# Building sustainable systems at the era of Farm to Fork and agroecology: Unraveling the interplay of quality attributes of animal-source foods

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# Introduction - Context

**Animal-source foods**

- **High consumption level in 'Western' countries** (but variations among countries, consumers)
- Expected **important increase** in **global demand** by 2050
- **Key issues for animal-source foods**: **environmental impacts**, **human health**, **ethics**
  - **Acceptability** and **sustainability of farming systems and animal source foods: environmental, social and economic dimensions ?**

*van der Linden et al, 2020*

- Commitments of stakeholders at various scales (**Farm to fork strategy**, EU Green deal) to **diversify products** and move towards **more sustainable food systems**: do more (or better) with less inputs and impacts

*Yu & Jensen, 2022; Hinrichsen & Stoier, 2024*

  - Linked and refers to the **Quality of food products**

⇩

All the **attributes** that give food the ability to **satisfy the expressed or implicit needs** of a user (ISO 9001)

- **Animal-source foods: which attributes, needs, users, variation factors?**

# The quality attributes of animal-source foods

**Collective scientific assessment (INRAE)**

**Sensory attributes**
Colour, texture, juiciness, odour, flavour, overall appreciation

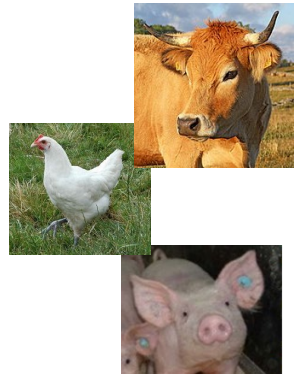
**Nutritional attributes**
Composition, bioavailability of nutrients


**Commercial attributes**
Carcasses or cuts: conformation, fatness, weight, regularity of supply
Milk: bacteriology, composition
Fish: weight, size, conformation
Egg: size, colour

**FOOD QUALITY**

**Image attributes**
Ethics, environmental impacts, farming and processing practices, origin, consumer perception

***Extrinsic Quality***



**Technological attributes**
Processing and preservation abilities
Yields after salting, cooking, smoking, ageing, slicing…

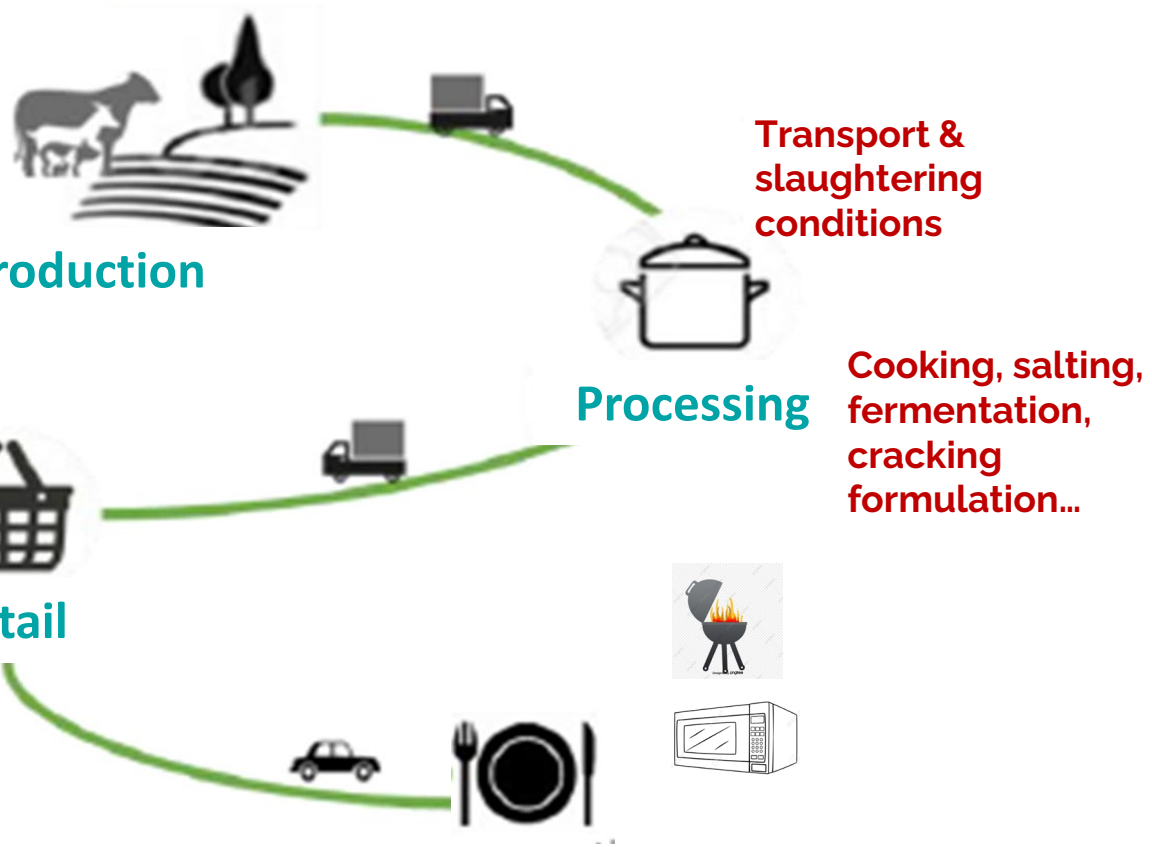
**Convenience attributes**
Ease of storage, distribution, preparation, packaging, portions, regularity of supply

