Altering foods derived from animals for the future?

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Animal-derived foods

• Contribute to
  – (essential) nutrient intake
  – taste and enjoyment of meals

• ... but are criticised for
  – being unhealthy
  – their environmental impact
  – animal welfare
Contribution of Meat and Milk/Products to Recommended Nutrient Intakes in the UK

Givens (2007)
Animal product quality

Product quality

Quality characteristics

- sensory
- technological
- nutritional and health value
- microbiological
- chemical-toxicological

Factors

- genetics
- animal health
- animal husbandry
- nutrition
- harvest conditions
- processing

Aim

- increasing eating, nutritional and health value of animal products
- animal and environmental friendly production
Challenges for animal production

- Consumer
- Environmental impact
- Animal welfare and health
- Human health impact
- Feed use for bio-energy
- Feed use for aquaculture
- Use of natural resources – ethics
Efficiency of classical breeding and management


Homo

- Most important traits during last 30-40 years: (milk, meat, egg) production yield, feed conversion efficiency, gross composition
- Progress has been large but starts leveling off, and side-effects
- Relative importance of other traits like fertility, animal health and welfare, product quality … increases for socio-economic and ethical reasons

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Average daily gain (g)</td>
<td>634</td>
<td>720</td>
<td>742</td>
<td>772</td>
</tr>
<tr>
<td>Food conversion ratio (food:gain)</td>
<td>3.09</td>
<td>2.74</td>
<td>2.52</td>
<td>2.45</td>
</tr>
<tr>
<td>Backfat thickness (mm)</td>
<td>2.90</td>
<td>2.42</td>
<td>1.89</td>
<td>1.90</td>
</tr>
<tr>
<td>Loin muscle area (cm²)</td>
<td>42.4</td>
<td>52.3</td>
<td>56.0</td>
<td>60.7</td>
</tr>
<tr>
<td>Fat to lean ratio</td>
<td>0.49</td>
<td>0.28</td>
<td>0.20</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Side effects classical breeding

Reduced eating quality

Reduced suitability for processing
Fat depots and fat in muscle tissue

- Subcutaneous
- Internal
- Intermuscular
- Intramuscular

Internal and subcutaneous fat – reducing the content is one of the primary breeding objectives for economic reasons.

Intramuscular fat – contributes to taste, too low in many modern genotypes.

Conflict of interest in the farm to fork chain.
Targeted gene expression

Modulating Skeletal Muscle Mass by Postnatal, Muscle-Specific Inactivation of the Myostatin Gene

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4Joslin Diabetes Center, Department of Medicine, Harvard Medical School, Boston, Massachusetts, USA

Genesis (2003)
Table 1. Food risk: UK deaths per year related to diet or food

<table>
<thead>
<tr>
<th>Risk</th>
<th>Approximate number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular disease(^a)</td>
<td>73,000</td>
</tr>
<tr>
<td>Cancer(^a)</td>
<td>34,000</td>
</tr>
<tr>
<td>Food-borne illness</td>
<td>~500</td>
</tr>
<tr>
<td>Food allergy</td>
<td>&lt;20</td>
</tr>
<tr>
<td>vCJD</td>
<td>15–25</td>
</tr>
<tr>
<td>GMOs, pesticides, growth hormones</td>
<td>Nil</td>
</tr>
<tr>
<td>Choking to death</td>
<td>200</td>
</tr>
<tr>
<td>Bed or chair accident</td>
<td>80</td>
</tr>
</tbody>
</table>

\(^a\) Assumes one-third of cardiovascular disease deaths and one-quarter of cancer deaths are diet-related.

Limit intake of red meat\(^1\) and avoid processed meat\(^2\)

PUBLIC HEALTH GOAL

Population average consumption of red meat to be no more than 300 g (11 oz) a week, very little if any of which to be processed.
### Animal-derived foods ~ fat intake

<table>
<thead>
<tr>
<th></th>
<th>Total fat</th>
<th>SFA</th>
<th>MUFA</th>
<th>PUFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk and dairy</td>
<td>25.5</td>
<td>39.8</td>
<td>16.4</td>
<td>4.3</td>
</tr>
<tr>
<td>products</td>
<td>(14 - 40)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat and meat</td>
<td>21.2</td>
<td></td>
<td>18.9</td>
<td>27.1</td>
</tr>
<tr>
<td>Products</td>
<td>(11 - 29)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eggs</td>
<td>2.2</td>
<td>1.8</td>
<td>2.6</td>
<td>2.3</td>
</tr>
<tr>
<td>(1 - 4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All animal fats</td>
<td>47.5</td>
<td>61.4</td>
<td>48.1</td>
<td>20.0</td>
</tr>
<tr>
<td>excl. fish</td>
<td>(28 - 72)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Median value (min – max) for 13 EU countries

Human dietary recommendations

- Lower intake of SFA and *trans* FA
- Increase intake of (long chain) omega-3 PUFA

