Use of irradiation, for the development of active edible coatings, beads and packaging to assure food safety and to prolong the preservation.

Monique Lacroix, Ph.D.
Professor
Fellow of the International Academy of Food Science and Technology
Director
Research Laboratories in Sciences, applied to food
Canadian Irradiation Centre
INRS-Institut Armand-Frappier
531 des prairies blvd.
Laval Québec Canada H7V 1B7
450-687-5010, poste 4489
Monique.lacroix@iaf.inrs.ca
Web :www.iaf.inrs.ca
Web :www.labo-resala.com

Global market of packaging

$ 417 Billion

100 000 industries

Food Packaging represent
65% of the market

Paperboard: 36%
Plastic: 35%
Glass, composites, wood etc. 29%

Current global consumption of plastics

200 million tonnes/year

Annual growth: 5%

PET; PVC; PE; PP; PS; PA

New regulations

In Canada, every company has to pay 50% of the cost of collection and recycling

Demand for the use of biopolymers is growing

Challenges

- **Bio-based packaging is defined as packaging containing raw materials originating from agricultural sources**

- **Proteins based films have high moisture sensitivity and a variable gas and water permeability**
- **Polysaccharides can improve the emulsion capacity but reduce the water resistance**
- **Lipid can improve the elasticity and improve the water resistance**

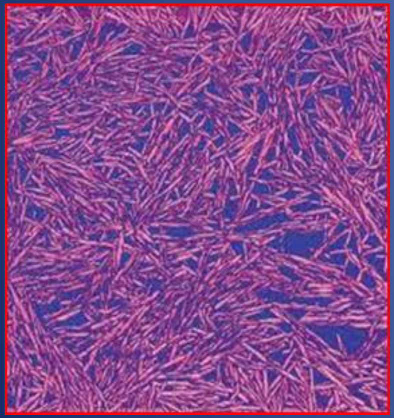
Nanocellulose and Food Packaging

Nanocomposite: New generation of polymer

The stability should be demonstrated

when in contact with the food

Some of the limited mechanical and barrier properties of biopolymers can be significantly enhanced by the use of reinforcing fillers like nanocellulose



Nanocellulose has

Low thermal expansion coefficient

High strength and modulus

Can act as reinforcing material

Potentially

Assure a control release of active compounds

Modulate the barrier properties

Ionizing irradiation

Ionizing irradiation can plays a major role in the development and **improvement of packaging polymers properties** as well as sterilizing material used in aseptic packaging.

Enhance barrier, adhesion, mechanical properties, thermal stability

Advantages of irradiation:

Crosslinking, Grafting and compatibilization

Formation of strong bridges between macromolecules

Compatibilization of polymer blend by high energy radiation

Addition of multifunction monomers and inomers to polymer blends in order to accelerate and increase the crosslinking degree in polymer blends

Post-process contamination

66% of the post-process contamination is caused by

Product mishandling

Faulty packaging

Active packaging and coating can interact with the food and have been proposed as innovative technologies

Natural Antimicrobial Compounds

Advantages

Replace synthetic compounds by natural compounds

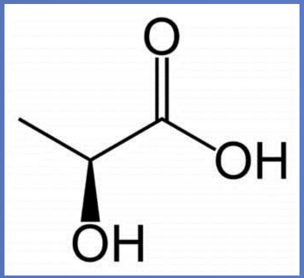
Scientific Challenges

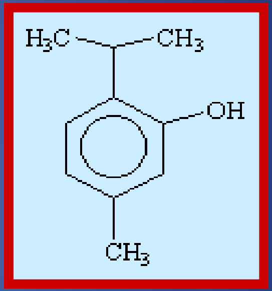
Instability during time and depend on the food composition

The immobilisation in polymers is a good alternative

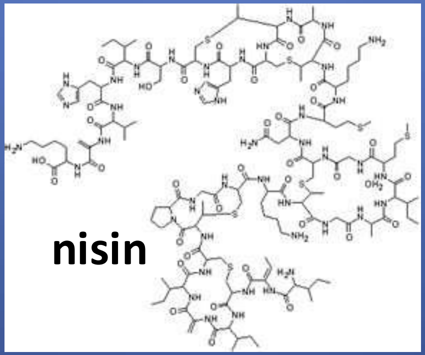
Natural antimicrobial compounds under consideration

- Bacteriocins (ex: Nisaplin® nisin, pediocins)
- Spice and herb extracts
- Organic acids





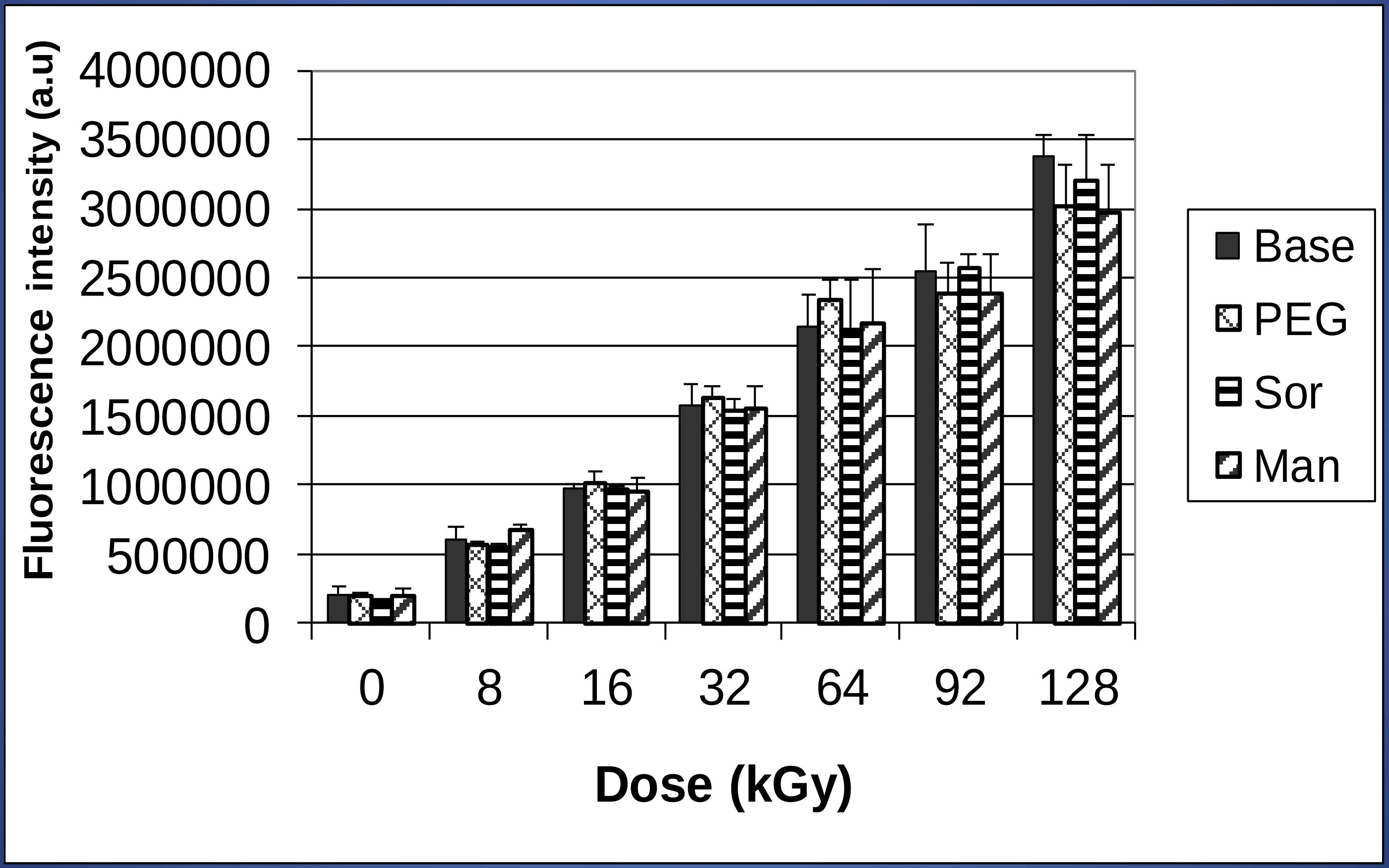
Thymol



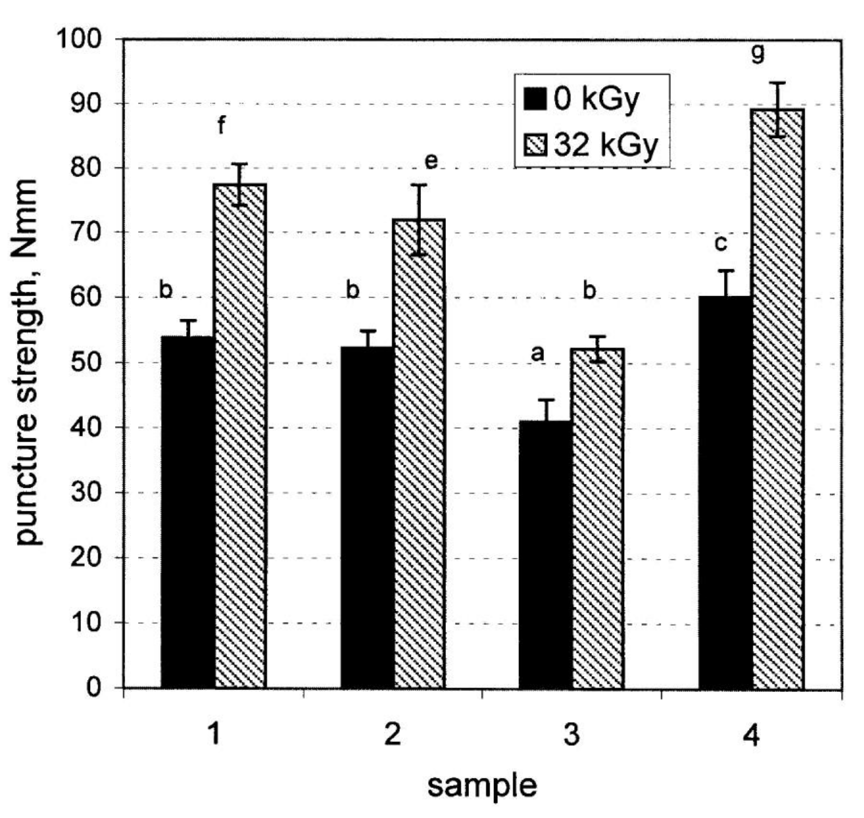
nisin

Crosslinking Reaction of bio-polymers with γ- Irradiation

Formation of bityrosine in calcium caseinate based-films as a function of irradiation dose

