Joint Bachelor Course on Organic Agriculture 2014

Lecture 10: Food quality and food processing, Part I

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SNF/SCOPES
Quality of organic food

“The totality of features and characteristics of a product, process or service that bear on its ability to satisfy stated or implied needs”

(FAO 2004, Twenty-fourth FAO regional conference for Europe)

“Food quality has an objective and a subjective dimension. Objective quality refers to the physical characteristics...(...). Subjective quality is the quality as perceived by consumers.”

(Grunert 2005, European Review of Agricultural Economics, 369-391)

Still no general agreement on the definition of food quality
Quantitative characteristics:
- Nutritional value of food
- Nutrient bioavailability
- Health aspects

Food quality

Sensory aspects:
- Sensory evaluation of fruits and vegetables
- Sensory evaluation of milk
- Sensory evaluation of meat

Food safety:
- Sources of food contamination
- Microbial contamination
- Chemicals and toxicants in food
- Health aspects

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Quantitative characteristics

Nutritional value of food

Essential nutrients:
- Carbohydrates
- Lipids
- Proteins
- Minerals
- Vitamins

Compounds with important biological functions:
- Amino acids
- Fatty acids
- Soluble and insoluble fibers
- Active peptides
- Etc…

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Nutritional value of plant produce

Variable and controversial results on nutritional value of organically versus conventionally grown agricultural produce

Table 1. Comparison of protein, nitrate and selected vitamin and mineral contents of organic v. conventionally-grown crops (derived from Worthington, 1998)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Increased</th>
<th>Same</th>
<th>Decreased</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein quality</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nitrate</td>
<td>5</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>21</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>β-carotene</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>B vitamins</td>
<td>2</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Ca</td>
<td>21</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Mg</td>
<td>17</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Fe</td>
<td>15</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>Zn</td>
<td>4</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

(No. of studies of organic crops shown to have increased, decreased or same nutrient content compared with conventionally-grown crops)

## Systematic review: Nutritional quality of organic foods

**Table 1**

Comparison of content of nutrients and other nutritionally relevant substances in organically and conventionally produced crops as reported in satisfactory quality studies

<table>
<thead>
<tr>
<th>Nutrient category</th>
<th>No. of studies</th>
<th>No. of comparisons</th>
<th>Standardized difference&lt;sup&gt;2&lt;/sup&gt;</th>
<th>P</th>
<th>Higher levels in organic or conventional crops?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>17</td>
<td>64</td>
<td>6.7 ± 1.9</td>
<td>0.003</td>
<td>Conventional</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>14</td>
<td>65</td>
<td>2.7 ± 5.9</td>
<td>0.84</td>
<td>No difference</td>
</tr>
<tr>
<td>Phenolic compounds</td>
<td>13</td>
<td>80</td>
<td>3.4 ± 6.1</td>
<td>0.60</td>
<td>No difference</td>
</tr>
<tr>
<td>Magnesium</td>
<td>13</td>
<td>35</td>
<td>4.2 ± 2.3</td>
<td>0.10</td>
<td>No difference</td>
</tr>
<tr>
<td>Calcium</td>
<td>13</td>
<td>37</td>
<td>3.7 ± 4.8</td>
<td>0.45</td>
<td>No difference</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>12</td>
<td>35</td>
<td>8.1 ± 2.6</td>
<td>0.009</td>
<td>Organic</td>
</tr>
<tr>
<td>Potassium</td>
<td>12</td>
<td>34</td>
<td>2.7 ± 2.4</td>
<td>0.28</td>
<td>No difference</td>
</tr>
<tr>
<td>Zinc</td>
<td>11</td>
<td>30</td>
<td>10.1 ± 5.6</td>
<td>0.11</td>
<td>No difference</td>
</tr>
<tr>
<td>Total soluble solids</td>
<td>11</td>
<td>29</td>
<td>0.4 ± 4.0</td>
<td>0.92</td>
<td>No difference</td>
</tr>
<tr>
<td>Copper</td>
<td>11</td>
<td>30</td>
<td>8.6 ± 11.5</td>
<td>0.47</td>
<td>No difference</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>10</td>
<td>29</td>
<td>6.8 ± 2.1</td>
<td>0.01</td>
<td>Organic</td>
</tr>
</tbody>
</table>

<sup>1</sup> Nutrient categories are listed by numeric order of the included studies.

<sup>2</sup> All values are means ± SEs (robust).

Main findings

› Organic crops are **as nutritious as** conventional crops.
› Organically grown agricultural produce may be **higher** in **vitamin C** and **phosphorus**.
› Organic crops are **lower in nitrates** than conventional crops.
› Superiority of carbohydrate and protein levels in organic foods are insufficiently documented.
Bioactive non-nutritive compounds: Phytochemicals

Phytochemicals
Secondary metabolites that protect plants from diseases and pests. Scientific evidences demonstrate the presence of higher amounts of phytochemicals in organic plants.

