How animal breeding can contribute to sustainable pig production

Pieter Knap
August 2018
cannibals with forks

the triple bottom line
of 21st century business

John Elkington

Elkington (1999)
Sustainability in animal breeding

Van Arendonk

Sustainability: triple bottom line
People – Planet – Profit

Sustainable production: favourable results for all 3

Session 19

Sustainable production: favourable results for all 4

People – Planet – Profit – Pigs, Poultry, Puminants, Phish

Sustainable livestock production

quadruple bottom line
People – Planet – Profit – Pigs

People:
- social justice (e.g. biopiracy: Access & Benefit Sharing)
- food safety (e.g. cholesterol, PUFA; Salmonella, Listeria etc)

Planet:
- resource efficiency
- environmental efficiency
- biodiversity (e.g. AnGR management)
People – Planet – Profit – Pigs

**People:**
- social justice (e.g. biopiracy: Access & Benefit Sharing)
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- resource efficiency
- environmental efficiency
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People – Planet – Profit – PigsPoultryPuminants

Profit:
productivity
food security: feed the globe

PigsPoultryPuminantsPhish:
animal welfare
Profit:
productivity
food security: feed the globe

Livestock and global food security

Jimmy Smith (2017)
GDP per capita (2013 USD per year)

proportion of calorie intake from animal products: six countries, 1961 to 2013

data from FAOstat, OECD, WorldBank (2015)
Proportion of calorie intake from animal products: 161 countries, 1961 to 2013

Data from FAOstat, OECD, WorldBank (2015)

GDP per capita (2013 USD per year)

Land use

More = worse

Less = better

0.25 gram ASF protein/day

9 to 20

65

Data from FAOstat, OECD, WorldBank (2015)
How many kilograms of meat per person is consumed in different regions:

- **North America/Europe**: 83.0 kg
- **Latin America/Caribbean**: 77.0 kg
- **East Asia/Pacific**: 58.0 kg
- **Central & West Asia/North Africa**: 52.0 kg
- **Africa south of the Sahara**: 31.0 kg

Compared to 2000:

- **2050**
  - North America/Europe: 87.0 kg
  - Latin America/Caribbean: 58.0 kg
  - East Asia/Pacific: 28.0 kg
  - Central & West Asia/North Africa: 20.0 kg
  - Africa south of the Sahara: 11.0 kg

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  - Africa south of the Sahara: 24.0 kg

Eating less meat helps the environment.
Developing countries: the rising urban middle class

Urbanization

2050: 2/3 of the human world population lives in large cities

2050: the rural human population is 8% **smaller** than in 2010

24 % smaller in China + India
Cities rarely contribute to the production of their food. Generally, they simply consume it.

Mauro Ghirotti (1999)

**Urban and peri-Urban Concentration**

- Productivity must increase
- Logistics of urban food supply
- Intensive production close to cities
How many kilograms per person to help the environment:

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Comparing 2000 to 2050:

- North America/Europe: 83.0 kg (2000), 87.0 kg (2050)
- Latin America/Caribbean: 87.0 kg (2000), 77.0 kg (2050)
- East & South Asia/Pacific: 58.0 kg (2000), 28.0 kg (2050)
- Central & West Asia/North Africa: 52.0 kg (2000), 20.0 kg (2050)
- Africa south of the Sahara: 31.0 kg (2000), 11.0 kg (2050)
What can animal breeding contribute to increasing productivity?

• A lot
• We knew that already & it will be very necessary
• Mainly to cater for the rising urban middle class, in cities all over the world

Knowledge transfer to producers: Olori, Van der Beek, Cleveland
Pigs, Poultry, Puminants, Phish: Animal Welfare
What can animal breeding contribute to improving animal welfare?

Animal welfare

Invasive treatments
  castration, tail docking, beak trimming, dehorning

Robustness; adaptability
  disease resilience; aggressive behavior in group housing

Behavioural deprivation
What can animal breeding contribute to improving animal welfare?