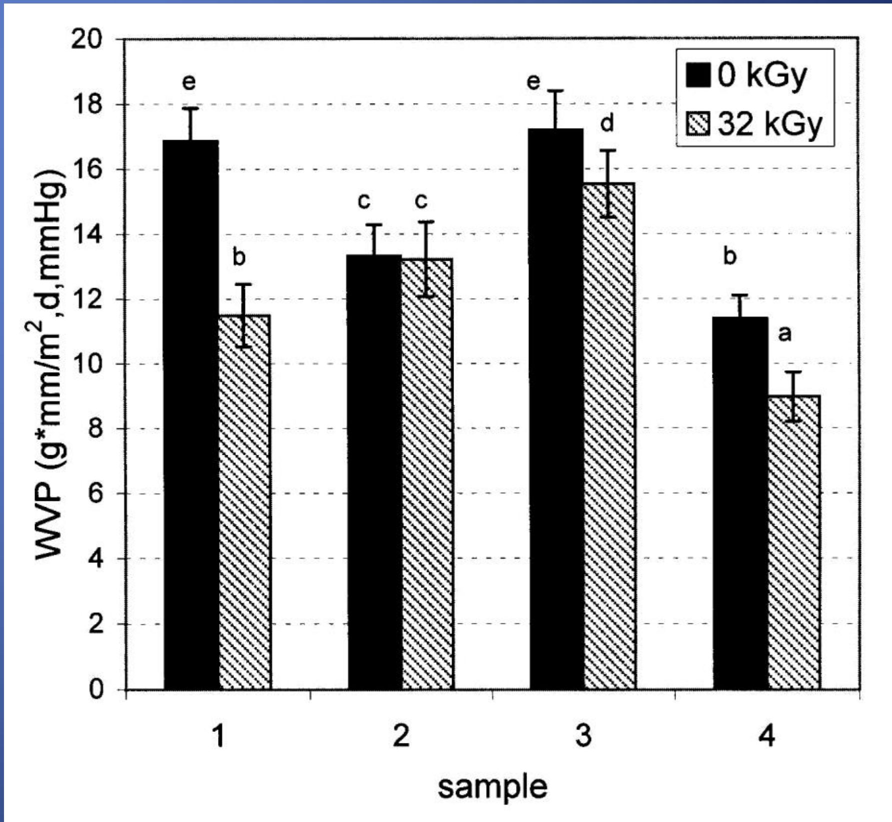


An increase by 10-60 times the molecular weight by irradiation



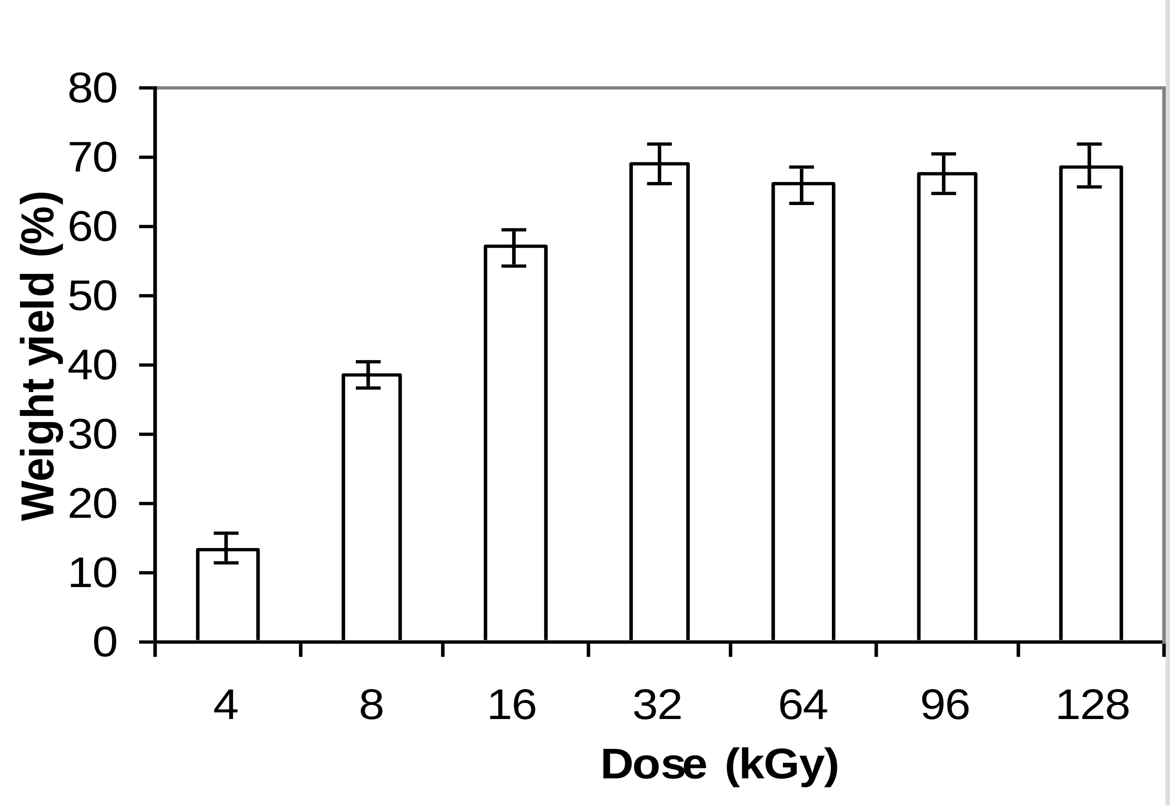
Effect of gamma irradiation on the puncture strength and On the WVP of Protein-Polyssacharides based edible films

