Ectoine protects biomolecules from ionizing radiation: Molecular mechanisms


Bundesanstalt für Materialforschung und -prüfung, D-12205 Berlin, Germany
marc-benjamin.hahn@bam.de

Ectoine properties

- Produced by halophilic bacteria to survive in saline environments
- Zwitterionic structure (fig. 1)
- Exerts kosmotropic effect on the local water structure[6]
- Influences protein functions[5]
- Effective cell protectant against UV-A (315-400 nm) radiation[1]

![Chemical structure of Ectoine and its first hydration shell. Source: [6]](image)

Electron irradiation of DNA in solution

- Irradiation of solution by a scanning electron microscope through a nanomembrane (fig. 3)[4]
- Solutions: Plasmid DNA with cosolutes (0-1 M ectoine, 0.5 M NaCl, 1 M ectoine+0.5 M NaCl)
- DNA strand-break detection by gel electrophoresis

![Electron trajectory diagram](image)

Irradiation results

1. Ectoine protects DNA efficiently from ionizing radiation
2. The protection is concentration dependent
3. The influence of NaCl is small

![Electron trajectory diagram](image)

Monte-Carlo simulations to characterize the ionizing radiation

- Ionizing radiation leads to water radiolysis (fig. 1)
- Radiolysis produces secondary damaging species (*OH, e_lee^+)
- Amount, production ratio & location depend on kinetic energy spectrum of the radiation and location of scattering events
- Determined by Monte-Carlo simulations (Geant4)

![Monte-Carlo simulation results](image)

Mechanism I: Increase in low energy electron scattering

- Large increase in the intensity of the acoustic water modes upon addition of ectoine was found (fig. 6)
- Ectoine leads to an increase in the inelastic scattering probabilities of LEE via energy-losses by the excitation of phonons
- Results in decrease of the total energy deposit by ionization and the total number of secondary damaging species

![Raman spectra of the acoustic water modes](image)

Mechanism II: Action as radical scavenger

- EPR measurements to test scavenging capabilities (*OH-radicals)
- Comparison of ectoine, glycine betaine (negative control) and isopropanol (positive control)
- Ectoine scavenges *OH-radical (fig. 7)

![EPR spectra of OH-DMPO and OH.](image)

Conclusion

Ectoine was found to protect DNA against ionizing radiation damage. Protection mechanisms:

1. LEE energy-loss due to the scattering at vibrational water modes and the resulting decrease in secondary particle production
2. *OH-scavenging by ectoine
3. Displacement of water in the extended hydration shell of DNA

![EPR spectra of OH-DMPO and OH.](image)

References:

- [2] Solutions: Plasmid DNA with cosolutes: (0-1 M ectoine, 0.5 M NaCl, 1 M ectoine+0.5 M NaCl).
- [3] Irradiation of solution by a scanning electron microscope through a nanomembrane.
- [4] Electron irradiation of DNA in liquid. The plasmids (green) diffuse on a random trajectory (yellow) through water (blue). They cross the trajectory of the electrons (white/black).
- [5] Protection mechanisms:
  - LEE energy-loss due to the scattering at vibrational water modes and the resulting decrease in secondary particle production
  - *OH-scavenging by ectoine
  - Displacement of water in the extended hydration shell of DNA

![EPR spectra of OH-DMPO and OH.](image)

More references can be found in the original article.