Influence of processing on food quality with focus on organic food

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From EC Reg. 834/2007

Article 3
Objectives
(b) aim at producing products of **high quality**;

Organic production method as in line with the preference of certain consumers for products produced using **natural substances** and **processes**

Organic processed products should be produced by the use of processing methods which guarantee that the **organic integrity** and **vital qualities** of the product are **maintained through all stages of the production chain**

**Specific principles applicable to processing of organic food**
(c) the exclusion of substances and processing methods that might be misleading regarding **the true nature** of the product;
(d) **the processing of food with care**, preferably with the use of **biological, mechanical and physical methods**.

Prohibition on the use of GMOs and of ionizing radiation
Consumers’ criteria related to quality for their choice of organic food

• High sensory quality
• Freshness
• Naturalness
• Minimum use of additives
• Health

Which criteria are important for an organic product to be successful on the food market? *(from QLIF project)*

• Sensory quality
• Minimum use of additives and processing aids
• Freshness
• Authenticity

Important but not the most important: health
Food processing serves multiple objectives ....

Preservation
- Stabilization
- Shelf-life

Safety

Ingredients
- End products

Convenience

Quality

Variability of food supply

Food availability

Nutrient availability

Health and wellness
A process is an organized and logical sequence of unit operations
<table>
<thead>
<tr>
<th>Discipline</th>
<th>Examples of food science and technology applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology, cell biology</td>
<td>Understanding of post-harvest plant physiology, food quality, plant disease control, and microbial physiology; food safety</td>
</tr>
<tr>
<td>Biotechnology</td>
<td>Rice with increased content of beta-carotene; enzymes for cheese-making, bread-making, and fruit juice manufacture</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Food analysis, essential for implementing many of the applications listed here; improved food quality; extended shelf-life; development of functional foods</td>
</tr>
<tr>
<td>Computer science</td>
<td>Food manufacturing process control, data analysis                                                                ------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Genomics</td>
<td>Understanding of plant and animal characteristics, improved control of desirable attributes, rapid detection and identification of pathogens</td>
</tr>
<tr>
<td>Material science</td>
<td>Effective packaging; understanding of how materials properties of foods provide structure for texture, flavor, and nutrient release</td>
</tr>
<tr>
<td>Microbiology</td>
<td>Understanding of the nature of bacteria (beneficial, spoilage, and disease-causing microorganisms), parasites, fungi, and viruses, and developments and advances in their detection, identification, quantification, and control (for example, safe thermal processes for commercial sterilization); hygiene; food safety</td>
</tr>
<tr>
<td>Nutrition</td>
<td>Foods fortified with vitamins, and minerals for health maintenance; functional foods for addressing specific health needs of certain subpopulations; development of diets that match human nutrient requirements; enhanced health and wellness</td>
</tr>
<tr>
<td>Physics, engineering</td>
<td>Efficient food manufacturing processes to preserve food attributes and ensure food safety; pollution control; environmental protection; waste reduction efforts</td>
</tr>
<tr>
<td>Sensory science</td>
<td>Understanding the chemosenses (for example, taste, odor) to meet different flavor needs and preferences</td>
</tr>
<tr>
<td>Toxicology</td>
<td>Assessment of the safety of chemical and microbiological food components; food additives</td>
</tr>
</tbody>
</table>

From: Floros J.D. et al. 2010. Comprehensive Reviews in Food Science and Food Safety, 1-28
Effects of heat treatments

Positive

• Inactivation of food-borne pathogens
• Inactivation of natural toxins or other detrimental constituents
• Prolongation of shelf-life
• Improved digestibility and bioavailability of nutrients
• Improved palatability, taste, texture and flavour
• Enhanced functional properties (including augmented antioxidants and other defense reactivity or increased antimicrobial effectiveness)