1: CC-WPI
2: CC-WPI-PS
3: CC-WPI-SPS
4: CC-WPI-Alginate

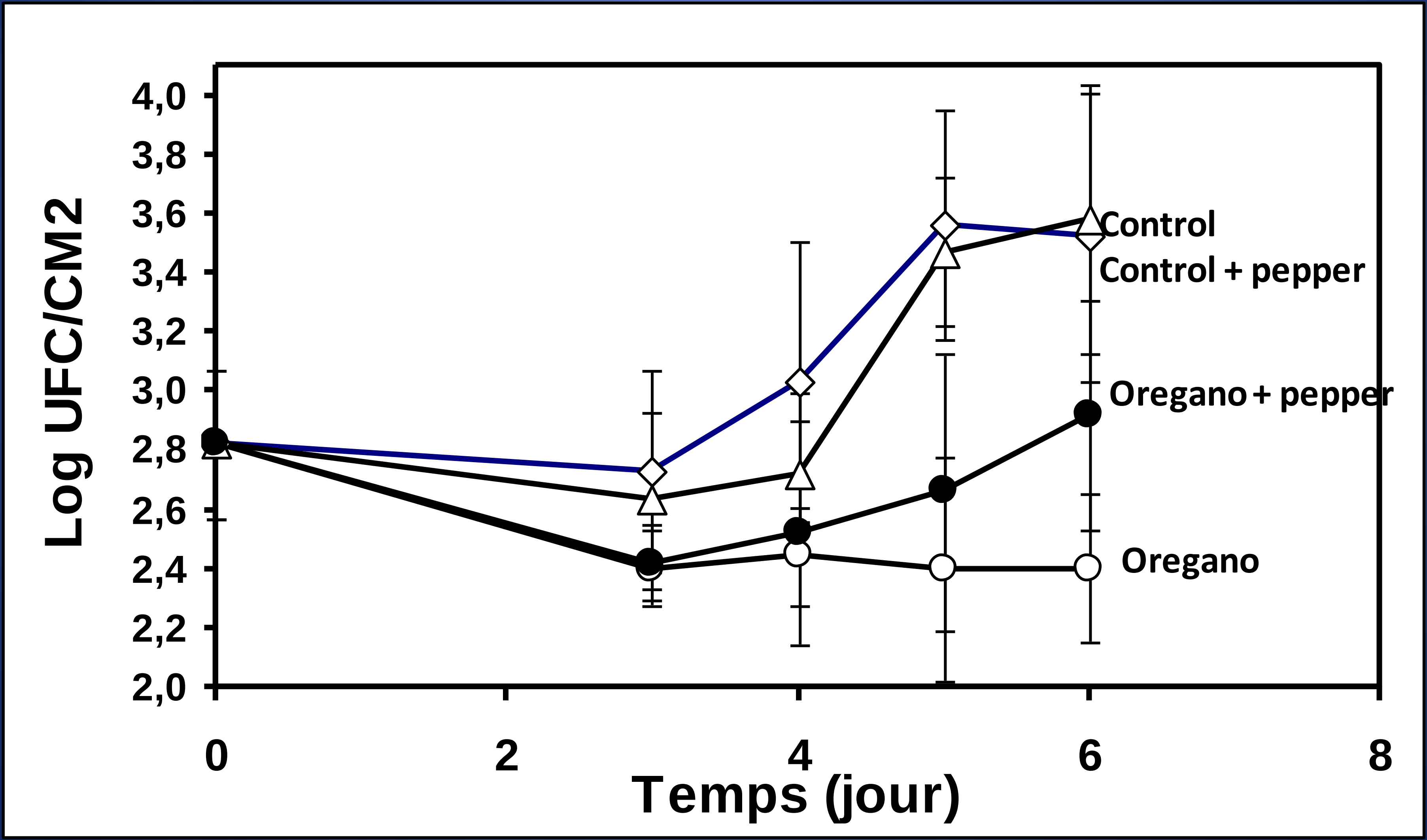


J.Sci.Agric.2006:908-914

Fraction of insoluble matter in function of the irradiation dose Results are expressed as the percentage in solid yield after soaking the films 24 hours in water



Films based on crosslinked caseinate (32 kGy) in presence of pepper and oregano: *E. coli* growth on fresh meat



Bilayer films based on

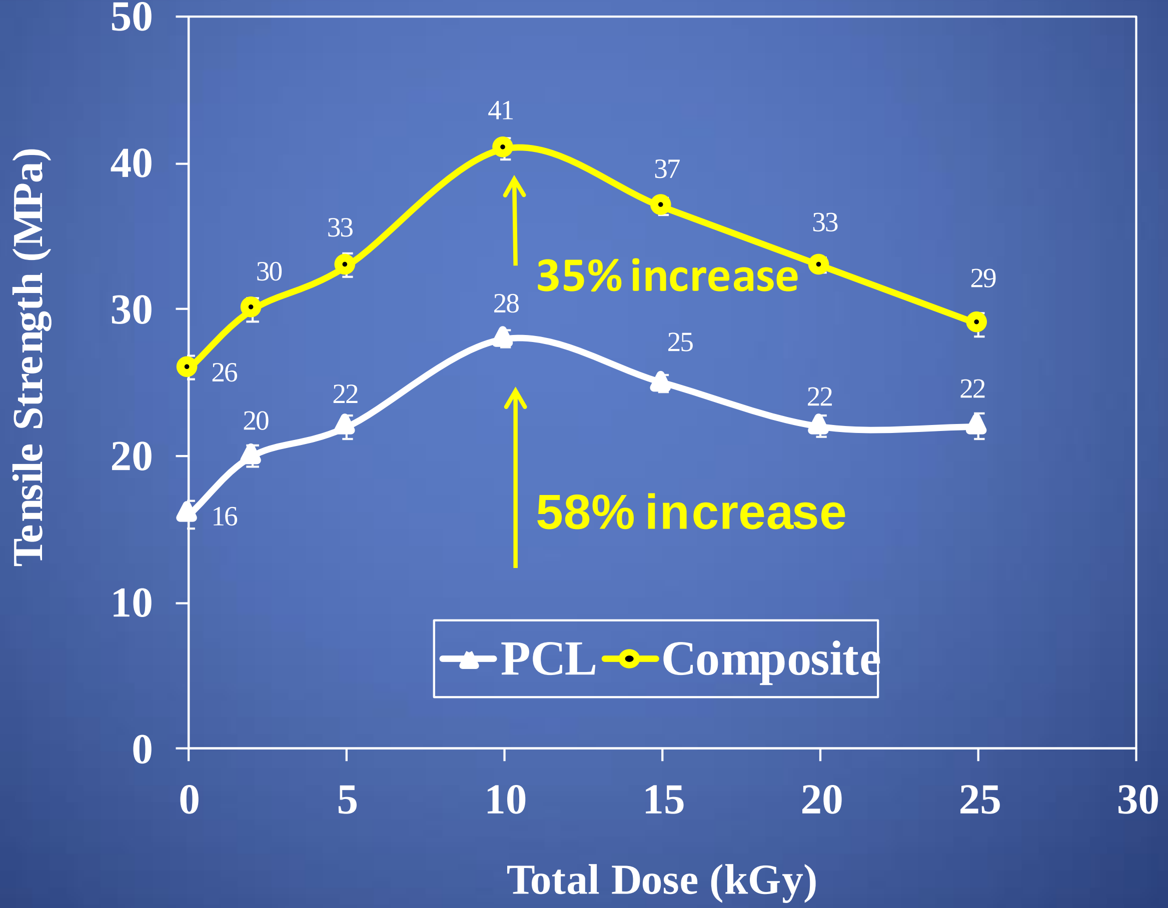
Proteins

methyl cellulose / carboxymethylcellulose

polycaprolactone

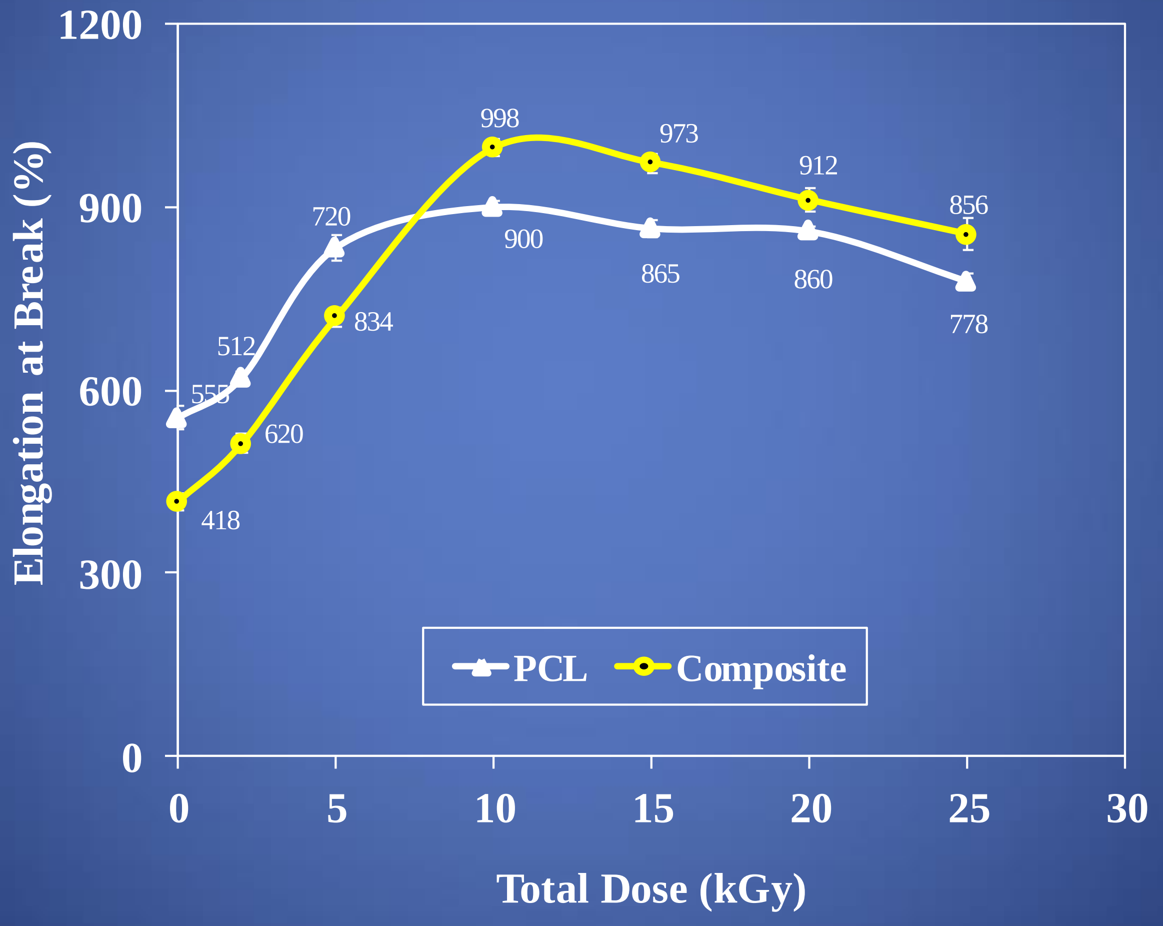
effect of crosslinking reaction using γ-irradiation

