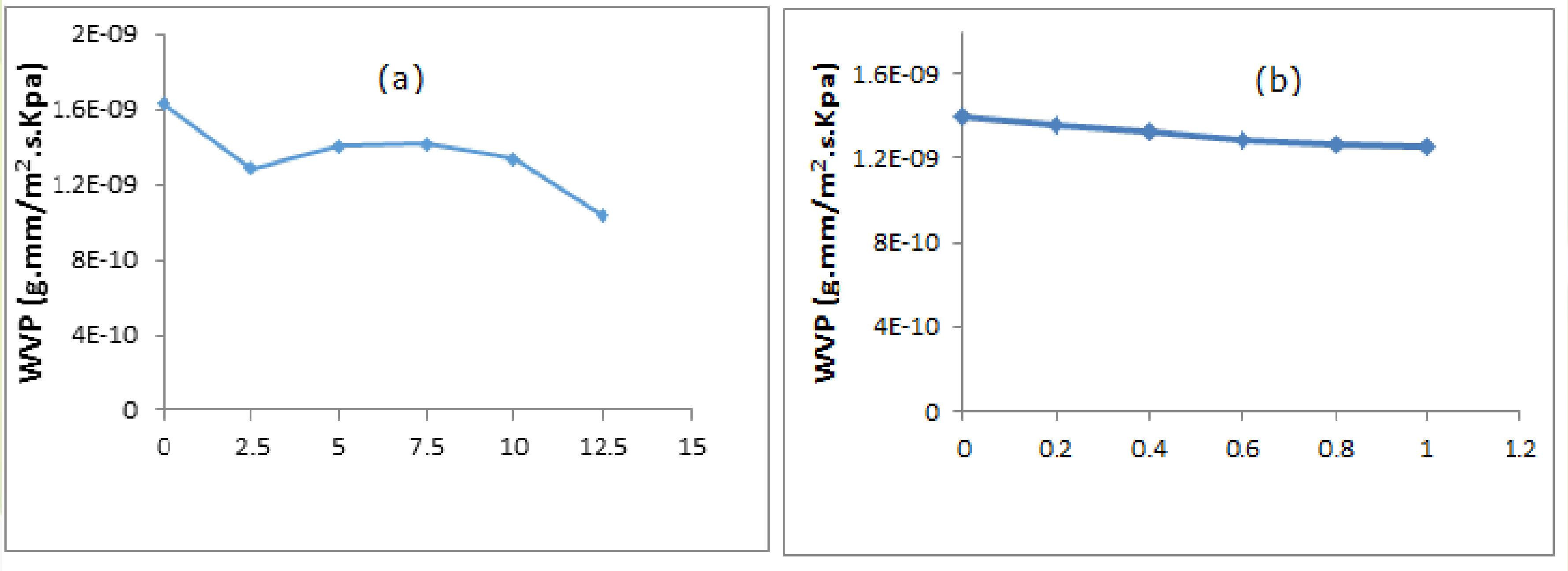
WG/CNC		WG/CNC 7.5%/TiO2	
Sample	Contact angle	Sample	Contact angle
WG	45.10 ± 1.18	WG/CNC 7.5%	64.04 ± 2.84
2.5% CNC	58.88 ± 0.74	0.2% TiO2	67.10 ± 0.11
5% CNC	62.00 ± 0.38	0.4% TiO2	68.86 ± 0.41
7.5% CNC	64.04 ± 2.84	0.6%TiO2	74.63 ± 0.66
10% CNC	75.19 ± 0.25	0.8% TiO2	85.6 ± 2.31
12.5% CNC	78.48 ± 1.18	1.0% TiO2	89.70 ± 0.14

Water vapor uptake test (WVU)



Dependence of WVU on CNC content (a) and TiO_2 content (b).

Water vapor permeability (WVP)



Dependence of WVP on CNC content (a) and TiO_2 content (b).

