Organic fertilisation and the health effects of fruits and vegetables

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Organic fertilisation and the health effects of fruits and vegetables

- How soil fertility affects plant composition to optimise plant health
  - Antioxidants
  - Secondary metabolites
- Predicted consequences for human health
  - Antioxidants
  - Secondary metabolites
Antioxidants

Types and roles in plants:

- **Vitamin C:**
  - involved in redox regulation (same as in animals)

- **Vitamin E:**
  - protect lipids against oxidation

- **Phenolic compounds:**
  - protect against UV-damage
  - (serve as pigments)
  - (involved in defence against pests and diseases)

- **Carotenes:**
  - involved in photosynthesis, protect against photooxidative stress
  - (serve as pigments)
Antioxidants

- If soil nitrate availability is less than a plant’s maximum uptake rate → “moderate N-stress”
  - Plant metabolism → ↑ N-use efficiency
  - ↓ number of chloroplasts
    - ↓ accumulation of carotenoids
  - Smaller, thicker leaves
    - ↓ accumulation of UV-protective phenolics
  - ↑ oxidative stress
    - ↑ accumulation of vitamin C
  - ↑ oil content compared with protein
    - ↑ Vitamin E(?)

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Antioxidants

- Organic fertilisation strategies cause nitrate to be released slowly in the soil, resulting in a relatively low nitrate availability.
- Due to this, organic plant products contain relatively:
  - more vitamin C
  - less carotenoids
  - different composition of phenolic compounds
  - more vitamin E?
Antioxidants

Comparisons are:
- fruits, herbs and vegetables
- same varieties
- same year
- same place
- (relevant organic and conventional commercial practice)
- on fresh weight basis

Distribution of results of controlled comparisons

- Vitamin C
- Carotenoids

Please note:
Unpublished (preliminary) results

Organic content as % of conventional

Average of all studies: Vitamin C: 117 % (32 comparisons)
Carotenoids: 93% (22 comparisons)
Defence-related secondary metabolites and fertilisation

- Organic/low input
- Subsistence farming
- Differentiated mass
- Conventional/high input
- Secondary metabolites

Resource availability, e.g. soluble N (graph from Stamp 2003)
Effect of production system on resistance to disease

Effect of growing conditions on incidence of storage diseases in onion varieties

(Bjørn & Fruekilde 2003)

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Chlorogenic acids, catechins and tannins defend the fruit against pests and diseases. In contrast, the probable primary role for flavonols in apples are as UV-protective antioxidants.

(data from Brandt et al. 2003)
Secondary metabolites

Distribution of results of controlled comparisons

Please note:
Unpublished (preliminary) results

Organic content as % of conventional

Average of all compounds and studies: 110 %
(189 comparisons)
Predicted consequences for human health

When is a moderate difference in content of a food compound important for human health?

1. The food must provide a large contribution to the dietary intake of this compound
2. The intake must be in a range where a change in intake of this compound affects health
3. Depending on this range, the effect can be beneficial or detrimental to health
Predicted consequences for human health

Effect of vitamin E in the diet on risk of lung cancer

Each data point represents 3380 male smokers for 6 years.

People with very low vitamin E intake tend to have a generally unhealthy diet.

Data from Albanes et al. 1996
Effect of vitamin E supplementation on risk of lung cancer

- Supplements can benefit health for those with a very poor diet, who are really deficient in the nutrient.
- Supplements provide no benefit if the diet contains enough of the nutrient to prevent deficiency.

Predicted consequences for human health
Effect of increased intake of fruits and vegetables on human health

(van’t Veer et al. 2000)

Fig. 1 Preventable proportion of chronic diseases as related to the intake of fruits and vegetables
Effect of increased intake of fruits and vegetables on human health

(van’t Veer et al. 2000)
Which dietary compounds mostly come from fruits and vegetables?