Negative

• Losses of certain nutrients
• Formation of toxic compounds (acrylamide, furan or acrolein)
• Formation of compounds with negative effects on flavour perception, texture or colour.
# Heat treatment and tomato products

<table>
<thead>
<tr>
<th>°Brix</th>
<th>6</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>trans-lycopene (mg/100 g f.w.)</td>
<td>20.1</td>
<td>86.9 (+ 432%)</td>
</tr>
<tr>
<td>trans-lycopene (mg/100 g corrected to 25 °Brix)</td>
<td>120.7</td>
<td>86.9 (- 28%)</td>
</tr>
</tbody>
</table>

The proportion of lycopene release was significantly different:
• among all degrees of homogenization for the minimally additionally heated tomatoes
• between severely homogenized and not or midly homogenized for the extensively heated tomatoes

Additional heat treatment significantly enhanced the release of lycopene only for not and mildly homogenized tomatoes

Lycopene isomerization

(all-trans and 5-cis-lycopene are the two most common isomers found in human and animal tissues)


<table>
<thead>
<tr>
<th>Lycopene source</th>
<th>% trans</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh tomato</td>
<td>100</td>
<td>Shi J. Crit Rev Food Sci Nutr 40:1–42, 2000</td>
</tr>
<tr>
<td>Fresh tomato, heated 200°C, 45 min</td>
<td>89.3</td>
<td></td>
</tr>
<tr>
<td>Tomato paste, heated 70°C, 3 hr</td>
<td>83.4</td>
<td></td>
</tr>
</tbody>
</table>
## Effect of homogenization of tomatoes on the response of lycopene in human tryglyceride-rich lipoproteins after 1 d of consumption of tomato products

<table>
<thead>
<tr>
<th>Degree of homogenization</th>
<th>None</th>
<th>Mild</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postprandial TRL response</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lycopene (nmol h/L)</td>
<td>54.9 ± 11.0 a</td>
<td>72.2 ± 11.0 ab</td>
<td>88.7 ± 11.0 b</td>
</tr>
</tbody>
</table>

## Effect of heat treatment of tomatoes on the response of lycopene in human tryglyceride-rich lipoproteins after 1 d of consumption of tomato products

<table>
<thead>
<tr>
<th>Heat treatment</th>
<th>Minimal</th>
<th>Extensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postprandial TRL response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lycopene (nmol h/L)</td>
<td>59.0 ± 16.6 a</td>
<td>84.9 ± 16.6 b</td>
</tr>
</tbody>
</table>

The increase of lycopene concentration in human TRL after consumption of tomato product indicates an increase in lycopene bioavailability related to the disruption of the matrix by homegenization and heat treatment and to the isomerization of lycopene from the configuration *all-trans* to *cis*-isomers.
Vit C retention in fresh, chilled and frozen vegetables

## Losses of ascorbic acid (% d.w.) due to canning and freezing processes

<table>
<thead>
<tr>
<th></th>
<th>Canning</th>
<th>Blanching + freezing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td>90</td>
<td>0-35</td>
</tr>
<tr>
<td>Green beans</td>
<td>63</td>
<td>28</td>
</tr>
<tr>
<td>Spinach</td>
<td>62</td>
<td>61</td>
</tr>
</tbody>
</table>