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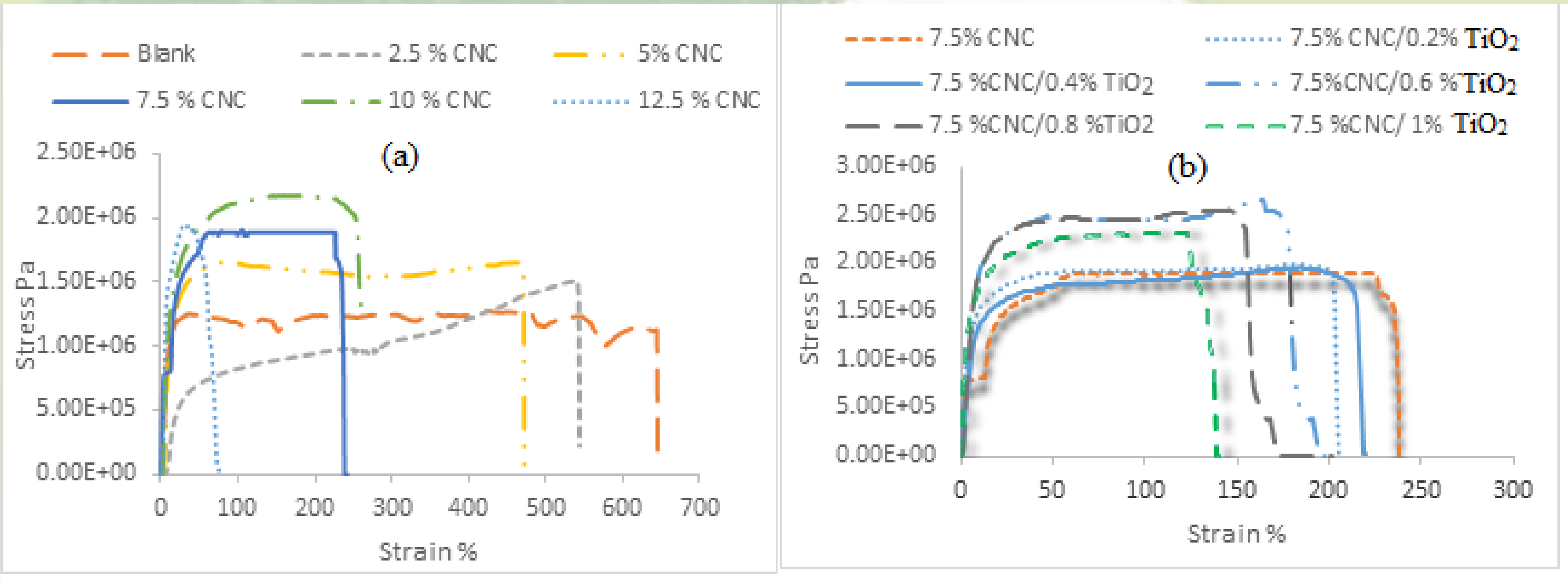
Mechanical testing