Effect of gamma radiation on tensile strength of PCL/NCC based films



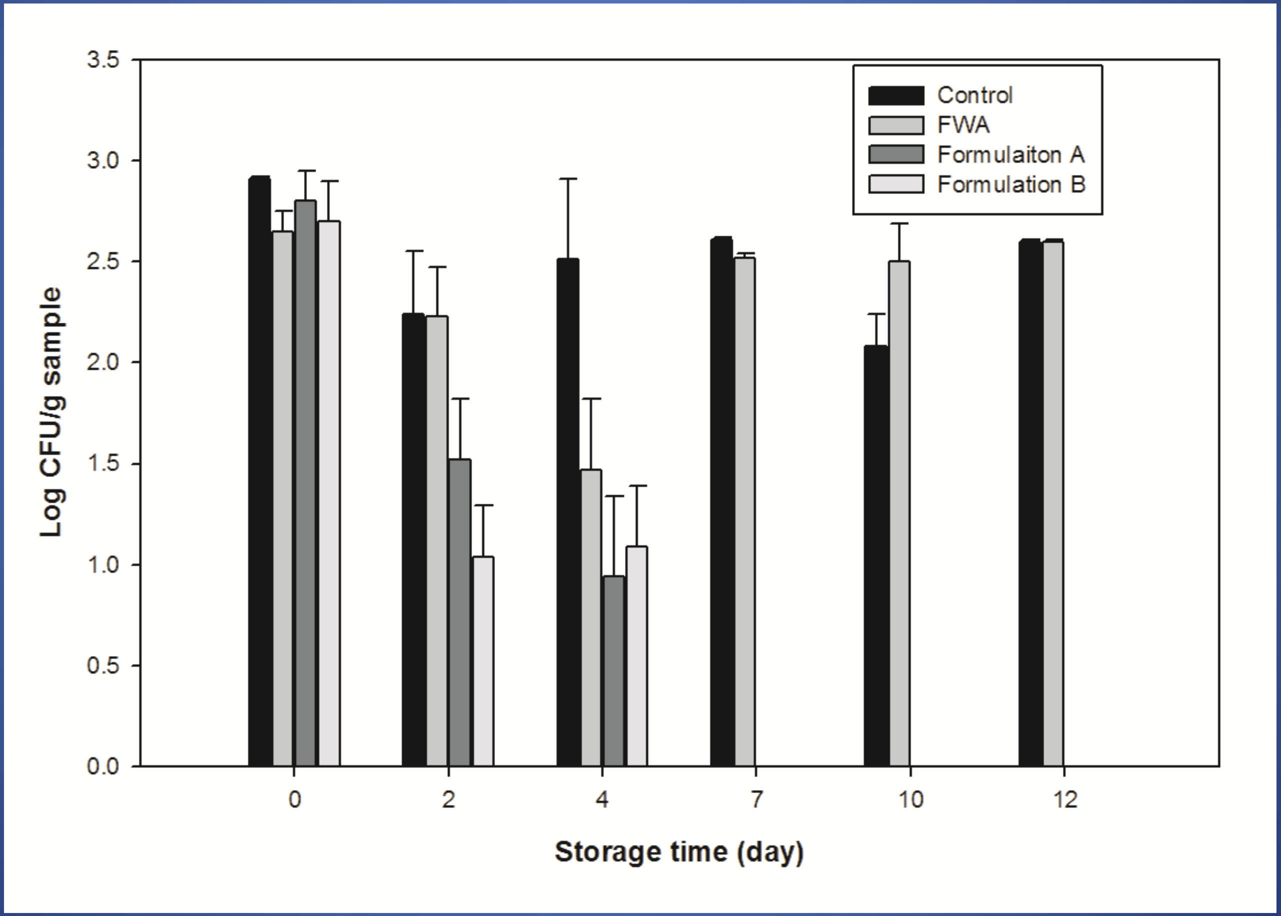
Khan et al., 2013 J. Appl. Polymer Sc. 129, 5, p. 3038-3046

Effect of gamma radiation on elongation at break of PCL / NCC based films



Khan et al., 2013 J. Appl. Polymer Sc. 129, 5, p. 3038-3046

Effect of Bioactive films based on crosslinked proteins, MC and ε-Polycaprolactone-diol on *Salmonella* Typhimurium on Broccoli



Takala et al., 2013 J.Food Eng. 648-655

Irradiation to produce grafting

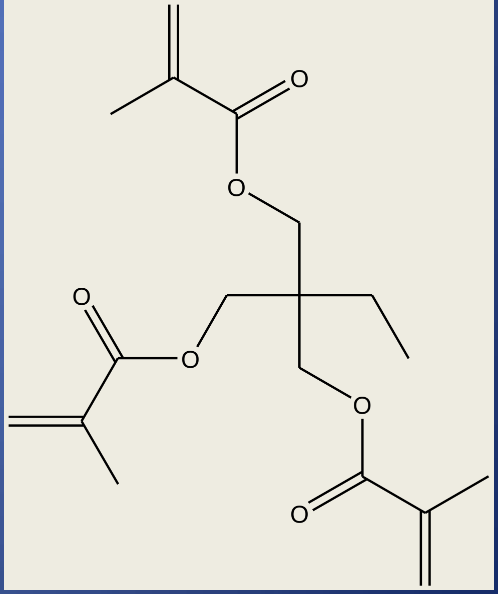
NCC-reinforced MC-*g*-TMPTMA films

NCC-reinforced MC-*g*-TMPTMA films

- **TMPTMA : ⇒ Contains 3 reactive methacrylic acid residues**
  ⇒ Wide acceptance as a cross-linker and plasticizer

Probable grafting mechanism

- **Reaction of OH groups from MC with the vinyl groups of TMPTMA during exposure to ɣ-radiation**
- **Formation of a grafted complex**
- **Low dose irradiation to prevent polymer degradation and by-products**



CNC-reinforced MC-*g*-TMPTMA films

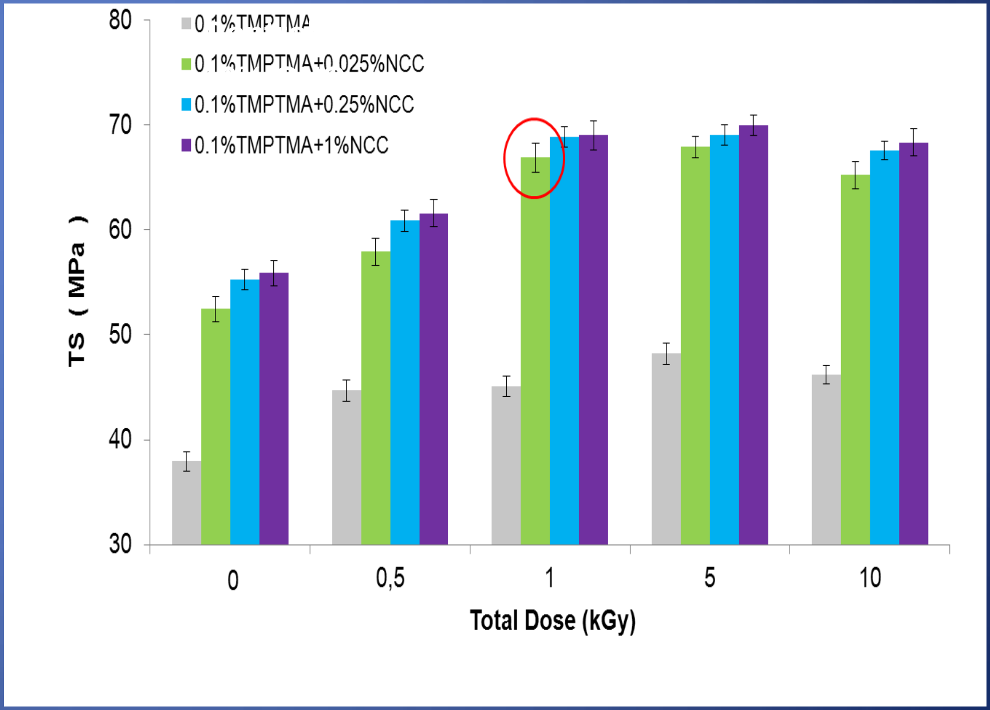
- Optimal concentration of TMPTMA : 7% (w/w, dry basis)
- Optimal irradiation dose : 5 kGy
- Incorporation of NCC into MC bulk (10-30% w/w, dry basis) allowed a remarkable improvement of :
  - Mechanical properties (+ 94-126% in PS)
  - WVP (- 25%)
  - Thermal properties (crystallinity ↗)

CNC-reinforced MC-*g*-TMPTMA films

Combined effects of CNC filling/ɣ-radiation dose on the mechanical properties of grafted films

- **Effect of radiation:** TS ↗ up to 5 kGy and then ↘ (degradation of the film)
- **Effect of radiation/NCC filling:** TS ↗ up to 1 kGy/10% CNC

