Use of irradiation to provide wider selection of foods for immuno-compromised patients

Csilla Mohácsi-Farkas
Immuno-compromised diet

- Steril diet (autoclaving / irradiation)
- „Clean” (low microbial count / neutropenic) diet
- Diet prepared under „normal” hygienic conditions
Aim of our studies

• to determine the radiation doses provide microbiological safety of selected products without diminishing the quality/ nutritional/ sensory parameters;
Neutropenic diet

Microbiological criteria suggested by the CRP

- Total plate count < 500 cfu/g
- *Listeria* spp. absent in 25 g
- *Salmonella* spp. absent in 25 g
- Yeasts and moulds < 50 cfu/g
- Coliforms < 10 cfu/g
- Coagulase-positive *Staphylococcus aureus* < 10 cfu/g
- Aerobic spore count < 10 cfu/g
- Anaerobic spore count < 10 cfu/g (absent in 25 g)
Survey of Hungarian institutional practices for dietary restrictions for immuno-suppressed patients

Foods which cannot be sterilized by heating, but are most frequently requested by patients:

- **Milk and dairy products** – Túró Rudi (a special Hungarian cottage cheese dessert), cottage cheese, cream cheese
- **Vegetables** – bell peppers, tomatoes, radishes, onions, cucumbers, lettuce
- **Fruit** – apples, pears, strawberry, raspberry, blackberry, grapes, citrus and tropical fruits
- **Dessert** – jelly rolls, sponge cake, diabetic desserts
- **Nuts** – almonds, peanuts
- **Other** – breaded steak
Products selected/examined

✔ Fresh-cut fruits
  ✔ apple (cultivar Golden, Idared, Granny Smith), orange, banana
✔ Fresh-cut vegetables
  ✔ tomato, carrot
✔ Dairy products
  ✔ cottage cheese cream, Túró Rudi
✔ Dessert
  ✔ raspberry - chestnut puree - sponge cake dessert
✔ Fruit-puree ice cream
  ✔ raspberry-banana sorbet
Examinations of

✓ changes in natural microbiota after irradiation and during refrigerated/frozen storage
  ✓ radiation dose: 0.5-3.0 kGy
  ✓ AGROSTER Zrt., Budapest, Hungary
✓ sensorically acceptable radiation dose (colour, odour, taste, texture)
✓ changes in nutritionally important components (antioxidant vitamins, fatty acid composition)
✓ challenge tests with *Listeria* strains
Use of irradiation to provide wider selection of foods for immuno-compromised patients

Pre-cut fruits - apple

Results

Idared Total Plate Count

<table>
<thead>
<tr>
<th>Log CFU/g</th>
<th>0 kGy</th>
<th>0,5 kGy</th>
<th>1 kGy</th>
<th>1,5 kGy</th>
<th>2 kGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 storage time (days)</td>
<td>0</td>
<td>1,0</td>
<td>2,0</td>
<td>3,0</td>
<td>4,0</td>
</tr>
</tbody>
</table>

Storage temperature: 5 °C

Idared Yeasts

<table>
<thead>
<tr>
<th>Log CFU/g</th>
<th>0 kGy</th>
<th>0,5 kGy</th>
<th>1 kGy</th>
<th>1,5 kGy</th>
<th>2 kGy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 storage time (days)</td>
<td>0</td>
<td>1,0</td>
<td>2,0</td>
<td>3,0</td>
<td>4,0</td>
</tr>
</tbody>
</table>
Pre-cut fruits - apple

Results

- Irradiation with 2 kGy dose could provide appropriate low microbial counts of fresh-cut apple.
- Refrigerated storage (5 °C) of irradiated cut/sliced fruits is recommended not longer than 5 days.
- According to Kramer’s rank test, statistically significant differences in organoleptic properties (colour, odour, taste and texture) were not found at doses up to 2 kGy.
Pre-cut fruits - apple

Results

- After irradiation with doses up to 2 kGy, there was no clear tendency in dose dependent response of total polyphenol content and antioxidant capacity.