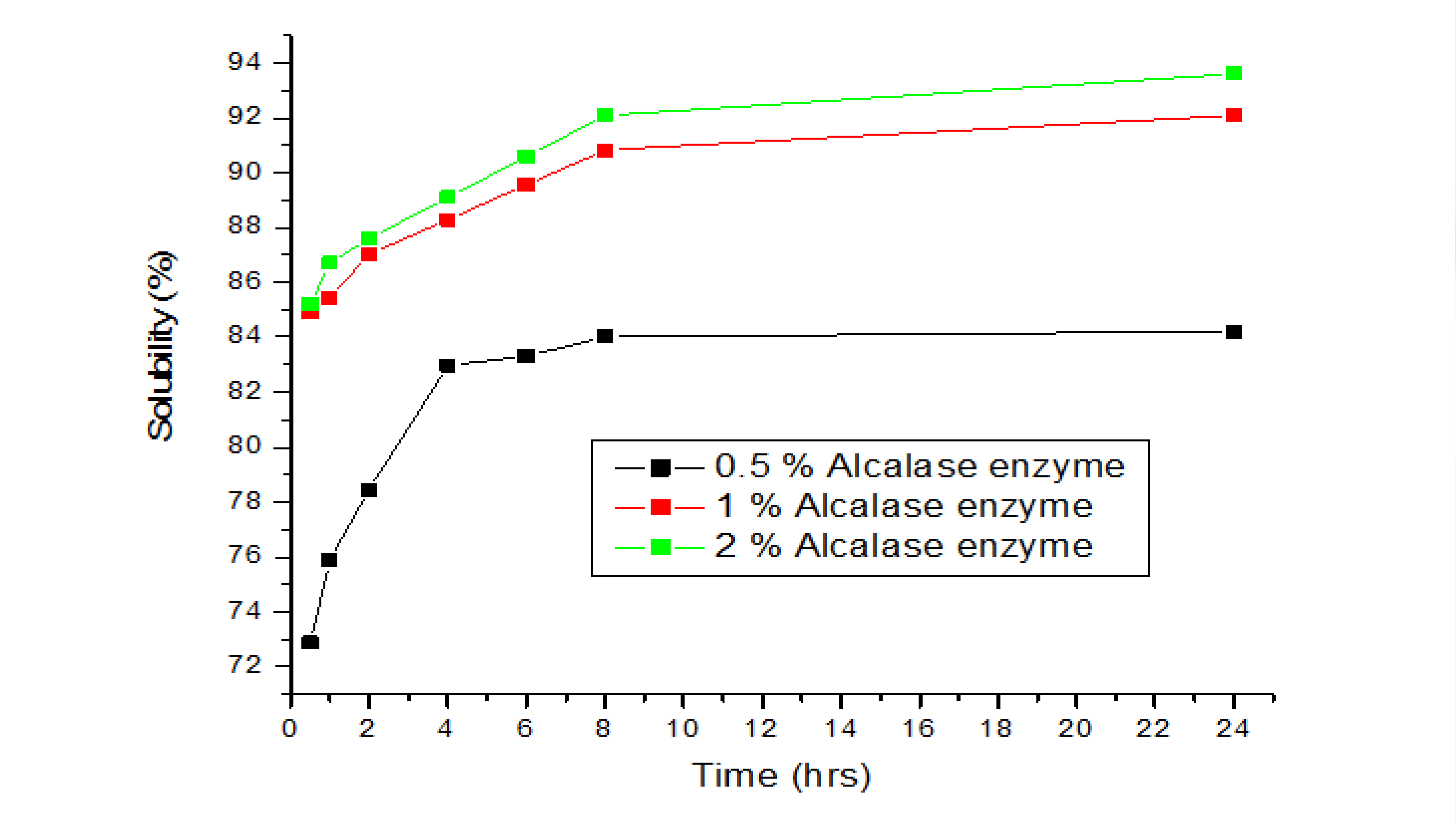
Typical stress-strain curves obtained from tensile tests for neat WG and WG filled with CNC (a) and WG with 7.5% CNC filled with TiO_2 (b).

Antimicrobial activity

The colony-forming units (CFU/ml) and the reduction % of surviving number of the tested bacteria of the coated paper with and without TiO_2 nanoparticles