Polyphenols
Phytochemicals with strong activity. Play a role in the prevention of cardiovascular diseases, cancers, and osteoporosis. (Scalbert et al. 2005)

Flavonoids
The most common group of polyphenols in human diet. Typical plant sources are apples, tea, onions etc.

Many studies show that levels of polyphenols (e.g. flavanoids) are higher in organic plant products.

Nutritional value of livestock products

Milk

- Beneficial fatty acid composition:
  - Higher contents of conjugated linoleic acid and polyunsaturated fatty acids (PUFA)
  - Lower ratio of omega-6/omega-3 fatty acids
  - Higher ratio of conjugated linoleic acid/linoleic acid
  - Evidence of higher vitamin and antioxidant concentration
  - Some deficiency of specific macro- and microelements since mineral supplements and fertilizers in organic farming are not allowed.

Source: Matt et al. 2011
**Meat**

- Meat from organic farms
  - Higher content of omega-3 acids
  - Lower content of saturated fats
  - Evidence of higher total fat content in beef and pork

**Eggs**

- Eggs from organic farms
  - Carotenoids’ profile of the yolk of organic eggs differs from that of conventionally produced eggs; Darker yolk color

Inconsistent research data on superiority of nutritive value of organic eggs and meat compared to conventional products.

Source: Matt et al. 2011
**Nutrient bioavailability**

Bioavailability of nutrients is defined by their potential to be released and efficiently used for metabolic purposes.

Factors influencing nutrient bioavailability:

- Chemical nature of the nutrient e.g. cations, protein conformation etc.
- Physicochemical environment during the digestive process e.g. pH, presence of complex carbohydrates, condensed tannins, etc.
- Food processing techniques and parameters.
- Presence of anti-nutritional factors.

No scientific data support better bioavailability of nutrients in organic food when compared to conventionally produced food.
Summary of health benefits

› Organic vegetables contain less nitrate (- 30-90%)
  (Matt et al. 2011, Hansen et al. 2002)
› Organic fruits and vegetables feature a higher content of antioxidants such as polyphenols, flavonoids and ascorbic acid, which may reduce the risk of cancer and cardiovascular diseases.
  (Matt et al. 2011)
› Organic animal products show a healthier fatty acid profile
  (Matt et al. 2011)
› Mineral levels of organic plant products are similar to conventional products (Dangour et al. 2009, Mäder et al. 2007, Ryan et al. 2004)
Experienced health effects of consumers of organic food

A total of 566 respondents participated.

Outcomes:

- no health effects (30%)
- feeling more energetic and having better resistance to illness (70%)
- positive effect on mental well-being (30%)
- improved stomach and bowel function (24%)
- improved condition of skin, hair and/or nails (19%)
- fewer allergic complaints (14%)
- improved satiety (14%)

In addition, the switch to organic food was often accompanied by the use of more freshly prepared foods and other lifestyle changes.

Source: van de Vijver et al. 2012

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Problems

Research data on the influence of organic food on human health are insufficient to formulate clear and straightforward conclusion.

Various factors may preclude the performance of well controlled experiments with human subjects:

- Nutrient bioavailability dependence on individual physiology.
- Differences in health status of each individual during an experiment.
- Factors other than eating habits may affect results.
Food safety

**Definition:** Safety of foods is the certainty that they will not cause harm or illness to humans.

**Broader meaning:** Food safety encompasses a set of conditions and practices during production, processing, distribution, storage and preparation of foods which are necessary to protect them from pathogenic microorganisms, exogenous chemical contaminants, naturally occurring toxic substances and newly formed toxic compounds during processing or preparation.

Sources of food contamination

1. Human & animal excreta
2. Infected food animal
3. Night soil
4. Irrigation & Wastewater
5. Domestic animals
6. Flies and pests
7. Contaminated household water
8. Polluted environment (soil, dust)
9. Dirty pots & Cooking utensils
10. Cross-contamination

FOOD (Raw/Cooked)

Time-Temperature Abuse

Contaminated Food

Source: Brown et al. 1998
Microbial contamination

› Bacterial contamination

› Use of farmyard manure and other animal wastes may increase the risk of contamination of agricultural produce with pathogens such as *E. coli* O157.

› Composting do not prevent growth of spore-formers such as *Clostridium perfringens* and *Clostridium botulinum*.

› Frequency and durability of *Salmonella* and *Campylobacter* infections in organically raised animals may be higher due to extended exposure of animals to out-door conditions and ban of antibiotics. Respectively, higher dissemination of foodborne pathogens of livestock products (meat, milk, and eggs) could be expected.