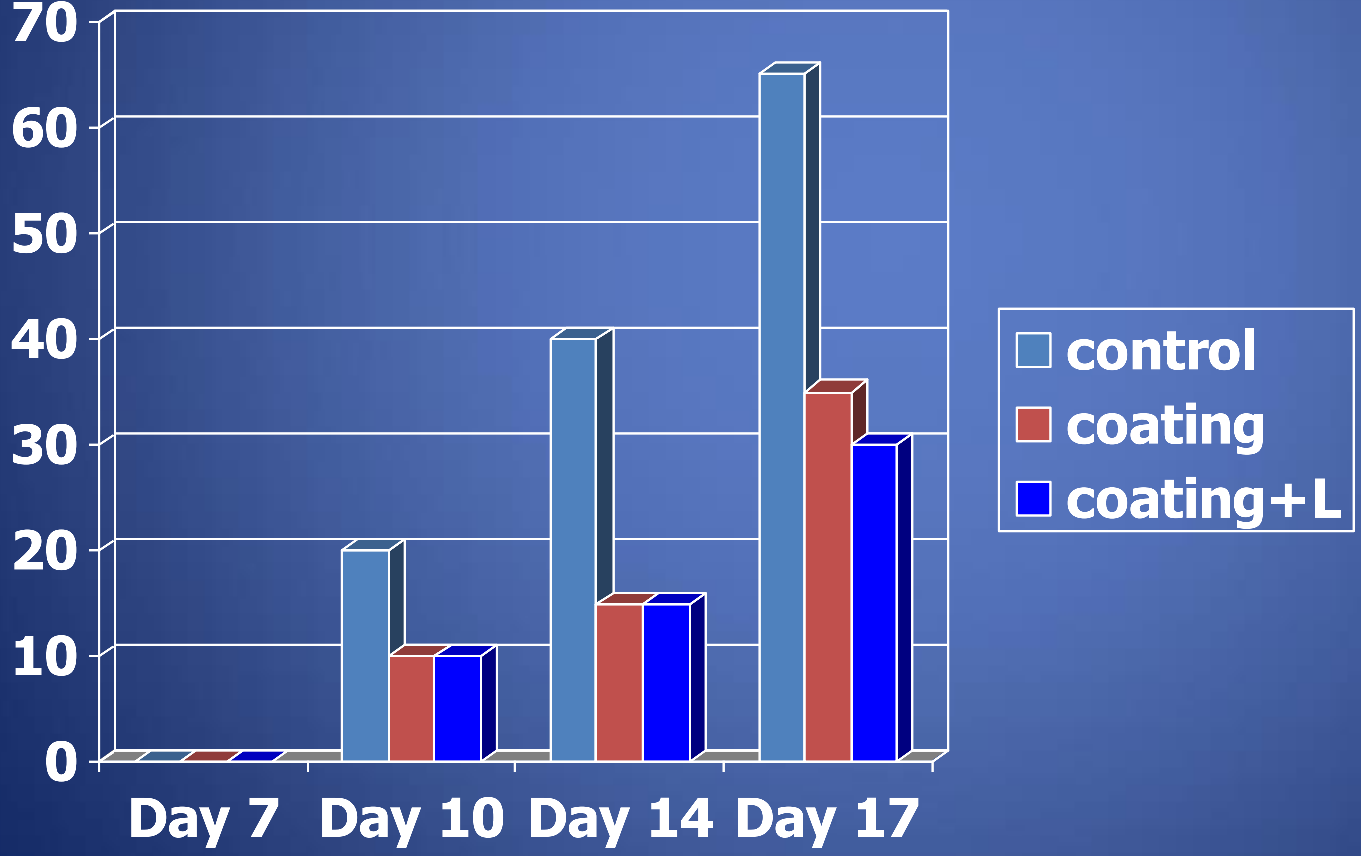
⇒ **Optimal TS = 67 MPa (+ 76%)** Synergy between grafting and NCC addition



Effect of NCC concentration combined with ɣ-radiation doses on the TS of MC-*g*-TMPTMA (7%) films.

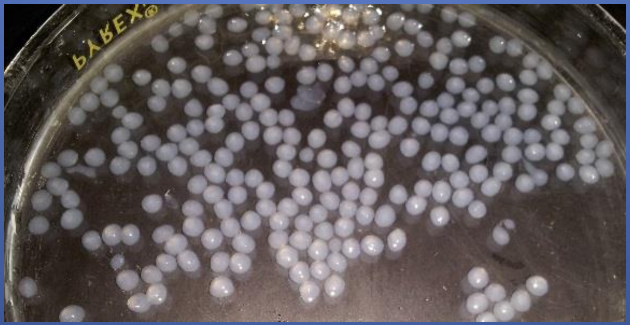
Irradiation to produce Crosslinked coating polymers

Effect of crosslinked coating based on proteins/MC and limonene on rotting fruits (%) during storage at 4 ºC

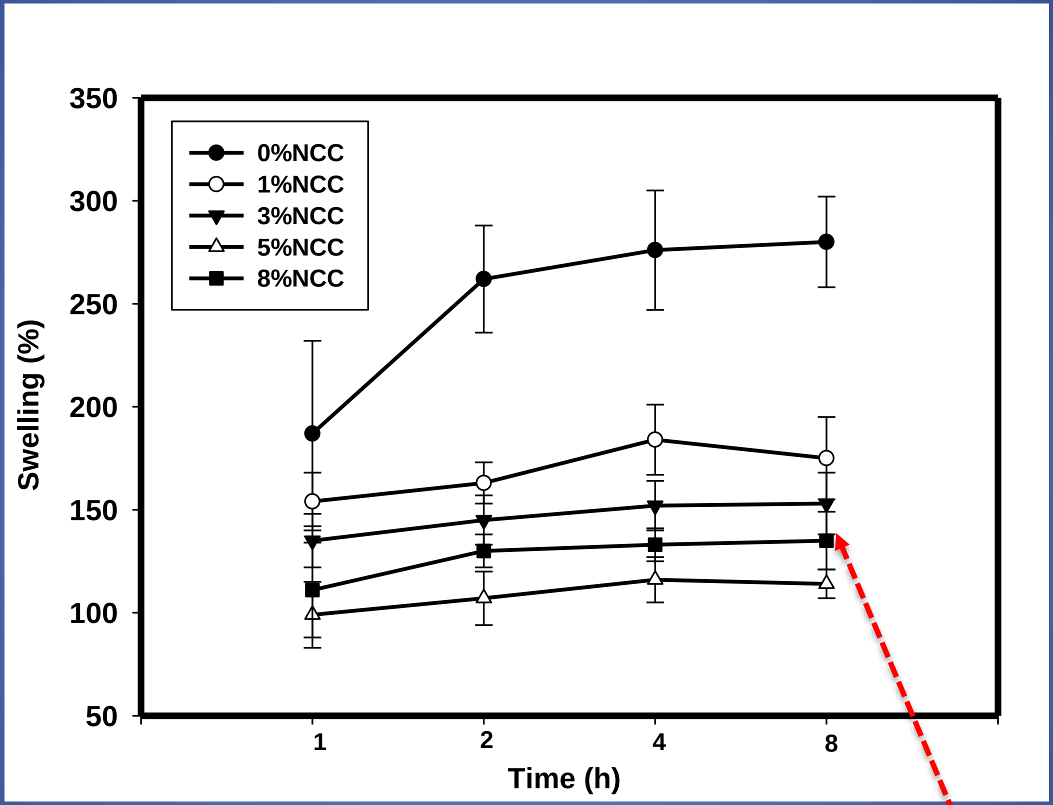


Beads based on alginate and nanocrystal cellulose

Effect of Ƴ-irradiation on swelling and application on food system

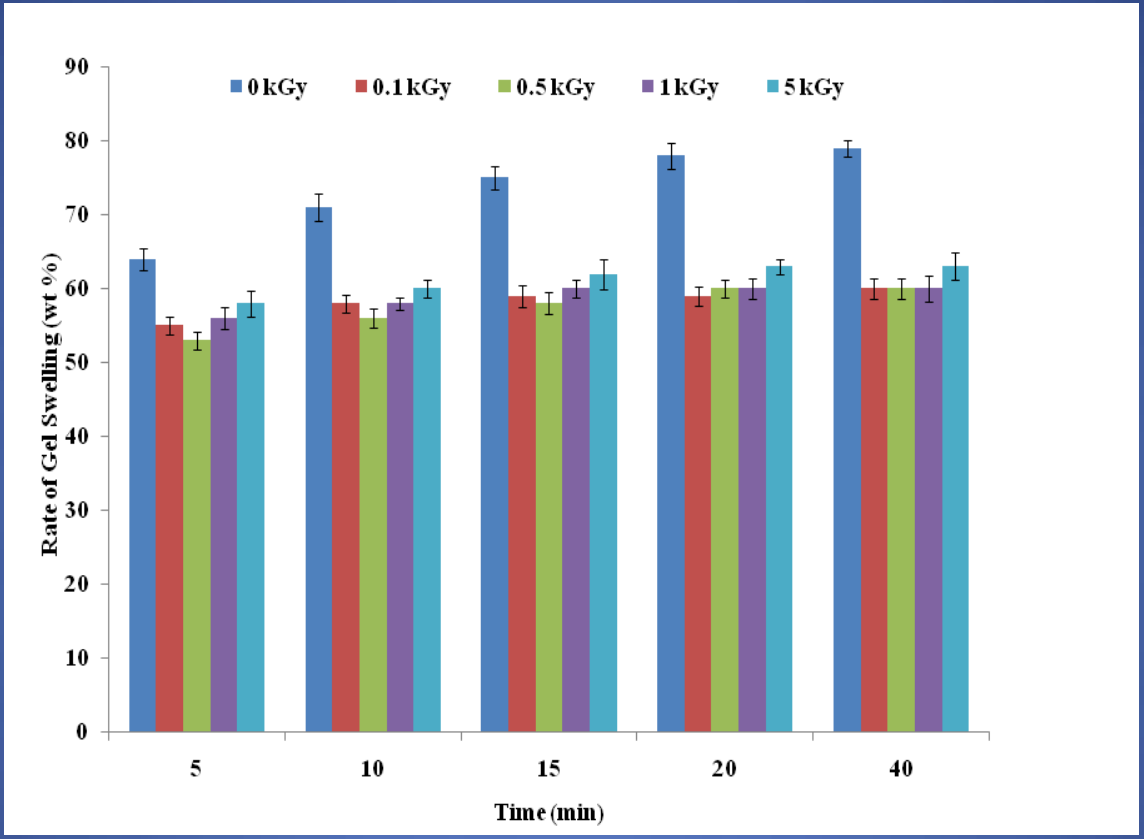


Effect of nanocrystal cellulose on beads sweeling Beads based on alginate and nanocrystal cellulose