Dairy consumption is inversely related to the metabolic syndrome

Givens (2007)
After Azadbakht et al (2005)
Am J Clin Nutr 82: 523

Dairy consumption is inversely related to the metabolic syndrome

(825 subjects; all trends P<0.03)
Fat ~ human health

- Functional FA
  - n-6 and n-3 PUFA
  - Conjugated linoleic acids
  - Odd & Branched chain FA

  ![Chemical structure of C18:3 n-3 – Linolenic acid]

- Adverse FA
  - Medium chain SFA
  - Trans FA

  ![Chemical structure of C18:1 trans-11 – Vaccenic acid]

CLA *cis*-9, *trans*-11 – Conjugated linoleic acid

(> 400 different FA present in milk !)
Relationships dietary fatty acid source – product fatty acid composition now rather well established in monogastrics, but more complicated in ruminants…

Diet ~ meat fatty acid composition in poultry

Potential of biodiverse pastures

Linolenic Acid
\(\text{cis-9, cis-12, cis-15 C}_{18:3}\)

Linoleic Acid
\(\text{cis-9, cis-12 C}_{18:2}\)

\(\text{cis-9, trans-11, cis-15 C}_{18:3}\)

\(\text{cis-9, trans-11 CLA}\)

\(\text{trans-11, cis-15 C}_{18:2}\)

\(\text{trans-15 or cis-15 C}_{18:1}\)

\(\text{trans-11 C}_{18:1}\)

\(\text{Stearic Acid C}_{18:0}\)

\(\text{Lipolysis and biohydrogenation in the rumen}\)

Adapted from Harfoot and Hazlewood, 1997

\(\text{cis-9, trans-11 CLA in the udder}\)
Biodiverse pastures ~ milk FA profile

For the first time, a plant gene expressed in a complex mammalian systeme!

Functional expression of a Delta 12 fatty acid desaturase gene from spinach in transgenic pigs

- Specific expression in white adipose tissue
- Levels of C18:2n-6 ~10-fold higher in adipocytes differentiated in vitro and ~20% higher in backfat in vivo
PUFA and meat quality

Product shelf-life and colour and flavour

- ↑ PUFA
- ↓ Lipid stability
- ↓ Product shelf life and colour
- Antioxidants

PUFA
- cooking
- Flavour
Commercial examples

Milk
- Campina
- Interagri-Dumoulin
- Nutex-feeding (extruded linseed)

Iberico ham
- Local breeds, high rusticity
- *Dehesa* forest ecosystem in south-west of Spain
- Feed: grass and acorns
- Current intake of some essential trace elements below Recommended Intake
  - Se, I, Fe, Zn

- Enrichment potential dependent on
  - trace element
  - source and concentration
  - interaction with other feed components
  - food item

Schematic diagram of trace element flux through the body. Major sites of homeostatic regulation are absorption (Zn, Fe, Cu, Mn) and urinary excretion (Se, I).

Windisch (2002)
Anal Bioanal Chem 372: 421
Dierick et al (2009)  
J Sci Food Agric 89: 584
Piglets
J Sci Food Agric 84: 811

Diet ~ milk selenium

~ 15% of RNI

Selenite

Selenium yeast

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http://www.lanupro.UGent.be – Stefaan.DeSmet@UGent.be
Animal-derived foods as a source of functional nutrients

Enhancing the nutrient profile by dietary strategies

• **Pro**
  - Natural
  - No shift in eating pattern required
  - No risk for overdosing
  - Added value for primary producers

• **Contra**
  - Less versatile compared to processing
  - Variable outcome
  - Allocation of added value questionable

Milk and eggs higher potential than meats

Muscle is a safe but ‘resistant’ tissue to modify
Need for proof of concept

n-6/n-3 ratio in humans on diet with

- milk and dairy products
- meat (pork, chicken)
- eggs

originating from animals with linseed in diet

Ann Nutr Metab 46: 182
Effect of modified dairy fats on plasma cholesterol

33 Men and women; 8 wk randomised crossover
Reduced SFA (50%) / enhanced MUFA (35%) dairy products vs normal

-6.00
-5.00
-4.00
-3.00
-2.00
-1.00
0.00

Total chol LDL HDL Total/HDL

Am J Clin Nutr 63: 42
with courtesy of I Givens
Conclusions

• Era of chronic diseases and RNI targets for several essential nutrients not met
• Enriched animal-derived foods have the potential to increase the intake of long-chain n-3 PUFA substantially
• Enriched animal-derived foods may also contribute to increasing the intake of other nutrients
• Future strategies require a fork-to-farm approach
Despite its wide-ranging environmental impacts, livestock is not a major force in the global economy, generating just under 1.5 percent of total GDP. But the livestock sector is socially and politically very significant in developing countries: it provides food and income for one billion of the world's poor, especially in dry areas, where livestock are often the only source of livelihoods. "Since livestock production is an expression of the poverty of people who have no other options," FAO says, "the huge number of people involved in livestock for lack of alternatives, particularly in Africa and Asia, is a major consideration for policy makers."