- Careful sorting of apple cultivars for preparing fruit salad is recommended.

- Among the apple varieties tested, Idared and Golden Delicious are suitable for preparing fresh-cut salads.
Based upon the microbiological criteria suggested by the CRP, irradiation of tomato salad with 2 kGy dose could provide appropriate low microbial counts.

Samples remain microbiologically safe during 8 days of refrigerated (5 °C) storage.
## Pre-cut vegetables - tomato

### Results

Sensory testing of sliced tomato (15 panelists)

<table>
<thead>
<tr>
<th>Radiation dose (kGy)</th>
<th>Colour</th>
<th>Odour</th>
<th>Taste</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7.87 ± 1.13</td>
<td>7.20 ± 1.97</td>
<td>7.13 ± 2.10</td>
<td>7.13 ± 1.85</td>
</tr>
<tr>
<td>1</td>
<td>7.60 ± 1.60</td>
<td>6.27 ± 2.22</td>
<td>5.60 ± 2.16</td>
<td>6.60 ± 1.40</td>
</tr>
<tr>
<td>2</td>
<td>7.60 ± 0.99</td>
<td>6.13 ± 2.56</td>
<td>5.67 ± 2.85</td>
<td>6.73 ± 1.44</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiation dose (kGy)</th>
<th>Colour</th>
<th>Odour</th>
<th>Taste</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>27.00</td>
<td>24.50</td>
<td>23.00</td>
<td>25.50</td>
</tr>
<tr>
<td>1</td>
<td>31.50</td>
<td>30.00</td>
<td>34.00</td>
<td>32.50</td>
</tr>
<tr>
<td>2</td>
<td>31.50</td>
<td>35.50</td>
<td>33.00</td>
<td>32.00</td>
</tr>
</tbody>
</table>

** rank sums within the range 22-38 are not significantly different at \( \alpha \leq 0.01 \) probability level

* rank sums within the range 23-37 are not significantly different at \( \alpha \leq 0.05 \) probability level

- According to Kramer’s rank test, statistically significant differences between unirradiated and irradiated samples were not observed.
Pre-cut vegetables - tomato

Effect of gamma irradiation on carotenoids, tocopherols and ascorbic acid content of pre-cut tomatoes

<table>
<thead>
<tr>
<th></th>
<th>Zeaxanthin</th>
<th>Licoxanthin</th>
<th>Lycopene</th>
<th>9Z+13Z lycopene</th>
<th>β-carotene</th>
<th>ζ-carotene</th>
<th>Fitoin</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 kGy</td>
<td>0.13±0.01</td>
<td>0.24±0.02</td>
<td>15.99±0.47</td>
<td>4.67±0.24</td>
<td>2.15±0.19</td>
<td>0.34±0.03</td>
<td>0.81±0.01</td>
</tr>
<tr>
<td>2 kGy</td>
<td>0.08±0.00*</td>
<td>0.25±0.04</td>
<td>13.92±0.84*</td>
<td>3.04±0.04*</td>
<td>1.77±0.08*</td>
<td>0.23±0.01*</td>
<td>0.53±0.40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Tocopherol</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>α-Tocopherol</td>
<td>4.44±0.03</td>
<td>0.31±0.00</td>
<td>2.88±0.15</td>
<td>0.15±0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>β-Tocopherol</td>
<td>2.86±0.01*</td>
<td>0.34±0.01</td>
<td>2.63±0.01</td>
<td>0.15±0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ascorbic acid content</th>
<th>Concentration μg/g fresh produce</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 kGy</td>
<td></td>
<td>61.71±0.33</td>
</tr>
<tr>
<td>1 kGy</td>
<td></td>
<td>56.07±0.46*</td>
</tr>
</tbody>
</table>

* significantly different at α ≤ 0.05 probability level

- Although losses in carotenoids, tocopherols and ascorbic acid content were statistically significant, they are less than the natural variation that may be found between varieties of produce and at different post-harvest conditions.