5wt% NcC decrease by 53% the swelling of beads

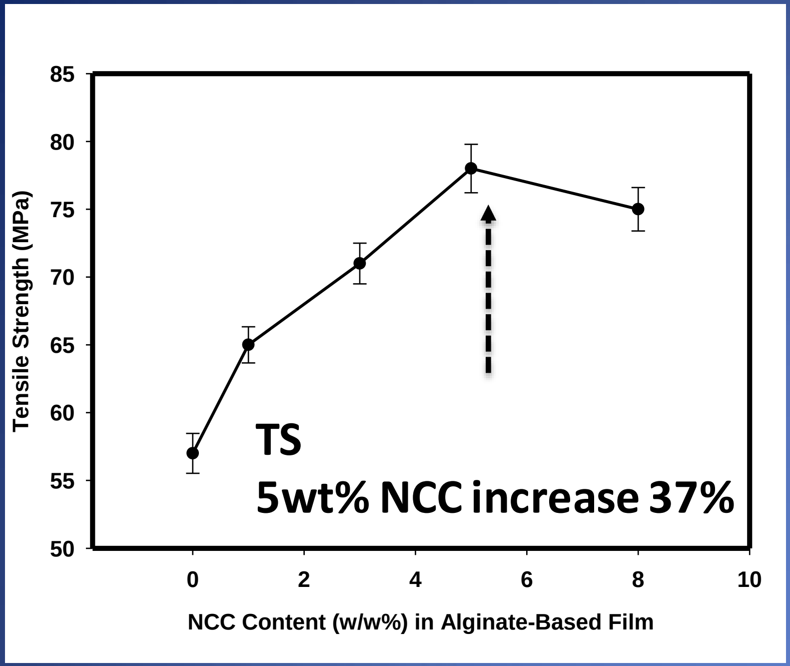
Effect of irradiation on beads swelling

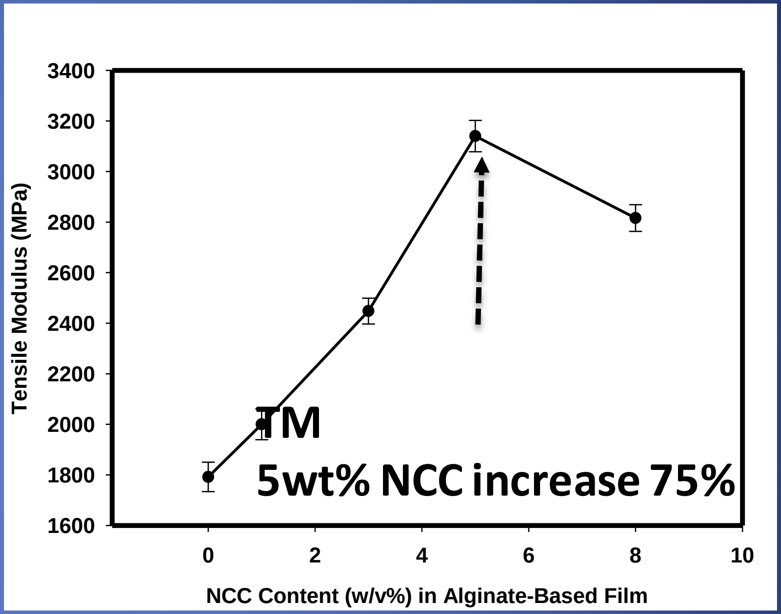


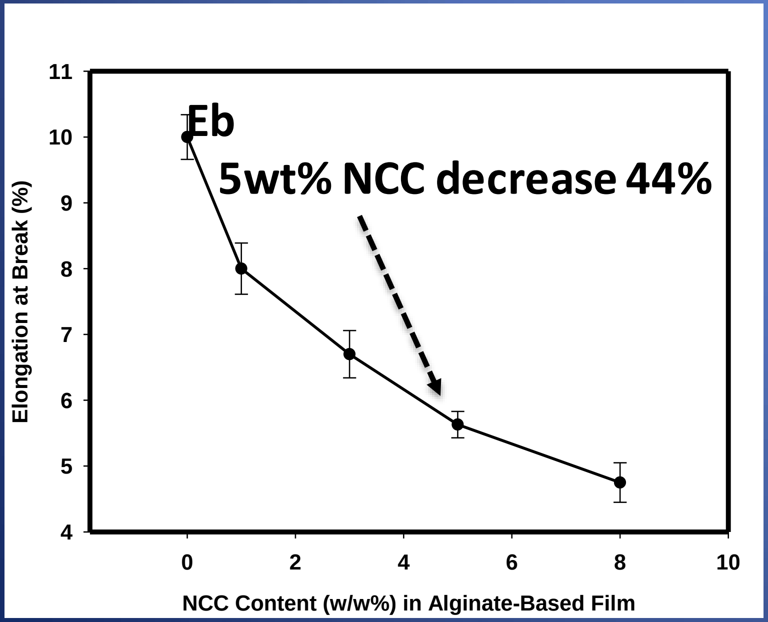
A dose of 0.5 kGy decreased by 25% the sweeling of beads

Huq et al. (2012) Rad. Phys. Chem. 81, 945-48.

Mechanical properties of films based on NCC/alginate







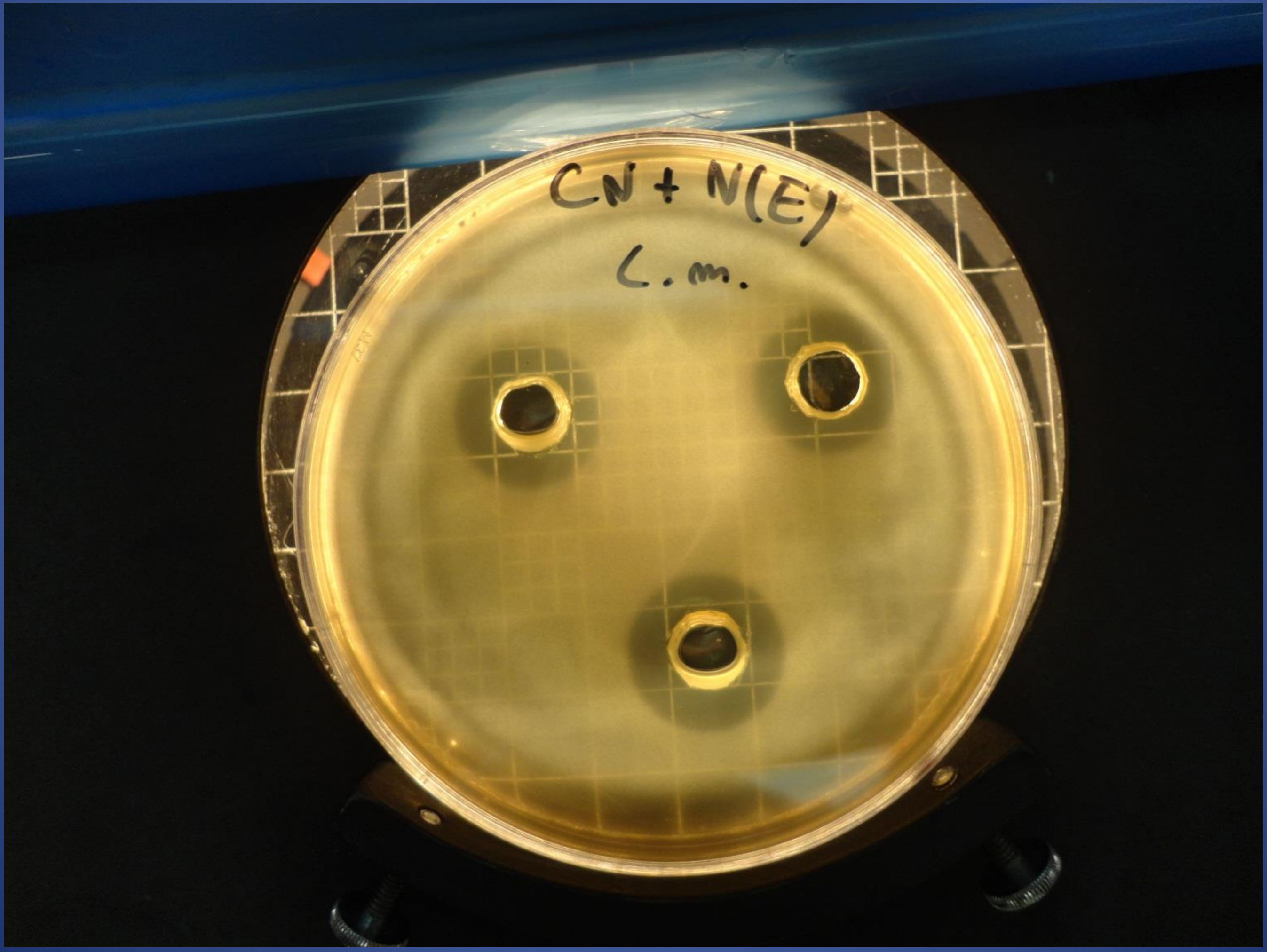
Effect of NCC content (w/w%) on a) tensile strength (MPa), b) tensile modulus (GPa) and c) elongation at break (%) of alginate-based film, as a function of NCC content in dry matrix of alginate-based film

Development of Cellulose Nanocrystal (CNC) Reinforced Bio polymeric Matrix for Encapsulation of Bioactive Compounds