- Vitamin C (but also used as food additive)
- Carotenes such as beta-carotene, lycopene
- Secondary metabolites
- Pesticide residues (in conventional F&V)
- Nitrate (mainly vegetables)

To find out which ones are important for health, it is necessary to do intervention studies with each compound at a time.
Effect of beta-carotene intake on lung cancer risk

Each data point represents 3380 male smokers for 6 years. The intake of dietary beta-carotene is closely correlated with intake of its main dietary source, carrots.

Data from Albanes et al. 1996
Effect of beta-carotene supplementation on lung cancer risk

Each data point represents 3380 male smokers for 6 years. The lack of interaction shows that the benefit of foods containing beta-carotene is due to another compound.

Data from Albanes et al. 1996
Effects of antioxidant supplementation on health

Antioxidants with no effect on mortality:
- vitamin C
- selenium

Antioxidants that significantly increase mortality:
- vitamin A
- beta-carotene
- vitamin E
Carrots are not only a source of beta-carotene. They are also the major dietary source of the polyacetylene falcarinol, a secondary metabolite.

Korean scientist have found that falcarinol from ginseng is a possible anti-cancer compound.

Falcarinol is a natural pesticide with strong biological activity.
Identification of health-promoting compounds in plant foods

Dose-response of *in vitro* effects of falcarinol and β-carotene

Proliferation of primary mammary epithelial cells in collagen gel cultures.

Mitogenic response (relative to basal medium)

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<th>Falcarinol (ng ml⁻¹)</th>
<th>Physiological range</th>
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Mitogenic response:

- Falcarinol
- β-carotene (ng ml⁻¹)

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Effect of carrots and a carrot secondary metabolite on Azoxymethane induced colorectal cancer in rats

(Kobæk-Larsen et al. 2005)
Antioxidants

- No studies have shown any benefits of increased intake in populations with adequate vitamin intake
- For vitamin C, no significant increase in risk
- For vitamin E and beta-carotene, moderate % change in intake causes a small increase in disease risk
- 20% increase in lung cancer risk by 700% increased intake of beta-carotene
- 3% increase in overall mortality by 2000% increased intake of vitamin E
Secondary metabolites

- Only type of potentially health-promoting compounds that are exclusive to plant foods and mainly occur in both fruits and vegetables
- 16% reduction in CVD risk and 19% reduction in cancer risk by 60% increased intake of F&V
Predicted changes in intake by switching to organic fruits and vegetables

- **Antioxidants**
  - Vitamin C: +5-10%
  - Carotenoids: -5%

- **Secondary metabolites**
  - All subgroups for which data is available: +10%
Predicted changes in disease risk when switching to organic F&V

- **Antioxidants**
  - Vitamin C: 0% change in disease risk
  - Beta-carotene: 5% reduction in intake → 0.15% reduction in smokers’ lung cancer risk
    (700% increased intake → 20% increased risk)

- **Does this matter?**
  - It is based on a linear extrapolation, which probably is not relevant (only for smokers who already take beta-carotene supplements)
  - Small numbers > 5 deaths/year in UK
  - F&V also contains protecting substances
Predicted changes in disease risk when switching to organic F&V

- Secondary metabolites
  - 10% increase in intake → 2.7% reduction in CVD risk and 3.2% reduction in cancer risk
    (60% increased intake → 16% reduction in CVD and 19% reduction of cancer)
  - Does this matter?
    - Experimental data indicate that this relation is linear in the relevant interval
    - Would correspond to approx. 10000 deaths per year in the UK

Please note: Unpublished (preliminary) results
Predicted consequences for human health

- Key assumption (testable):
  - That most of the health benefits of F&V intake are due to defence-related secondary metabolites

- Known omissions, which may change conclusions:
  - Potential health benefits of nitrate or of pesticide residues
  - Effects of fibres and folate
Effect of organic farming methods on the health of those who consume the food

Conclusions

• Organic and conventional plant food production methods result in consistent compositional differences
• Some of these differences are large enough to potentially significantly benefit consumer health
• Improved understanding of these mechanisms is necessary to quantify, preserve and increase the benefits
• If we develop the organic fertilisation strategies to provide as much nitrogen as the conventional fertiliser, then we will lose health benefits for both plants and consumers
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Thank you for your attention!
Questions, comments?