Tagetes: A two-fold story

André Heeres, Hanzehogeschool, Groningen
Papenburg, March 2019
Bulb farming

- Tulips, lilies etc.
- Nematodes
  - Pratylenchus
  - Trichodorus
- Entering via roots (bulb) of the plant
- Low growth, starvation
Chemical treatment

- An example: Monam
- Metam sodium/methylisothiocyanate
  
  ![Chemical structure](image)

  \[
  \text{H}_3\text{C}\text{N} = \text{C} = \text{S}
  \]

- 300-500 l/hectare
- High costs
- Environmental issues
Biological treatment

Tagetes

- Roots contain thiophene related compounds

\[
\begin{array}{c}
\chem{\cyclopentadiene}
\end{array}
\]

- Protection against nematodes

- Oxidation
Biological treatment (II)

Tagetes: Results

• Decrease in nematodes observed
• Soil improvement (organics, etc.)
• “Beneficial for bees population”

• Tagetes (orange) versus Monam (blue)
• Lillies, bulb growth
Biological treatment (III)

• Major drawback Tagetes: Loss in revenues!

• Biorefinery/Plant ingredients
  - Biogas
  - **Lutein**
  - Thiophenes
  - Other
  - Herbicide potential!

**share your talent. move the world.**
Lutein

- Potential source of lutein, a high-value carotenoid

\[
\text{HO}
\]

- Pharmaceutical, cosmetic (and nutraceutical) applications
- Ocular health
- Skin care (UV protection)
- Reduction of cancer
- Strengthening the immune system

- In 2010, lutein occupied a $233 million share of the worldwide carotenoid market (BCC Research 2011).

- Lutein market value $309 million in 2018, a CAGR of 3.6%.
Lutein from Tagetes

Proces:

• Tagetes selection (herbicide + lutein)
• Harvesting flowers
• Drying and milling
• Extraction towards lutein esters
• Hydrolysis and purification
• Stabilization
• Conversion to other carotenes
Achievements

Tons/flowers tagetes per ha (2017, 6 x harvested)
Achievements

- Hybrid Tagetes

<table>
<thead>
<tr>
<th>Lutein from tagetes</th>
<th>in kg</th>
<th>Drenthe 2016</th>
<th>Drenthe 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-60 ton per hectare</td>
<td>30000</td>
<td>33000</td>
<td>84000</td>
</tr>
<tr>
<td>drying</td>
<td>4500</td>
<td>4950</td>
<td>1260</td>
</tr>
<tr>
<td>hexane extraction</td>
<td>450</td>
<td>495</td>
<td>126</td>
</tr>
<tr>
<td>hydrolysis and crystallisation</td>
<td>67,5</td>
<td>74,25</td>
<td>15,12</td>
</tr>
</tbody>
</table>

- 2016
  - Planted middle May
  - 6 x harvested
  - Sunny conditions

- 2017
  - Planted middle June (extremely wet)
  - 3 x harvested
  - Wet, cloudy weather

- 2018
  - Analysis in progress
  - Dry conditions, yields < 2016
Achievements

• > 100 kg dried and milled flowers available
• 2017 > 5000 kg (wet) flowers (0.5 hectare)
• Extraction with heptane
• Saponification and purification towards lutein > 50 g scale
Business models

• Dried flowers (chicken feed)
  - Lutein in eggs (coloring, food supplement)

• Extract of crude lutein esters
  - Chinese suppliers

• Purified and stabilized lutein/other carotenes
  - Kenim, etc.
Towards higher value carotenes

Lutein → Zeaxanthin → Astaxanthin
Markets Zeaxanthin/Astaxanthin

Zeaxanthin

- Food/feed, cosmetics, pharma
- Anti-oxidant, macular degeneration
- Synthetic, extraction (marigold, paprika)
- Market 2020: USD 50 Million

Astaxanthin

- Food/feed, cosmetics, supplement
- Anti-oxidant, coloring properties
- Synthetic, extraction (plant, marine, yeast/microbes)
- Market 2020: USD 800 Million
Current synthesis

- Lengthy synthesis, low atom efficiency (lots of waste produced)

Fig. 2 $C_{15} + C_{10} + C_{15}$-Strategy.
Zeaxanthin from Lutein (extracts)

- From lutein
- Stereochemistry (3R, 3S'(meso))
- Epimerization needed in order to achieve market interest (3R, 3R')
(3R,3R’)-Zeaxanthin from epi-Lutein

- Topic of Interreg program Bioökonomie - Grüne Chemie
- Proof of concept for synthesis and purification of epi-lutein
- Optimization and further conversion towards (R,R) zeaxanthin in progress
Conclusions

• Tagetes has potential as a natural herbicide in bulb pharming
• Biorefinery of (part of) the plant is needed to compensate for loss in revenues
• Lutein (crude, purified) from Tagetes has potential for commercialization
• Lutein might be an attractive starting material for other high-value carotenones (zeaxanthin, astaxanthin).
Acknowledgements

New Businesses
Agrifood

share your talent. move the world.