Centre - INRS–Institut Armand-Frappier

INRS
Université d'avant-garde

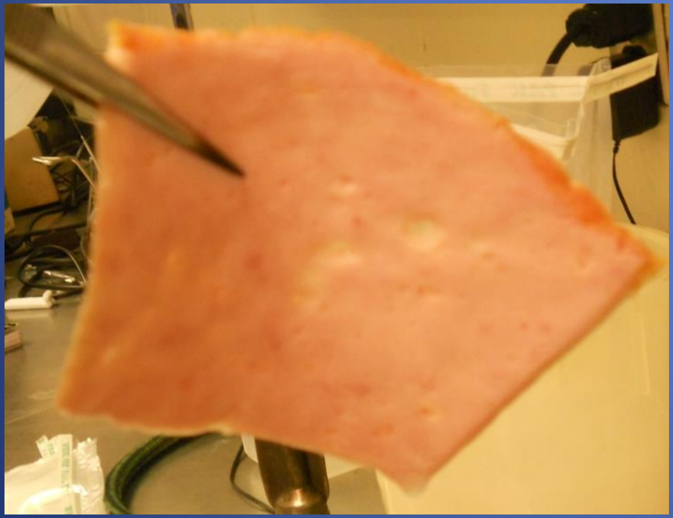
Encapsulation of Antimicrobial Compounds in beads based on alginate-NCC



Antimicrobial properties of the CNC reinforced alginate beads on ready-to-eat (RTE) meat against *Listeria monocytogenes*

HAM Application

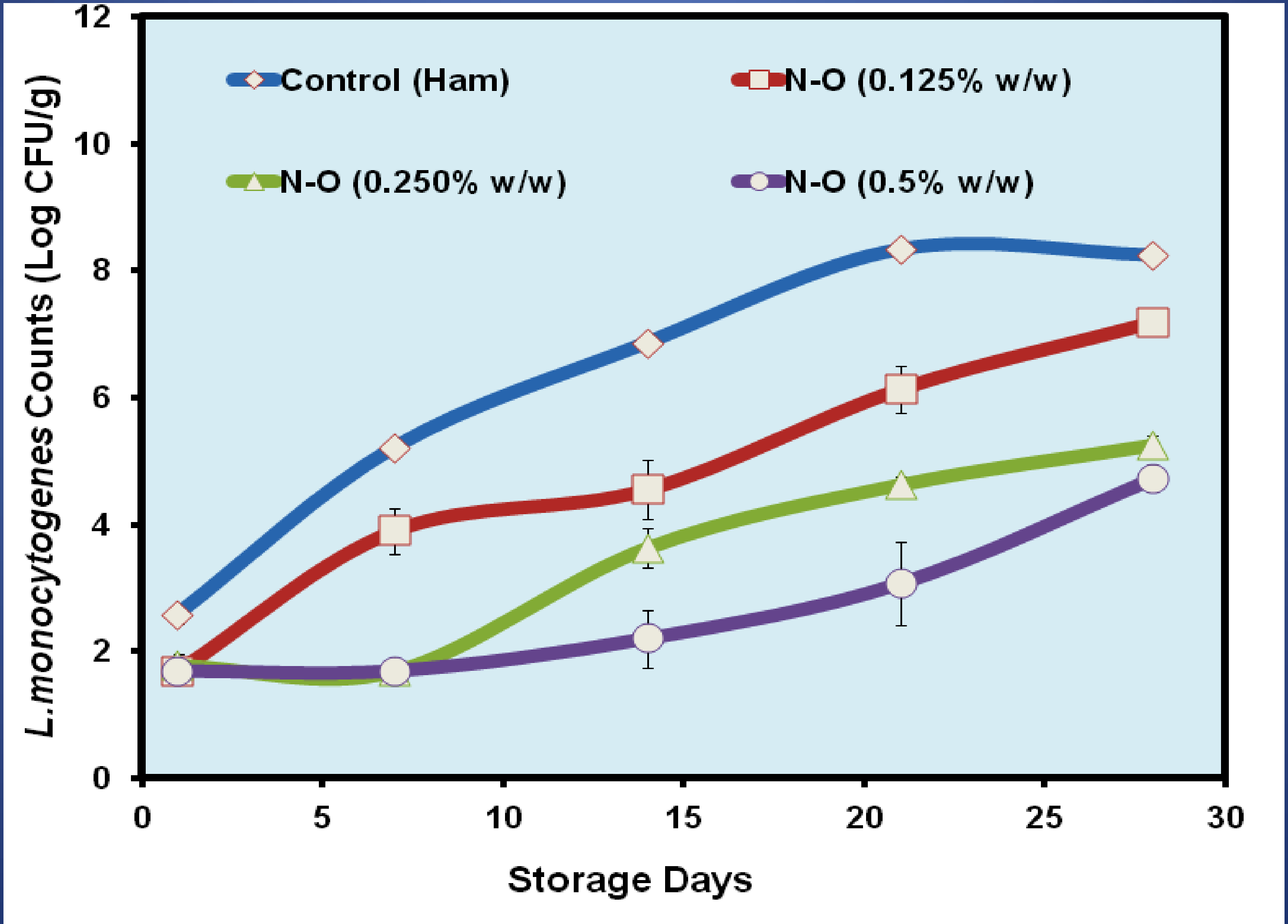
Cooked HAM



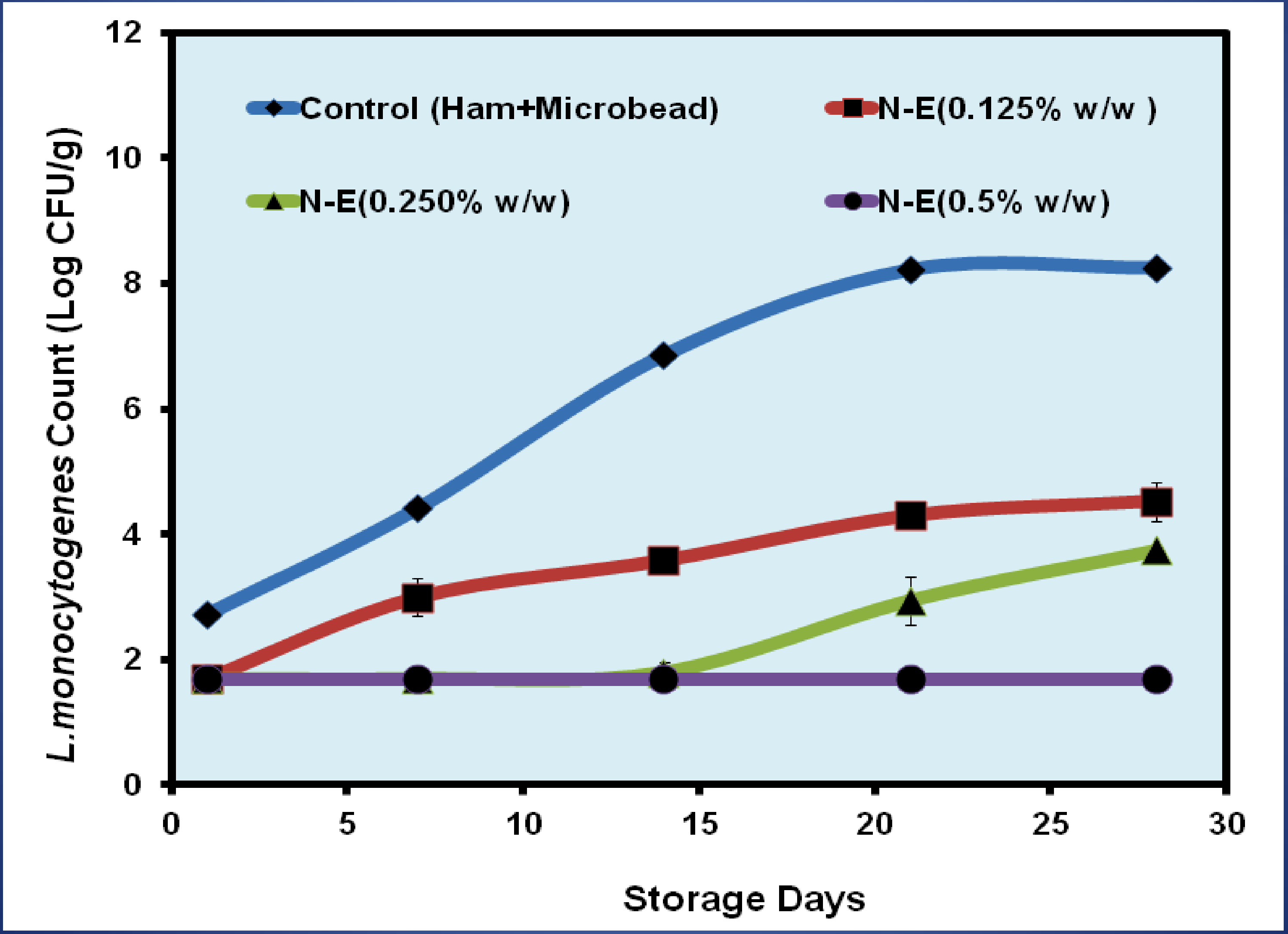
HAM without Microbead

HAM with Microbead

Growth of *L. monocytogenes* on vacuum packaged cooked ham slices coated with non-microencapsulated nisin at 4° C



Growth of *L. monocytogenes* on vacuum packaged cooked ham slices coated with microencapsulated nisin at 4° C