Use of irradiation to provide wider selection of foods for immuno-compromised patients

Radiation treatment in frozen form, Storage at 5 °C

Results
Dairy products- Túró Rudi

Results

**Microbiological evaluation**
- Irradiation of frozen Túró Rudi with 3.0 kGy dose could provide appropriate low microbial counts.
- Samples remain microbiologically safe during 8 days of refrigerated storage.

**Sensory testing**

<table>
<thead>
<tr>
<th>Radiation dose (kGy)</th>
<th>Colour</th>
<th>Odour</th>
<th>Taste</th>
<th>Texture</th>
<th>Colour</th>
<th>Odour</th>
<th>Taste</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8.67 ± 0.65</td>
<td>8.00 ± 1.21</td>
<td>6.25 ± 1.91</td>
<td>7.83 ± 1.27</td>
<td>32.00</td>
<td>30.00</td>
<td>28.50</td>
<td>30.50</td>
</tr>
<tr>
<td>2.0</td>
<td>8.33 ± 2.02</td>
<td>8.42 ± 0.67</td>
<td>8.00 ± 1.13</td>
<td>7.92 ± 1.44</td>
<td>30.50</td>
<td>26.00</td>
<td>20.50*</td>
<td>27.00</td>
</tr>
<tr>
<td>2.5</td>
<td>8.83 ± 0.39</td>
<td>7.83 ± 1.47</td>
<td>5.75 ± 2.22</td>
<td>7.75 ± 1.22</td>
<td>29.50</td>
<td>30.00</td>
<td>36.00</td>
<td>32.00</td>
</tr>
<tr>
<td>3.0</td>
<td>8.92 ± 0.29</td>
<td>7.75 ± 1.22</td>
<td>5.50 ± 2.68</td>
<td>7.83 ± 1.53</td>
<td>28.00</td>
<td>34.00</td>
<td>35.00</td>
<td>30.50</td>
</tr>
</tbody>
</table>

**rank sums within the range 19-41 are not significantly different at α ≤ 0.01 probability level**

**rank sums within the range 21-39 are not significantly different at α ≤ 0.05 probability level**
Results

Determination of lipid oxidation:

- Coating chocolate part (39.1%) and filling cottage cheese part (60.9%) were analysed separately.

- Statistical evaluation of fatty acid analysis data showed no significant changes in fatty acid composition of dairy products due to irradiation up to 3 kGy dose.

- These results indicate that undesirable lipid oxidation did not occur in irradiated samples.
Dessert food items – raspberry puree

Results

Radiation treatment and storage at -18 °C

Use of irradiation to provide wider selection of foods for immuno-compromised patients
Use of irradiation to provide wider selection of foods for immuno-compromised patients

Dessert food items – sweet chestnut puree

Results

Radiation treatment and storage at -18 °C
Dessert food items – sponge cake

Results

Radiation treatment and storage at -18 °C

Use of irradiation to provide wider selection of foods for immuno-compromised patients
Dessert food

<table>
<thead>
<tr>
<th>Sensory testing of chestnut-raspberry dessert (19 panelists)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation dose (kGy)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

* rank sums within the range 30-46 are not significantly different at $\alpha \leq 0.05$ probability level

- Score means given by the members (healthy adults) were above 5.6 in all samples;
- Very high variations in scores of all irradiated samples show the individual sensitivity of panelists;
- Written comments: most of them found “very good” all samples. The relatively low scores for odour properties of irradiated desserts were due to the off-odour of sweet chestnut puree part.
Challenge tests

Bacterial strains used for inoculation studies:

Listeria innocua (formerly identified as L. monocytogenes 4ab No. 10, an avirulent strain, obtained from Dr. B. Ralovich, Hungarian Meat Research Institute)

Listeria monocytogenes Scott A, obtained from ATO-DLO, Wageningen, The Netherlands
Effect of irradiation on the survival and growth of *Listeria innocua* and *Listeria monocytogenes* ScottA inoculated on pre-cut tomato (initial pH 4.0±0.2) stored at 5 °C
## Challenge tests

