Meta-regression models describing the effects of essential oils and added lactic acid bacteria on *L. monocytogenes* inactivation in cheese

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MOTIVATION

- *L. monocytogenes* (LM) has been described as a prevalent foodborne pathogen in goat (12.8%) and sheep (3.61%) milk cheeses (Gonzales-Barron et al., 2017).

- Soft and semi-soft cheeses sampled at retail: level of LM contamination up to 5% (EFSA report 2017).

- In faulty fermentations, pathogens can survive and even grow during the brining and ripening stages.
MOTIVATION

- Biopreservatives have been proposed as hurdles to increase microbiological safety and stability of cheeses:
  - plant-based antimicrobials (essential oils, plant extracts)
  - bacteriocinogenic starter cultures
- Meta-regression models can be used to understand LM growth, allowing optimisation of hurdles that provide long term stability and safety to cheeses
OBJECTIVES

To summarise the effectiveness of (i) lactic acid bacteria (LAB) and (ii) essential oils (EO) on *L. monocytogenes* inactivation in cheese

To evaluate other affecting factors and possible interactions
METHODOLOGY

LAB meta-regression model

24 studies, N = 429

Mixed-effects linear models with weights

• Exposure time as nested fixed effects in application type

EO meta-regression model

23 studies, N = 754

Mixed-effects linear models with weights

• Exposure time and antimicrobial concentration as nested fixed effects in application type
RESULTS

(i) LAB meta-regression model

- Significant impact on LM inactivation in cheese:
  - application type (p<0.0001)
  - pathogen inoculum level (p=0.0007)
  - storage temperature (p=0.001)
  - application type / exposure time (p<0.0001)

× LAB concentration showed no significant effect (p=0.317)
RESULTS

(i) EO meta-regression model

- Significant impact on LM inactivation in cheese:
  - ✓ application type (p<.0001)
  - ✓ storage temperature (p=0.001)
  - ✓ application type / exposure time (p<.0001)
  - ✓ application type / concentration applied (p<.0001)

- Pathogen inoculum level showed no significant effect (p=0.526)
# RESULTS

<table>
<thead>
<tr>
<th>EO</th>
<th>N</th>
<th>RE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black cumin seed</td>
<td>35</td>
<td>-0.652</td>
</tr>
<tr>
<td>Zataria multiflora boiss.</td>
<td>56</td>
<td>-0.406</td>
</tr>
<tr>
<td>Pink pepper</td>
<td>38</td>
<td>-0.391</td>
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<tr>
<td>Thyme</td>
<td>124</td>
<td>-0.196</td>
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<tr>
<td>Sage</td>
<td>12</td>
<td>-0.143</td>
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<tr>
<td>Rosemary</td>
<td>16</td>
<td>-0.141</td>
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<tr>
<td>Lemon balm</td>
<td>12</td>
<td>-0.105</td>
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<tr>
<td>Pennyroyal</td>
<td>24</td>
<td>-0.041</td>
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<tr>
<td>Basil</td>
<td>36</td>
<td>-0.036</td>
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<tr>
<td>Hogweed</td>
<td>15</td>
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<tr>
<td>Tarragon</td>
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<td>-0.015</td>
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<tr>
<td>Clove</td>
<td>68</td>
<td>0.028</td>
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<tr>
<td>Oregano</td>
<td>85</td>
<td>0.050</td>
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<tr>
<td>Mint</td>
<td>83</td>
<td>0.147</td>
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<tr>
<td><strong>Salvia</strong></td>
<td>34</td>
<td><strong>0.471</strong></td>
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<tr>
<td><strong>Cinnamon</strong></td>
<td>47</td>
<td><strong>0.595</strong></td>
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<tr>
<td><strong>Bay</strong></td>
<td>45</td>
<td><strong>0.862</strong></td>
</tr>
</tbody>
</table>
CONCLUSIONS

- Meta-analytical regression models were built, summarising the effects of LAB and EO on LM log reduction.
- Antimicrobials’ effectiveness depends on storage temperature, exposure time, [EO], application type:
  - for the same exposure time, application in milk or surface cause greater log reduction (LAB model).
  - for the same exposure time, application in cheese causes greater log reduction; application in milk causes the lowest log reduction (EO model).
- Insight on the most effective EO for LM control in (soft) cheeses.

Through meta-regression modelling it is possible to optimise manufacturing processes and the use of hurdles → ensure microbial stability and safety of cheeses ←
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