---

## Losses of ascorbic acid (% w.w.) due to storage of fresh, frozen and canned vegetables

<table>
<thead>
<tr>
<th></th>
<th>Fresh</th>
<th>Frozen</th>
<th>Canned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Days</td>
<td>°C</td>
<td>Loss (%)</td>
</tr>
<tr>
<td>Carrots</td>
<td>84</td>
<td>4</td>
<td>5-10</td>
</tr>
<tr>
<td>Green beans</td>
<td>16</td>
<td>4</td>
<td>90</td>
</tr>
<tr>
<td>Spinach</td>
<td>21</td>
<td>4</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Fresh</th>
<th></th>
<th>Frozen</th>
<th></th>
<th>Canned</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uncooked</td>
<td>Cooked</td>
<td>%</td>
<td>Uncooked</td>
<td>Cooked</td>
</tr>
<tr>
<td>Green beans</td>
<td>0.163</td>
<td>0.097</td>
<td>-40</td>
<td>0.129</td>
<td>0.041</td>
</tr>
<tr>
<td>Peas</td>
<td>0.400</td>
<td>0.142</td>
<td>-65</td>
<td>0.180</td>
<td>0.099</td>
</tr>
<tr>
<td>Spinach</td>
<td>0.281</td>
<td>0.098</td>
<td>-65</td>
<td>0.243</td>
<td>0.022</td>
</tr>
</tbody>
</table>

- Fresh is often best for optimal vit C content, as long as the fresh product undergoes minimal storage at refrigerated temperature.
- Canning process causes significant initial loss of ascorbic acid; further losses due to storage and cooking are minimal.
- Blanching and freezing process is not as destructive to ascorbic acid, but continued storage and subsequent cooking result in significant degradation of the vitamin.

Fresh products category

Their shelf life is shorter than that of the raw materials from which they are obtained. Convenience
Short shelf-life
Their preservation is based on:
• the high quality of raw materials, both microbiological, sensory, nutritional;
• the presence of hurdles to the growth of the microorganisms

Refrigeration  Hurdle technology concept
Minimally processed foods. Possible definitions


The least possible treatment to achieve a purpose

Minimal processes are those which minimally influence the quality characteristics of a food whilst, at the same time, giving the food sufficient shelf-life during storage and distribution.

Techniques that preserve food but also retain to a greater extent their nutritional quality and sensory characteristics by reducing the reliance on heat as the main preservative action.

Minimal processing describes those technologies to process food in a manner to guarantee the food safety and preservation, as well as to maintain as much as possible the fresh like characteristics.

High level of convenience. Synonym of minimally processed are ready-to-use, ready-to-eat, pre-cut, fresh-cut, lightly processed, etc.

Developments in thermal technologies have been considered minimal where they have minimized quality loss in food compared to the conventional thermal techniques.
Nowadays, for the consumers «fresh pasta» is ......

FRESH PASTA DIFFERENT PRODUCTION TECHNOLOGIES AND SHELF LIFE

- Flour and similar products
- Kneading machine
- Dough (lamination or extrusion)
- Cylinder
- Crossed sheeting unit
- Sizing (to desired thickness)
- Thin sheet
- Cutting
  - Sheeted pasta
  - Lasagna/Tagliatelle (Cannelloni)
- Shaping
  - Single sheeted pasta
  - (folded Ravioli, pinched pasta, Tortellini)
- Filling
- Shaping
- Double sheeted pasta
- Drying
- Heat treatment
- MAP
- 2nd Heat treatment
- Frozen
- Dried pasta

Unpackaged pasta shelf-life: 2 days at +4°C

- Shelf life 6 days (unpackaged pasta)
- Shelf life 25/40 days
- Shelf life 40/120 days
- Shelf life 6 months
- Shelf life 12 months
The European milk market is split between pasteurized and aseptic.

Source: Elopak Market Units, Euromonitor. 2003
ESL milk is a product that has been treated in a manner to reduce the microbial count beyond normal pasteurization, packaged under extremely hygienic conditions, and which has a defined prolonged shelf life under refrigerated conditions.