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  disease resilience; aggressive behavior in group housing

Behavioural deprivation
Behavioural deprivation

• instinct $\rightarrow$ motivations $\rightarrow$ coping behaviour patterns

• goal: remove a stressor, or remove its stressful effects

• intensive housing conditions may obstruct these patterns
  • by preventing the coping behaviour
    • e.g. the required substrate is not available: rooting material, nestbuilding material, other pigs
  • by keeping the stressor in place in spite of coping
    • e.g. tethered sows, pigs in an overcrowded pen
preventing the coping behaviour e.g. the required substrate is not available
keeping the stressor in place in spite of coping
e.g. tethered sows, pigs in an overcrowded pen
The classical welfare movement approach:
- remove those blockades
- change the animal management system
  = downstream control
But what about upstream control?
Upstream control of animal adaptation issues

- Morris (2006): "the body simply has not evolved the capacity to not secrete corticosteroids during a crisis – in effect, evolution has only gotten so far..."

- evolution could be usefully moved on by targeting the regulator of the HPA axis: the limbic system

- modify instinctive patterns: reduce the motivation for behaviour that cannot be supported by the production system

- = change the intensity of behavioural responses = domestication (Grandin & Deesing 1998)

- adaptation of behaviour through selection = reduction of the drives for exploration, aggression etc: extension of 10,000 years of domestication

- so, what has happened during those 10,000 years?
Brain weight versus body weight

% reduction of brain mass

Kruska (1988); Zeder (2012)
FeelGood:
Erfassung positiver Emotionen beim Schwein

Katja Krugmann, Farina Warnken, Irena Czycholl und Joachim Krieter

Institut für Züchtung und Tierhaltung

11. April 2017
Session 8

Structural equations model

Czycholl (2015)

- Size of hippocampus
- Size of adrenals
- Number of astroglia
- IgA concentration
Upstream control of animal adaptation issues

• Find the genes that control:
  • exploratory and aggressive motivations in the limbic system
  • oversupply of corticosteroids
  • corticosteroid receptors in the limbic system

• Get them under control → speed up domestication & improve welfare

<table>
<thead>
<tr>
<th>Generation</th>
<th>Cortisol post-ACTH (ng/ml)</th>
<th>low line</th>
<th>high line</th>
</tr>
</thead>
<tbody>
<tr>
<td>G0</td>
<td>40</td>
<td>(298)</td>
<td>(152)</td>
</tr>
<tr>
<td>G1</td>
<td>63</td>
<td>(201)</td>
<td>(357)</td>
</tr>
<tr>
<td>G2</td>
<td>100</td>
<td>(313)</td>
<td>(313)</td>
</tr>
<tr>
<td>G3</td>
<td>158</td>
<td>(251)</td>
<td>(330)</td>
</tr>
<tr>
<td></td>
<td>251</td>
<td>(357)</td>
<td>(403)</td>
</tr>
</tbody>
</table>
It is tempting to think that in the tame foxes we observe a prolongation of the phase in which young neurons possess their unique properties, as has been shown in rats.

In the tame foxes, this might be regulated by genes that are targeted during domestication and that are expressed heterogeneously along the septotemporal axis.

- Get them under control → improve welfare
What can animal breeding contribute to improved animal welfare?

• Technically, a lot ...
• ... but in practice, it all depends on the breeding goals.
• Someone must be willing to pay for it.
• Needs incentives from market forces / legislation.
Planet:
resource efficiency
environmental efficiency
What can animal breeding contribute to improving efficiency?

Resource efficiency

Feed efficiency

Losses

Environmental efficiency
What can animal breeding contribute to improving efficiency?