Microbiological examination of organic vegetables

Microbiological results of ready-to-eat organic vegetables \((n = 3200)\)

- Escherichia coli detected in 48 samples (out of 3200 samples)
- Listeria spp. (excluding L. monocytogenes) detected in 6 samples
- Listeria monocytogenes not detected
- Salmonella spp. not detected
- Campylobacter spp. not detected
- E. coli O157 not detected

«The vast majority (99.5%) of uncooked ready-to-eat organic vegetables (...) were of satisfactory/acceptable microbiological quality.»

«(...) the absence of pathogens (...) indicates that overall agricultural, hygiene, harvesting and production practices were good.»

<table>
<thead>
<tr>
<th>Food-borne pathogen</th>
<th>Study population</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Escherichia coli</em> O157</td>
<td>Beef cattle</td>
<td>No difference in prevalence between organic and conventional cattle at harvest</td>
<td>Reinstein et al. 2009</td>
</tr>
<tr>
<td><em>E. coli</em> O157</td>
<td>Dairy cattle</td>
<td>No difference in percentage of positive samples in organic and conventional dairy farms</td>
<td>Cho et al. 2006a</td>
</tr>
<tr>
<td><em>E. coli</em> O157 and Shiga toxin-producing <em>E. coli</em> (STEC)</td>
<td>Dairy cattle</td>
<td>No difference in prevalence or risk of carrying <em>E. coli</em> O157 or STEC</td>
<td>Kuhnert et al. 2005</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>Dairy cattle</td>
<td>No difference in prevalence between organic and conventional dairy farms</td>
<td>Fossler et al. 2005a, 2005b</td>
</tr>
<tr>
<td><em>Salmonella</em></td>
<td>Beefsteak</td>
<td>No positive samples detected</td>
<td>Miranda et al. 2009</td>
</tr>
<tr>
<td><em>Campylobacter</em></td>
<td>Dairy cattle</td>
<td>No difference in prevalence between organic and conventional dairy farms</td>
<td>Sato et al. 2004</td>
</tr>
<tr>
<td><em>Listeria monocytogenes</em></td>
<td>Beefsteak</td>
<td>No difference in percentage of positive samples in organic and conventional products</td>
<td>Miranda et al. 2009</td>
</tr>
</tbody>
</table>

The UK Food Standards Agency’s (FSA)
› “There is currently no firm evidence to support the assertion that organic produce is more or less microbiologically safe than conventional food”


The UK Ministry of Agriculture, Fisheries and Food (MAFF)

› “There is insufficient information at present to state categorically whether the risk of pathogen transfer to produce on organic farms differs significantly from that associated with conventional farming practices”

Chemicals and toxicants in foods

Effect of ban on pesticides on product safety in organic farming compared to conventional farming

<table>
<thead>
<tr>
<th>Compound</th>
<th>Product</th>
<th>Prevalence</th>
<th>Impact on human health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticides</td>
<td>Fruits, vegetables, cereals</td>
<td>None or very low concentrations in organic products</td>
<td>Positive</td>
</tr>
<tr>
<td>Ochratoxin (mycotoxin)</td>
<td>Cereals</td>
<td>Higher than in conventional products</td>
<td>Negative</td>
</tr>
<tr>
<td>Aflatoxin (mycotoxin)</td>
<td>Milk</td>
<td>Absent</td>
<td>Positive</td>
</tr>
</tbody>
</table>

**Mycotoxins:** Secondary metabolism products of *Aspergillus*, *Penicillium*, and *Fusarium* which have carcinogenic and immunosuppressive effects on human health.

No evidence to indicate that organic food is more prone to mycotoxin contamination than conventional food (FAO, 2000)

Source: Hansen *et al.* 2002
Effect of ban on synthetic fertilizers and growth promoters on product safety in organic farming compared to conventional farming

<table>
<thead>
<tr>
<th>Compound</th>
<th>Product</th>
<th>Prevalence</th>
<th>Impact on human health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy metals</td>
<td>Cereals, carrots, potatoes</td>
<td>Same or lower than in conventional products</td>
<td>Positive</td>
</tr>
<tr>
<td>Residues of growth regulators</td>
<td>Cereals</td>
<td>Not present in organic products</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Effect of lower nitrogen levels on product safety in organic farming compared to conventional farming

<table>
<thead>
<tr>
<th>Compound</th>
<th>Product</th>
<th>Prevalence</th>
<th>Impact on human health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate</td>
<td>Spinach, potatoes, beetroots</td>
<td>30-90% lower than in conventional products</td>
<td>Positive</td>
</tr>
</tbody>
</table>

Source: Hansen et al. 2002

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Summary of food hazards

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Comparison of organic and conventional products with respect to food hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic &lt; Conventional</td>
<td>Organic = Conventional</td>
</tr>
<tr>
<td>Synthetic agrochemicals(^a)</td>
<td>Environmental pollutants(^d)</td>
</tr>
<tr>
<td>Nitrate(^b)</td>
<td>Biological pesticides</td>
</tr>
<tr>
<td>Contaminants in feedstuffs(^c)</td>
<td></td>
</tr>
<tr>
<td>Veterinary drugs(^c)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) vegetables and fruits.
\(^b\) nitrophillic vegetables.
\(^c\) foods of animal origin.
\(^d\) heavy metals (e.g. cadmium, lead), dioxins, polychlorinated biphenyls, radioactive nuclides.