Current methods for ESL:

- Microfiltration
- Direct heat treatment (injection or infusion)
- Indirect heat treatment
<table>
<thead>
<tr>
<th>Process</th>
<th>Log reduction aerobic psychrotrophic spores</th>
<th>Expected shelf life Max 6°C storage (days)</th>
<th>Lactulose (mg/kg)</th>
<th>β-lactoglobulin (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw milk</td>
<td></td>
<td></td>
<td>0</td>
<td>3,500</td>
</tr>
<tr>
<td>Pasteurization</td>
<td>0</td>
<td>10-12</td>
<td>10</td>
<td>3,100</td>
</tr>
<tr>
<td>Direct heating</td>
<td>8</td>
<td>180</td>
<td>25</td>
<td>1,600</td>
</tr>
<tr>
<td>Indirect heating</td>
<td>40</td>
<td>180</td>
<td>32</td>
<td>1,000</td>
</tr>
<tr>
<td>Microfiltration</td>
<td>2-3</td>
<td>30</td>
<td>17</td>
<td>2,500</td>
</tr>
</tbody>
</table>


CLA content is higher in organic milk than in conventional. Several studies on the effect of heating milk and processing have shown no changes in CLA content. (Butler G. et al., 2011. NJAS – Wageningen Journal of Life Sciences, 58, 97-102).
Lactulose content in Italian UHT milk

<table>
<thead>
<tr>
<th>UHT milk Commercial products</th>
<th>Lactulose (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
</tr>
<tr>
<td>A</td>
<td>102.2</td>
</tr>
<tr>
<td>B</td>
<td>134.9</td>
</tr>
<tr>
<td>C</td>
<td>475.4</td>
</tr>
<tr>
<td>D</td>
<td>193.3</td>
</tr>
<tr>
<td>E</td>
<td>859.1</td>
</tr>
<tr>
<td>F</td>
<td>200.5</td>
</tr>
<tr>
<td>G</td>
<td>354.3</td>
</tr>
<tr>
<td>J</td>
<td><strong>905.6</strong></td>
</tr>
<tr>
<td>H</td>
<td>771.7</td>
</tr>
<tr>
<td>K</td>
<td>626.1</td>
</tr>
</tbody>
</table>

Range min - max: 102.2 – 905.6 (mg/kg)

It means that different procedure have been applied to have the same product from a product sector point of view.

Several (more or less careful) technological solutions can be adopted to achieve the same objective.

Source: Manzi and Pizzoferrato. Food and Bioprocess Technology, 2013, 6: 851-857
Novel technologies

**Thermal**

- Ohmic heating

- Internal generation of heat due to the electrical resistance of food components to the passage of an electric current

**Non-thermal**

- High pressure
  - Pressure 100 – 1000 MPa
  - Pascal principle
  - Le Chatelier principle
  - Protein denaturation

- Pulsed electric field
  - High intensity electric field (> 0.5 kV/cm) in form of very short pulses (μs to ms)
  - Membrane permeabilization (electroporation)
Number of commercial high-pressure equipment units around the world (2009)

- **32% vegetable products**
- **24% meat products**
- **21% juices and beverages**
- **17% seafood and fish**
- **6% other products**

100 – 800 MPa

High Pressure Processing (HPP) and High Pressure Thermal Sterilization (HPTS)

- Inactivation of vegetative organisms and spoilage enzymes at low or moderate temperature
- Opportunities for increased shelf life and preservative-free stabilization
- Modification of physical and functional properties of some food (gelation of protein)
- Improvement of protein digestibility
- Tenderization of meat products
- Fresh-like qualities retained

For the inactivation of microbial spores a combination of high pressure and elevated temperatures, HPTS, is necessary. Synergistic inactivation at potentially lower temperatures or shorter processing times: improving quality while reducing energy consumption.
### Advantages

- Energy efficient
- Very rapid treatment (OH, PEF)
- Little effect on colour, flavour, nutrients
- Reduction unwanted thermal effects

