eXtraction of Lycopene from tomato processing wastes

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Food and technology: the future?

- Competitive production and processing.
- Manufacturing practices have to consider food safety and security (GMP).
- Sustainable agriculture and environmentally friendly practices are unavoidable.
- Global supply and total quality standards.
- EU manufacturers will specialise in high value added products or disappear (i.e. FOSHU- Food for Specified Health Use).
- Awareness of health benefits coming from diet (despite currently regulations) will be significant marketing tool.
- There are a great variety of presumed value-added products in by-products from biological origin.
Recycling by-products is of interest from the environmental viewpoint (reduction of potential contaminant charge) and for the health benefits derived from their bio-active compounds. These products may be used as such or may be starting materials for the preparation of innovative compounds.

“..la vita dell’omo si fa dalle cose mangiate..”
Leonardo da Vinci
## 2007 forecast

<table>
<thead>
<tr>
<th>Country</th>
<th>2007 f</th>
<th>2.006</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>10.800</td>
<td>9.164</td>
</tr>
<tr>
<td>China</td>
<td>5.000</td>
<td>4.300</td>
</tr>
<tr>
<td>Italy</td>
<td>4.600</td>
<td>4.400</td>
</tr>
<tr>
<td>Iran</td>
<td>1.900</td>
<td>1.800</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.800</td>
<td>1.450</td>
</tr>
<tr>
<td>Spain</td>
<td>1.600</td>
<td>1.580</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.200</td>
<td>1.160</td>
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<tr>
<td>Portugal</td>
<td>950</td>
<td>900</td>
</tr>
<tr>
<td>Greece</td>
<td>750</td>
<td>710</td>
</tr>
<tr>
<td>Chile</td>
<td>700</td>
<td>630</td>
</tr>
<tr>
<td>Canada</td>
<td>560</td>
<td>571</td>
</tr>
<tr>
<td>Tunisia</td>
<td>500</td>
<td>463</td>
</tr>
<tr>
<td>Other US</td>
<td>450</td>
<td>478</td>
</tr>
<tr>
<td>Other countries</td>
<td>2.549</td>
<td>2.771</td>
</tr>
<tr>
<td>Total</td>
<td>33.359</td>
<td>30.377</td>
</tr>
</tbody>
</table>

(1.000 Metric Ton)

Source: WPTC
Cultivation of processing tomatoes: 3 regions account for almost 90% of total production (4.4 MTons):
- Emilia Romagna 40%
- Puglia less than 40%
- Campania about 10%

Processing Industry:
- **NORTH** Less than 15 processing plants for almost 2.2 MTons
- **SOUTH** Still around 200 processing plants for almost the same MTons
Average processed tomato by-products created in 2007

ITALY and Pianura Padana District “numbers”

ITALY
- 4,600,000 Tons tomato processed yearly
- 106,000 Tons pomace produced yearly (yield of 2.3%)

Pianura Padana “district”
- 2,000,000 Tons Tomato processed yearly
- 46,000 Tons Pomace produced yearly (yield of 2.3%)
Which are the antioxidants in tomatoes?

- Tomatoes contain a variety of antioxidants such as the two carotenoids lycopene and b-carotene, vitamins C and E, polyphenolics such as kaempferol and quercitin. Lycopene is the most abundant one in red tomatoes.
Agenda

- *Why the tomato* by-products
- *State of the art of the research*
- *Extraction techniques*
- *World Market of Carotenoids*
- *Conclusions*
Agenda

- Why the tomato by-products?
Why the tomato by-products?

- Processing industry might optimize their productions with added value new products in terms of higher consistency and higher colour intensity.
- Moreover processing tomato by-products (solid wastes) could became a very cheap fresh matter for the formulation of new nutraceuticals, pharmaceuticals, and cosmetically reach new products.
- And (obviously) could became “supernatural” colorants for additives industry and potential natural fibers for new packaging material environmentally friendly.
- P.S. Tomato Skins holds high concentration of Carotenoids more than pulp; it seems that the pigment is concentrated in the insoluble fiber fraction close to the peel.
Why the tomato by-products?

- The tomato “pomace” by-product composition is rich in bioactive compounds:
  1) **Lycopene** and other carotenoids
  2) **Tomato fibers**
  3) **Tomato Oils** (tocopherols) from seeds
  4) **Enzymes and acids**
Why the tomato by-products?

- Several studies shows the health benefits of tomato and of their industrial derivates.
- Bioactive compounds are certainly present also in by-product (solid waste) that are usually not exhaustively exploited.
- In SSICA since year 2000 we started applying some research protocols to verify this significant opportunity.
Agenda

- Why the tomato by-products
- State of the art of the research
State of the art of the research

SSICA Know How

1. Evaluation of carotenoid content into tomato products and relative wastes;
2. Evaluation of new “high pigment” tomato varieties;
3. Characteristics of lycopene and its maintenance during extraction phases from by-products (solid wastes);
4. State of the art of the different extraction methods of bioactive components coming from processing tomato waste (with solvents and with Supercritical CO$_2$);
5. Development of cost-effective method and partial results obtained by research projects developed at SSICA (last with Pectine Industrie Company – Supercritical CO$_2$);
6. Exploitation of future potential scenarios;
Examples of high lycopene varieties