### Results

<table>
<thead>
<tr>
<th>Product</th>
<th>D$_{10}$-value (kGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>L. monocytogenes</strong></td>
</tr>
<tr>
<td></td>
<td>Scott A</td>
</tr>
<tr>
<td><strong>Refrigerated cottage cheese</strong></td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Frozen cottage cheese</strong></td>
<td>0.38</td>
</tr>
<tr>
<td>Pre-cut tomato</td>
<td>0.40</td>
</tr>
<tr>
<td>Phosphate buffer (pH 7.0)</td>
<td>0.40</td>
</tr>
<tr>
<td>Alfalfa sprout</td>
<td>0.46</td>
</tr>
<tr>
<td>Phosphate buffer (Patterson, 1989)</td>
<td>0.32-0.49</td>
</tr>
<tr>
<td>Ice cream at -72 °C (Kamat et al., 2000)</td>
<td>0.38</td>
</tr>
<tr>
<td>Ice cream at 0 °C (Kamat et al., 2000)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

For **L. monocytogenes** ScottA in freezed cottage cheese:

\[
y = -2.1406x + 6.7447 \\
R^2 = 0.9719 \\
D = 0.38\text{kGy}
\]

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**Use of irradiation to provide wider selection of foods for immuno-compromised patients**

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**CORVINUS UNIVERSITY of BUDAPEST**

**Csilla Mohácsi-Farkas**
Important task:

Education to increase acceptance of the technology

- Workshops to inform health care professionals (dietitians, nutritionists, nurses) on the use of irradiated food in hospital diets;
- Education of the general public concerning the safety of food irradiation;
- Cost-benefit analysis of enhanced microbiological safety to provide decision makers a sound basis to plan infrastructure of the supporting services of the immuno-compromised patients;
- [www.foodirradiation.eu](http://www.foodirradiation.eu) (in Hungarian)
  - “willingness to pay” survey for immuno-compromised patients
- [https://www.facebook.com/elelmiszerbesugarzas](https://www.facebook.com/elelmiszerbesugarzas)
Élelmiszer besugárzás

A kutatás során elért eredmények

A projekt azzal a céljával indult, hogy besugárzással kezelt élelmiszereket készítsünk, annak érdekében, hogy biztonságos, táplálkozási élettani legfeljebb természetesen körben elérhetőek legyenek immunitásukat és emberek számára. A kutatás a Budapesti Corvinus Egyetem Élelmiszertruevőként karban indult az ÖETI-vel szomszédos együttműködésben.

Elsőként egy ÖETI által készült kérdőív került kiküldésre 11 hazai kórházba. Ebben a leggyengült immunrendszerű páciensek napi étkezésétől független energia és erőforrások mellett az általuk kivánatosnak tartott már jelenleg nem érhető el (hőkezelésen nem tanúsított) ételekről is képet kaphattunk. Ezek a következők voltak: tej és tejtermékek (Túró Rudi, túró, krémsajt), zöldségek (paprika, paradicsom, retik, harisnya, uborka, saláta), gyümölcsök (alma, kört, eper, málna, szőlő, citrusfélék és trópusi gyümölcsök), desszertek (piskóta, kakaó, diabetikus édességek), magvak (mandula, mogyoró) és egyéb (rántott hús).

Az egyetemen végzett munka során elsősorban mikrobiológiai szempontból vizsgáltuk az élelmiszereket. Emellett néhány zöldség és gyümölcs kémiai analízisére is sor került.

Az eddig vizsgált élelmiszerek:

- frissen vágott gyümölcsök: banán, alma, narancs
- frissen vágott zöldségek: paradicsom, répa
- tejtermékek: Túró Rudi, túrókrém
- piskóta, kakaó, diabetikus édességek, kakaó, mandula, mogyoró
Use of irradiation to provide wider selection of foods for immuno-compromised patients

Contributors

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Thank you for your attention!

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