### Disadvantages

* Unless in combination with heat

<table>
<thead>
<tr>
<th></th>
<th>Ohmic heating</th>
<th>HPP</th>
<th>PEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniformity of treatment</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Limited throughput</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>High cost equipment</td>
<td>---</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Labor</td>
<td>No</td>
<td>Yes</td>
<td>---</td>
</tr>
<tr>
<td>Spore inactivation</td>
<td>Yes</td>
<td>No *</td>
<td>No *</td>
</tr>
<tr>
<td>Enzyme inactivation</td>
<td>Yes</td>
<td>Reversibility of inactivation, activation of latent forms *</td>
<td>Many are not affected *</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Yes</td>
<td>To be developed</td>
<td>To be developed</td>
</tr>
<tr>
<td>Type of product</td>
<td>No limit</td>
<td>No limit</td>
<td>Liquid, semi-fluid</td>
</tr>
<tr>
<td>N. applications in food industry</td>
<td>Scarce</td>
<td>126 plants worldwide (2009)</td>
<td>Still scarce</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>No</td>
<td>Yes *</td>
<td>Yes *</td>
</tr>
</tbody>
</table>
Nanotechnology

Involves the manufacture, processing and application of materials that have one or more dimensions of the order of 100 nm or less.

From the convergence of nanotechnology with other technologies:

- Nanostructured food ingredients and delivery systems for nutrients and supplements
- **Innovations**
  - production, processing, storage, transportation, traceability, safety and security of food (e.g., nano-biosensors, electronic tongue, etc.)
- Food packaging
Objectives of the incorporation of nanoparticles in food packaging materials

- to improve packaging properties (flexibility, gas barrier properties, temperature stability)
- produce active packaging (nanoparticles with antimicrobial or oxygen scavenging properties)
- produce intelligent food packaging (incorporating nanosensors to monitor and report the condition of food)
- produce biodegradable polymer-nanomaterial composites

The knowledge about this technology is still very scarce.

Potential migration of nanoparticles into food and drinks from food packaging:

Migration data are not currently available. A number of such food packaging materials containing already available and in commercial use in some countries.
Indirect sources of food contamination with nanoparticles:

- nano-sized pesticides and veterinary medicines
- contact of food with nanoparticulate-based coatings
- as the environmental behavior, distribution and fate of nanoparticles is currently not fully understood, it is difficult to assess whether nanoparticles in the environment will bioaccumulate/bioconcentrate in the food chain

- Few studies have been carried out into the toxicology of nanomaterials
- The potential effects of nanoparticles through the gastrointestinal route are largely unknown.
- A growing body of scientific evidence indicates that free nanoparticles can cross cellular barriers and that exposure to some forms can lead to increased production of oxyradicals and, consequently, oxidative damage to the cell.
Use of nanoparticles to deliver ingredients and supplements in food

Functional foods can be divided into three categories according to the nature of the functional ingredients:

a) natural food containing high levels of the functional ingredient or with high functionality;
b) food to which functional ingredients were added or removed;
c) food in which the nature of functional ingredients has been changed.

Consumers buy organic food because they associate them to naturalness; in contrast, the decision to buy functional food is related to rationality and consumer associate functional food with a more technological approach (Kahl et al., 2012)

This should be even more valid for food enriched by nanotechnology
Some considerations

- A possible definition for careful processing could be «the one which allows to achieve a preset objective while reducing at minimum the (undesirable) side effects»
- Careful processing is not an absolut concept and its assessment needs a comparison between different solutions to achieve a specific objective for a specific product based on the assessment of different parameters
- Sensory characteristics and freshness, in particular, are the most important indicators. The parameters have to be individuated for the different products
- Like for the environmental impact assessment (LCA method), also for the assessment of the impact of a technology on quality the entire life cycle of a product should be considered, including also its preparation for consumption (CE Reg. 834/2007 recommendation for quality maintenance)
• The “minimal process” seems to be suitable for the organic sector, but it appears as a part of the more comprehensive concept of careful processing.
• Many novel technologies seem to be suitable for the organic sector and consider a “minimal processes” but further research is needed.
• There is a need of research for packaging material (biodegradable, recyclable, etc.).
• Traditional and innovative. Structural problems of the organic SMEs; different ideological visions of the organic production.
Thanks for your attention!