Health aspects of chemicals and toxicants

Benefits of organic foods for human health as a consequence of the strict regulation of organic plant and animal production:

**Organic plant production**
- a ban on genetic engineering and GMOs
- lower nitrogen levels: maximum limits for manure application of 170 kg N ha\(^{-1}\) yr\(^{-1}\)
- a ban on synthetic pesticides
- a ban on synthetic mineral fertilisers
- a ban on growth promoters

**Organic animal production**
- extended access to out-door areas with a lower stocking density
- restrictions on animal feeds:
  - compulsory use of roughage feeds
  - ban on antibiotics, growth promoters and additives
  - ban on GMOs
  - ban on meat and bone meal
- double retention time after medicine treatment
Sensory aspects

Sensory attributes:

External appearance:
- Shape,
- Color,
- Size,
- Freshness,
- Firmness

Organoleptic properties:
- Taste,
- Flavor,
- Texture
Sensory evaluation of fruits and vegetables

Nine studied objects,
Six sample batches of each food,
three organic and three conventional:

carrots (raw and cooked),
onions, broccoli,
vine tomatoes, cherry tomatoes,
apples, potatoes,
bananas and oranges.

Descriptors:

Color
Aroma
Hardness
Moistness
Crunch
Sweetness
Bitterness (aftertaste)

Conclusion:
No significant differences between the sensory properties of organically and conventionally grown fresh fruits and vegetables.

Controversial results on sensory evaluation of fruits and vegetables

Table 1. Recent studies on the sensory comparison of organic and conventional foods and their findings.

<table>
<thead>
<tr>
<th>References</th>
<th>Food tested</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haglund et al., 1999</td>
<td>Carrots</td>
<td>Conventional carrots higher in carrot taste, sweetness and crunchness. Organic carrots higher in hardness and pronounced after-taste (P&lt;0.01 or less).</td>
</tr>
<tr>
<td>Wszelaki et al., 2005</td>
<td>Red skin potatoes</td>
<td>In a triangle test, panelists could distinguish between organic and conventional samples only when the skin was left on.</td>
</tr>
<tr>
<td>Gilsenan et al., 2008</td>
<td>Carrots and Mashrooms</td>
<td>Descriptive analysis of carrots for appearance, aroma, texture and taste found no significant difference (P&lt;0.05). Analysis of mashrooms for the same descriptors also showed no significant difference; however, it was indicated that organic mashrooms had darker gills and stronger aroma (P&lt;0.05).</td>
</tr>
<tr>
<td>Gilsenan et al., 2010</td>
<td>Potatoes</td>
<td>No significant difference in appearance, aroma and taste was observed. However, baked conventional samples were perceived to be significantly softer, less adhesive and wetter than organic baked samples (P&lt;0.05).</td>
</tr>
<tr>
<td>Hajslová et al., 2005</td>
<td>Potatoes</td>
<td>In a 4-year study, differences were seen within single crop years; however, pooled results showed that year-to-year, variety and geographical variations were equal or more important factors.</td>
</tr>
</tbody>
</table>
Sensory evaluation of milk

Sensory panelists clearly differentiate organic cow milk from conventional milk by:

- Overall flavor
- Liking
- Mouthfeel

Consumers clearly show preference to conventional milk. It is primarily due to specific cow’s milk odor which consumers are not accustomed to.

Source: Bopanna N. 2007, MSc Theses
Sensory evaluation of meat

Sensory description of organic meat perceived by light and heavy users:

- **Taste:** Satisfying taste, rich, strong taste, tastier, the taste as I remember it from earlier days, the real taste / unpleasant strong animal taste, sweeter, taste too much like animal, stronger in taste, very delicious, artificial aromas missing

- **Appearance:** Nicer / deeper red, natural color since it lacked nitrate, less pink, fresh and red, Bordeaux color, does not get a grey sheen as quickly as conventional meat

- **Texture:** More tender and less tough, firmer and tougher (especially for chicken) when frying, meat does not shrink as much and less water comes out, retains volume during cooking and loses less liquid, tender, soft as butter, well-seasoned, better consistency, stays firm, tender and moist, juicy but not watery, compact texture, tender, more tender, firm in consistency, more tender, less water

- **Odor:** Fat smelling, right and pleasant smell

References


References

Thank you!

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