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>R.R. (°Brix)</th>
<th>Colore Gardner</th>
<th>Lycopene (ppm)</th>
<th>Lycopene (mg/Kg s.s.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 01 Cois</td>
<td>4.70</td>
<td>22.62 28.82</td>
<td>12.06 2.39</td>
<td>118 2511</td>
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<tr>
<td>H 04 Cois</td>
<td>4.24</td>
<td>22.99 28.71</td>
<td>12.23 2.35</td>
<td>111 2618</td>
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<tr>
<td>DR 10747</td>
<td>5.44</td>
<td>22.01 31.47</td>
<td>12.09 2.60</td>
<td>188 3456</td>
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<tr>
<td>DR 10750</td>
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<td>22.18 28.87</td>
<td>12.04 2.40</td>
<td>125 2572</td>
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<tr>
<td>DRD 8133</td>
<td>4.54</td>
<td>21.82 29.95</td>
<td>11.91 2.51</td>
<td>170 3744</td>
</tr>
<tr>
<td>ES 85/95</td>
<td>4.48</td>
<td>23.77 28.60</td>
<td>12.72 2.25</td>
<td>113 2522</td>
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<tr>
<td>Nun 1365</td>
<td>4.54</td>
<td>22.28 30.34</td>
<td>12.00 2.53</td>
<td>137 3018</td>
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<tr>
<td>Nun 4994</td>
<td>4.40</td>
<td>23.09 29.46</td>
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<td>PLX 1129</td>
<td>4.14</td>
<td>23.20 28.75</td>
<td>12.19 2.36</td>
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<td>Forum</td>
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<td>21.35 28.97</td>
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<td>PS 1617</td>
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<td>22.68 30.54</td>
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<tr>
<td>Perfectpeel</td>
<td>4.28</td>
<td>23.03 28.53</td>
<td>12.17 2.34</td>
<td>116 2710</td>
</tr>
</tbody>
</table>
Agenda

- Why the tomato by-products
- State of the art of the research
- 2 Extraction techniques
 Extraction techniques
Examples and applications

- LycoRed Patents
- Separation of Carotenoids from fruits and vegetables (PCT Int. Appl. 2001) - John Shi Canada, Minister of Agriculture and Agri-Food
- Solvent extraction of lycopene from tomato peel (Chinese Patent 2002) – Ding, Xiaoling, et. al.
- Enzyme mediate extraction of lycopene from tomato skins. (Abst. Of papers 227° ACS National Meeting USA 2004) - Lavecchia Roberto, et. al.
- Exploitation of By-Products (solid wastes) from tomato processing to obtain high value antioxidants (ISHS Acta Horticulturae 724 2006) - L. Sandei et al.
Extraction techniques:

A) SOLVENTS

- Conventional Solid/Liquid extraction with Hexane, THF, Ether, Ethyl Acetate, Ethanol or pseudo other “natural/chemical solvents”

**PRO:**
- Extraction Yield very good (cost-effective)
- Technique already successfully tested (LycoRed® and other players)

**CONTRO:**
- Technique not environmentally friendly.
- Solvent residues
- Not good in food perception
Extraction techniques

B) CO₂ Supercritical Extraction

Efficiency of the Supercritical Extraction process is dependent on the physic-chemical characteristics of the matrix used. Since water content negatively affects the solvent capacity of the CO₂ SFE, the pomace drying phase becomes extremely important.

**PRO:**
- Technique environmentally friendly
- Good for food perception

**CONTRO:**
- Plant costs
- Extraction Yield complexity (cost-effective)
- Pre-treatment process indispensable
**eXtraction of Lycopene from tomato processing wastes**

- **OPTIMISATION** of Pre-Extractions conditions for SFE CO2 System (SSICA trials 2000-2007):

  - Indispensable employ of dry pomace (Dry Matter Content - exit plants is 25-30%)
  - Draining operation: Turbo Decanter System for the first drying step
  - Drying operation with drum dryers, or belt air dryers, or fluid bed dryers until 90-95% of dry matter residue (4-5% moisture)
  - Milling operations with mills for dry substances (hammer mill or other homogenizers systems)
  - Study of stocking conditions (dry material pre-extracted must be maintained under protected modified atmosphere – oxygen and light protection)
  - CO₂ SFE Treatment (Set up and study of processing parameters)
  - Purification of the extracted compounds
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- Conclusions
World Market of Carotenoids

- The world carotenoid market is expected to reach €0.77bn ($1.06bn) by 2010 as consumers continue to look for natural ingredients, a new report has predicted.
- A recent report on the $348.5 million (€291.4m) carotenoid market from market analysts Frost & Sullivan revealed that the European food and health industry has 'under-utilised' the nutraceutical properties of carotenoids, and consumers are still unaware of their health benefits.
- Frost & Sullivan claims that carotenoids are still used primarily as a colouring agent for the food and feed industries. Consumers in most European regions are unaware of their use as a food fortifier and this poor level of public awareness about the health benefits of carotenoids is expected to stifle market growth in the short term.
- Currently, the European carotenoid market is forecast to grow to €349.3 million in 2010.

Source: Nutraingredients.com
Conclusions

- Health consciousness of the world population has increased during the last years significantly.
- Tomato by-products should become a very cheap raw material alternative for the extraction of tomato bio-active compounds.
- The economic feasibility depends on product final value which is currently very high (€ 5000/kg?) ;
- At the moment, seems to be achieved adequate extraction conditions for economically practicable industrial recovery.
Conclusions

- It’s predictable a more deep analysis upon economic feasibility for scale up opportunity to decide the best hypothesis to apply.
- Exploiting, obviously, logistic and timing organization systems to guarantee cost-effective capability; taking into account that we have to work with several tons of fresh matter (unstable) concentrated in almost 70/80 days and this will require adequate scale plants.
- Total Plan Costs: Euro/year …………………
- Total profits: Euro/year ………………………
- Creation of Residue Valorization Companies?
LAST but NOT LEAST
“exhausted wastes” coming from CO₂ treated pomace could anyway turn into:

• **Animal feed** (microbiologically purified by CO₂ treatment)

• **Clean thermal energy power** for a complete natural recycled resources (Life Cycle Assessment).

• **New Supplement Products** rich in fibre and in residual genuine antioxidants!
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