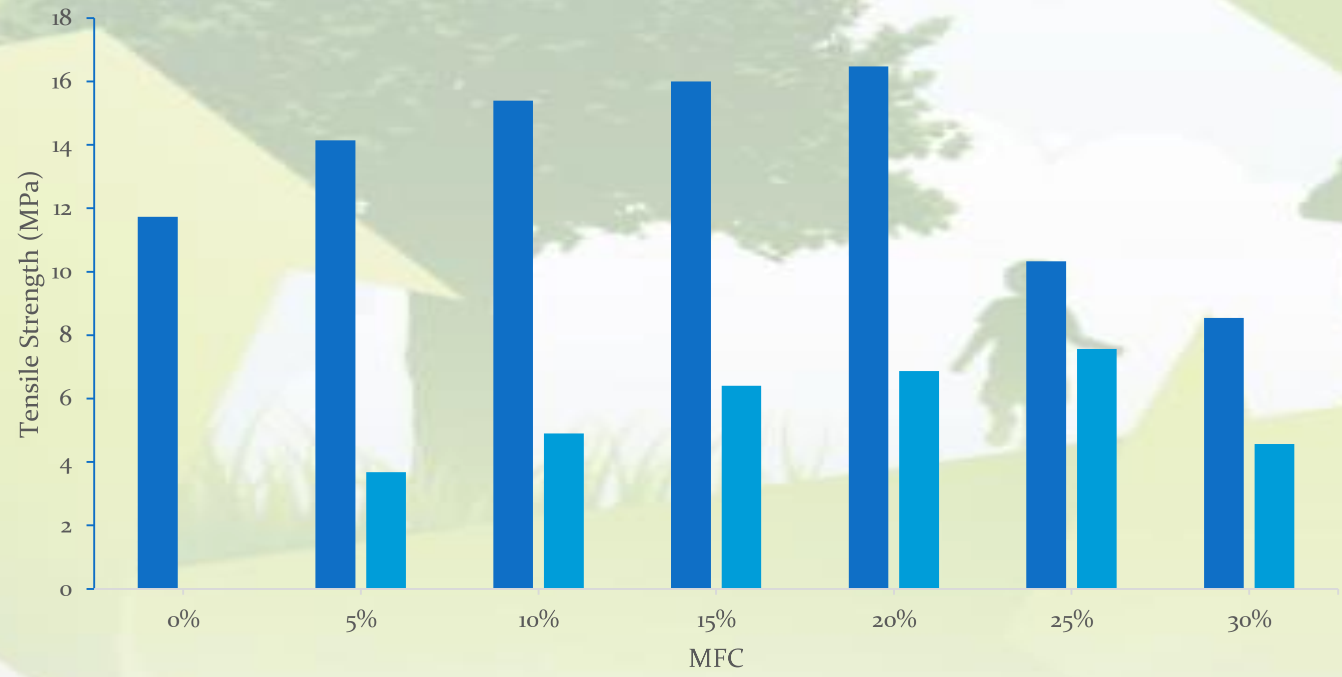
	S. aureus						*E. coli*					
	Time of UVA light exposure (h)											
	1/2		1		2		1/2		1		2	
Sample	CFU/ml	R (%)	CFU/ml	R (%)	CFU/ml	R (%)	CFU/ml	R (%)	CFU/ml	R (%)	CFU/ml	R (%)
Blank	2.4×10^5	-	3.7×10^5	-	3.1×10^5	-	3.2×10^5	-	6.0×10^5	-	6.6×10^5	-
I layer	1.0×105	58.3	8.0×10^4	78.4	0	100	2.5×10^5	21.9	2.9×10^5	51.7	1.0×10^5	84.9
II layers	3.7×10^4	84.6	1.0×10^4	97.3	0	100	1.9×10^5	40.6	1.0×10^5	83.8	3.0×10^4	95.5
III layers	2.9×10^4	87.9	3.0×10^3	98.2	0	100	1.5×10^5	53.1	6.0×10^4	90.0	1.0×10^4	98.5

Enzymatic denaturation of wheat gluten (EWG)



Effect of time on solubility of wheat gluten obtained with different percent of Alcalase enzyme

Mechanical testing



Tensile strength of WG/MFC and EWG/MFC films

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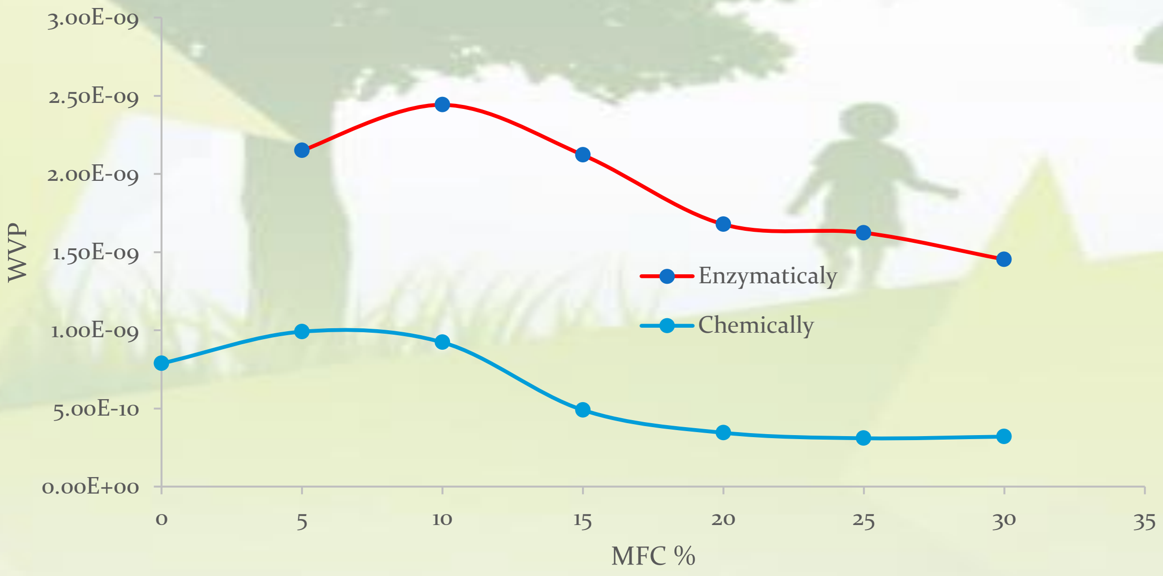
Water vapor permeability (WVP)