Resource efficiency
- Feed efficiency
- Losses

Environmental efficiency
Resource efficiency: the Food Feed Fuel trade-off

- Broiler chicken production (2017, worldwide):
  
  149.3 mio ton liveweight

- $\Delta G(\text{FCR}) = -0.015 \text{ kg/kg per year}$

- this saves $-0.015 \times 149.3 \text{ mio} = 2.24 \text{ mio ton feed}$

- 4800 km$^2$ arable land per year, cumulative: $1.8 \times$ Luxembourg
Krebs Cycle, aka Citric Acid Cycle

modified from Osellame et al (2012)
Reactive Oxygen Species
- superoxide
- hydrogen peroxide
- hydroxyl radicals

DNA oxidation

mutations

inefficiency

DNA oxidation + electron leakage
\[
\text{O}_2 + \text{electron} \rightarrow \text{O}_2^- \rightarrow \text{H}_2\text{O}_2 \rightarrow \cdot\text{OH}
\]

less \( \text{O}_2 \rightarrow \text{H}_2\text{O} \)
less ATP

membrane damage
lipid peroxidation
protein oxidation

more protein turnover

inefficiency

heat instead of ATP

inefficiency

a positive feedback system with negative consequences, generating its own genetic component

modified from Bottje & Carstens (2009)
modified from Bottje et al (2002)

feed conversion ratio

mitochondrial respiratory activity

r = -0.68

r = -0.56

mitochondrial enzyme activities

C-II

C-IV

C-V

C-III

C-I

residual feed intake ($\sigma_p$) = net feed efficiency

feed conversion ratio

feed conversion ratio ($\sigma_p$) = gross feed efficiency

data from Sharifabadi et al (2012)
Proteomic analysis indicates that mitochondrial energy metabolism in skeletal muscle tissue is negatively correlated with feed efficiency in pigs

Liangliang Fu, Yueyuan Xu, Ye Hou, Xiaolong Qi, Lian Zhou, Huiying Liu, Yu Luan, Lu Jing, Yuanxin Miao, Shuhong Zhao, Huazhen Liu & Xinyun Li

Figure 5. Key signaling pathways represented by DEPs in skeletal muscle tissues between high- and low-FE pigs. Pink represents up-regulated proteins and green represents down-regulated proteins in high-FE pigs.
• Losses

• More efficient systems tend to be more sensitive to external disturbance

• Less idle capacity to fall back on, in times of trouble
modified from Knol (2010); www.thebudgetwarrior.com/2010/06/how-value-of-your-benefits-can-leak.html
Efficiency of the production process:

• Losses

modified from Knol (2010); www.thebudgetwarrior.com/2010/06/how-value-of-your-benefits-can-leak.html
Phenotypic trends: survival (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>DK</th>
<th>FR</th>
<th>NL</th>
<th>GB</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>2010</td>
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Genetic trends: survival (%)

sirelines: piglet, nursery, G/F

damlines: farrow, piglet, nursery, G/F
What can animal breeding contribute to improving efficiency?

Resource efficiency
  Feed efficiency
  Losses

Environmental efficiency
Cities rarely contribute to the production of their food. Generally, they simply consume it.

Mauro Ghirotti (1999)

**Urban and peri-Urban Concentration**

- **Poultry**
- **Swine**

- Productivity must increase
- Logistics of urban food supply
- Intensive production close to cities
- Must be environmentally friendly
What can animal breeding contribute to improving efficiency?

Resource efficiency

Feed efficiency

Losses

Environmental efficiency

<table>
<thead>
<tr>
<th>FCR (kg / kg)</th>
<th>Total N excretion (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
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<td>5</td>
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<td>6</td>
<td>7</td>
</tr>
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<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

Shirali et al (2012)
Genetic improvement reduces nitrogen excretion of pigs

selection for lean tissue growth rate (= N retention) has reduced ...

• … N excretion per 120-kg pig from 5.0 to 4.0 kg = by 20 % in 35 years
• … N excretion per kg N retention by 25 % in 35 years

... when fed to minimum excretion
What can animal breeding contribute to improving efficiency?

• A lot …

• … and much of the environmental efficiency improvement is happening as a side effect.

• Can be targeted more explicitly …

• … but that will require a clear economic value.

• Shadow prices of greenhouse gases. Coming up now, in USA.
improve sustainability

Trade-offs between sustainability elements.
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