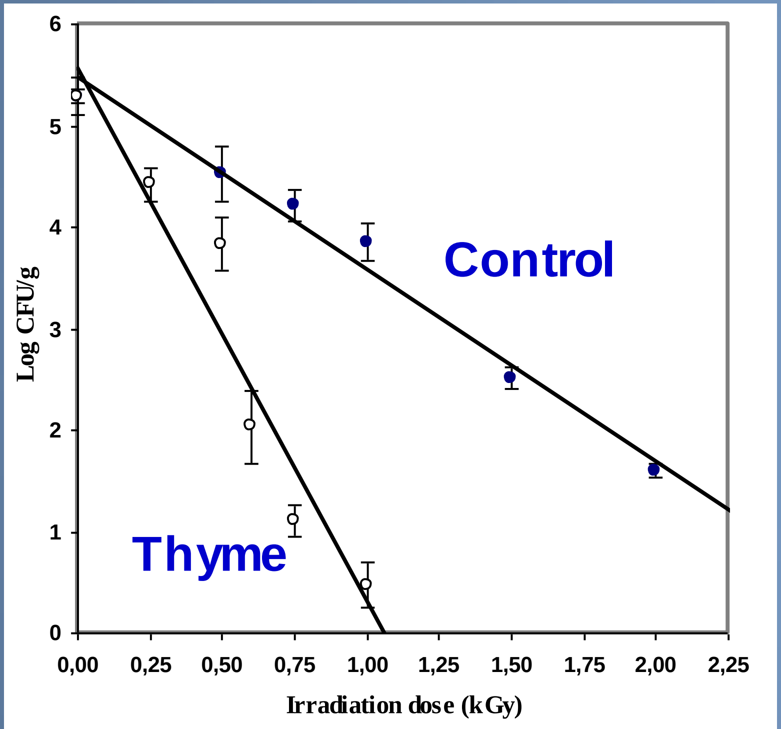


Crosslinked active beads by ϒ-irradiation and ϒ-irradiation of meat coated with the active beads

Evaluation of the synergistic effect on pathogens elimination

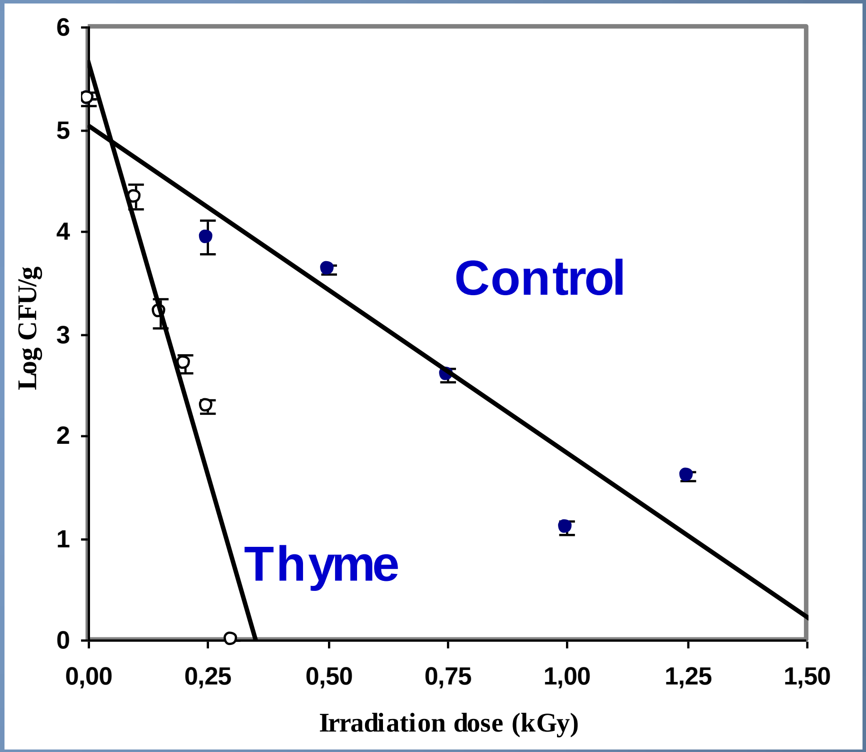
Example of bacterial radiosensibilization in meat

Air



5 times

MAP



20 times

Salmonella

D_{10} and Radiosensitivity (RS) for non and microencapsulated antimicrobial microbeads against *L.monocytogenes*[*]

	D_{10} (kGy)	RS
C	0.57±0.031[a]	1±0.00[a]
CN+N	0.16±0.001[e]	3.57±0.15[g]
CN+N (E)	0.08±0.002[f]	6.89±0.30[h]

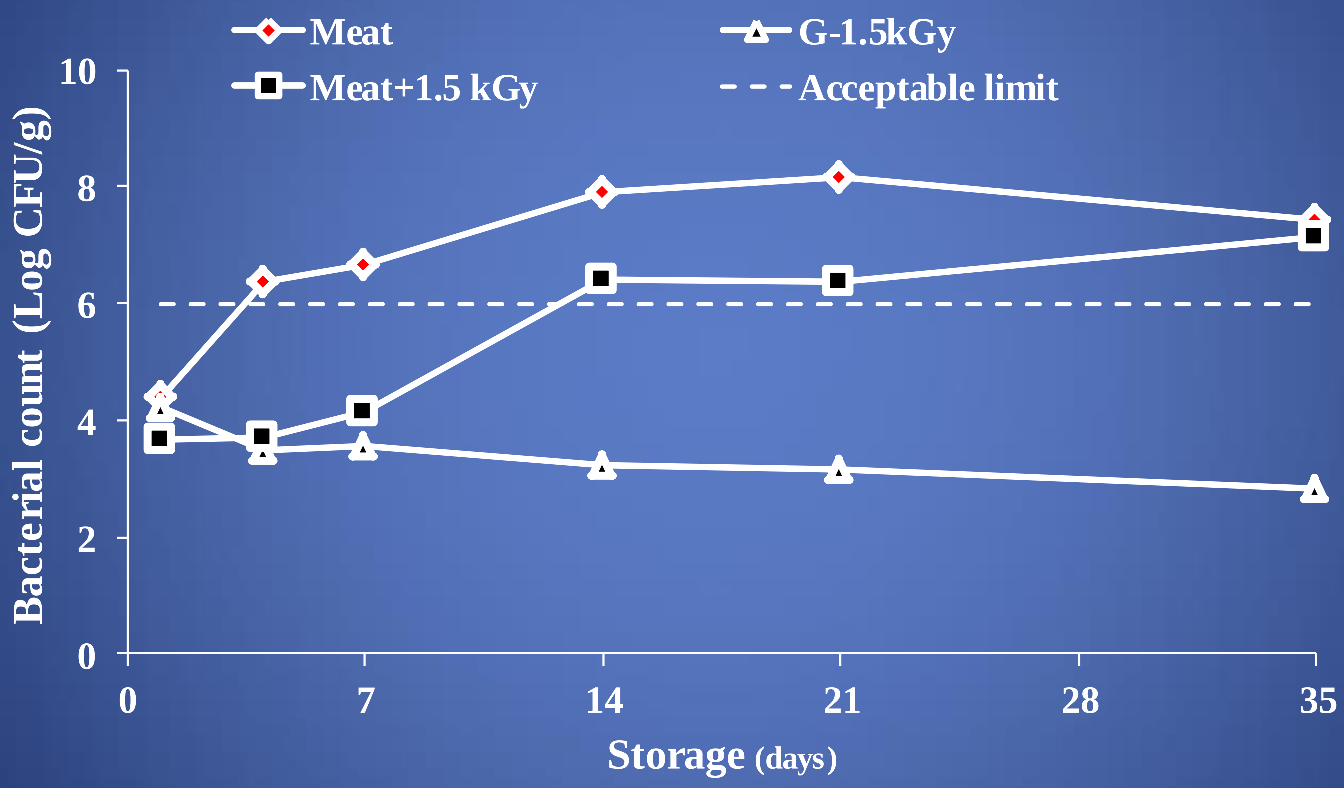
An increase of the bacterial radiosensitization can permit to reduce the dose needed to eliminate pathogens

[*]Values are means ± standard deviations. Means with the same letter are not significantly different ($P > 0.05$).

Food Microbiology 2015, 46, 507-514.

Active films based on crosslinked chitosan-NCC and nisin on total microflora on ham

Population of mesophilic bacteria in fresh pork during storage at 4°C



Innovative Food Science and Emerging Technologies. 2016, 35, 96-102

Conclusions

Crosslinking and graft copolymerization by ϒ-irradiation and the development of nanocomposites

Can improve the physico-chemical, the water resistance and barrier properties (WVP) of the films, beads and coating and can assure a better control of the active compounds release during storage.

Antimicrobial edible crosslinked films, coatings and beads can also act in synergy with γ-irradiation on food in order to eliminate pathogens, assure food safety and can increase the food shelf life.

Microencapsulation technology combined with irradiation could be an advanced process to improve the food safety.

Contact:

Monique Lacroix, Ph.D., Professor
INRS-Institut Armand-Frappier
Research Laboratories in Sciences Applied to Food
Canadian Irradiation Centre
531, Bd des prairies, Laval, QC, H7V 1B7, Canada
Tel: 450-687-5010 #4489 ; Fax: 450-686-5501
E-mail: monique.lacroix@iaf.inrs.ca
Web: www.iaf.inrs.ca

Research Laboratories in Sciences Applied to Food Canadian Irradiation Centre