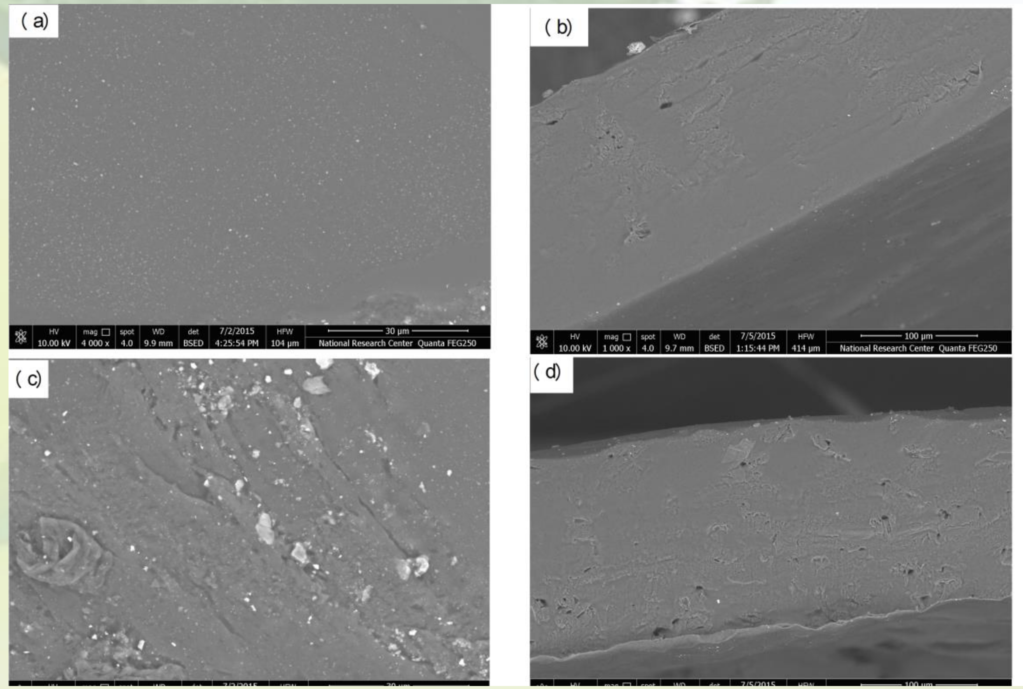
WVP of WG/MFC and EWG/MFC films

Contact angle measurment

Contact angle of EWG/MFC films

WG/MFC	
Sample	**Contact angle**
5 % MFC	30.85
10 % MFC	34.77
15 % MFC	38.22
20 % MFC	39.33
25 % MFC	40.5
30 % MFC	38.4

Scanning electrone microscopy



SEM micrographs of EWG/20% MFC (a and b) and EWG/30% MFC (c and d) surface and cross section.

Conclusion

Filling of chemically and enzymatically denatured wheat gluten with MFC enhanced the mechanical and barrier properties of the prepared nanocomposites. However, this enhancement is significant in case of chemical denaturation specially for MFC content > 15%.

Attempts to develop thermoplastic films from wheat gluten to replace synthetic polymer based films need more extensive studies to achieve the target

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