**Safety attributes**
Microbiological contamination
Chemical contamination
Additives, newly-formed products
Health effect (prevention or illnesses)

Producers, processing actors | Consumers | ⟷ Contribute to

*Prache et al., 2022*

# Quality along the value chain



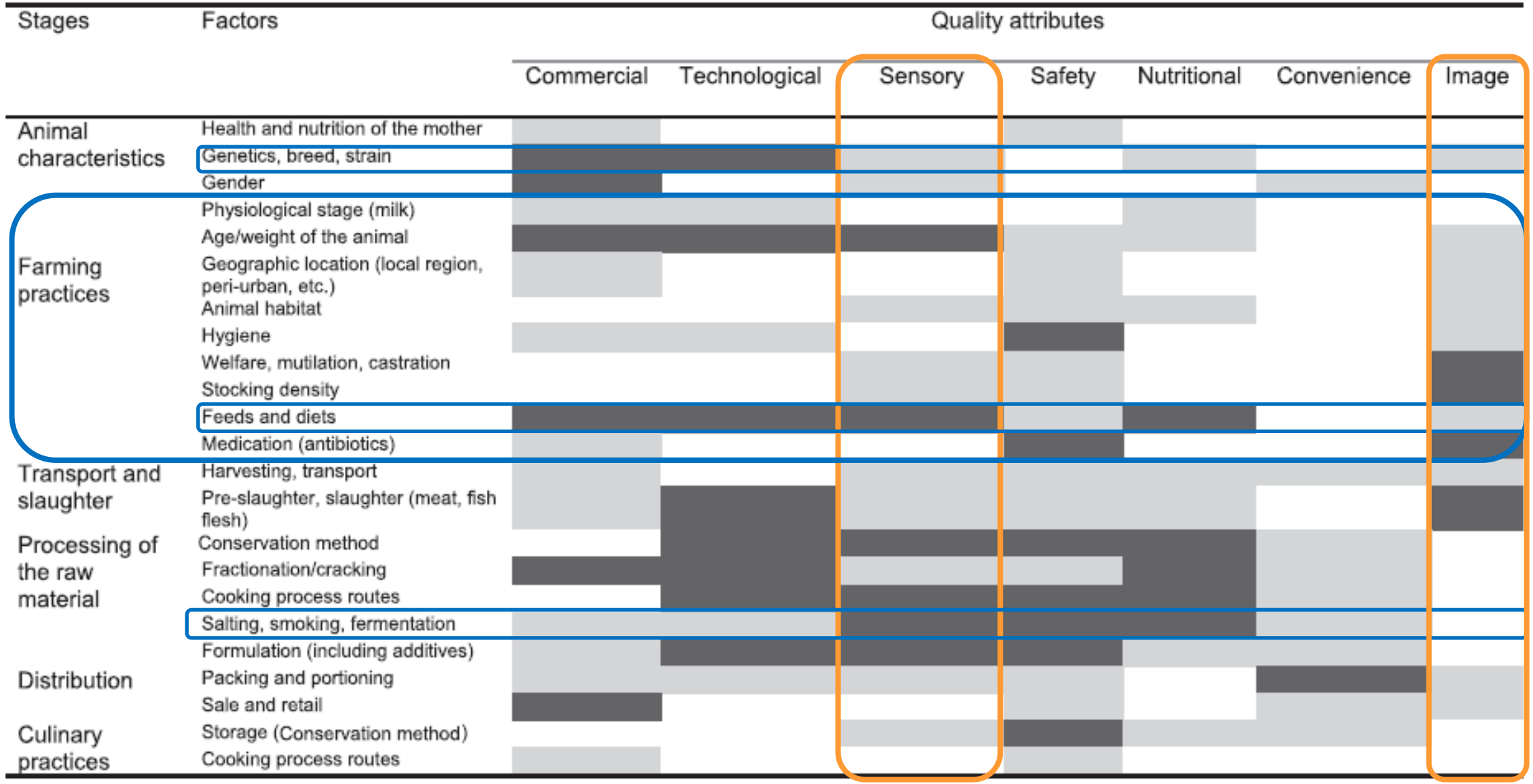

- **Quality** is **built** but can be **impaired** at all steps from **farm to fork**
- Some **antagonisms** but also **synergies** can be found between **steps**, and between quality **attributes**

*Prache et al., 2022*
*Lebret & Candek-Potokar, 2022 a, b*

# Some major factors and steps

1 attribute: many factors

1 factor: many attributes



# Examples of synergies between production and processing conditions

## 1 - Main processing steps and associated quality attributes of specific products

### PDO dry-cured ham

**Raw ham:** *pig breed & rearing conditions; weight, backfat thickness, pH...*

↓

**Salting** : *method, duration, brine composition*
**Resting - equalizing**

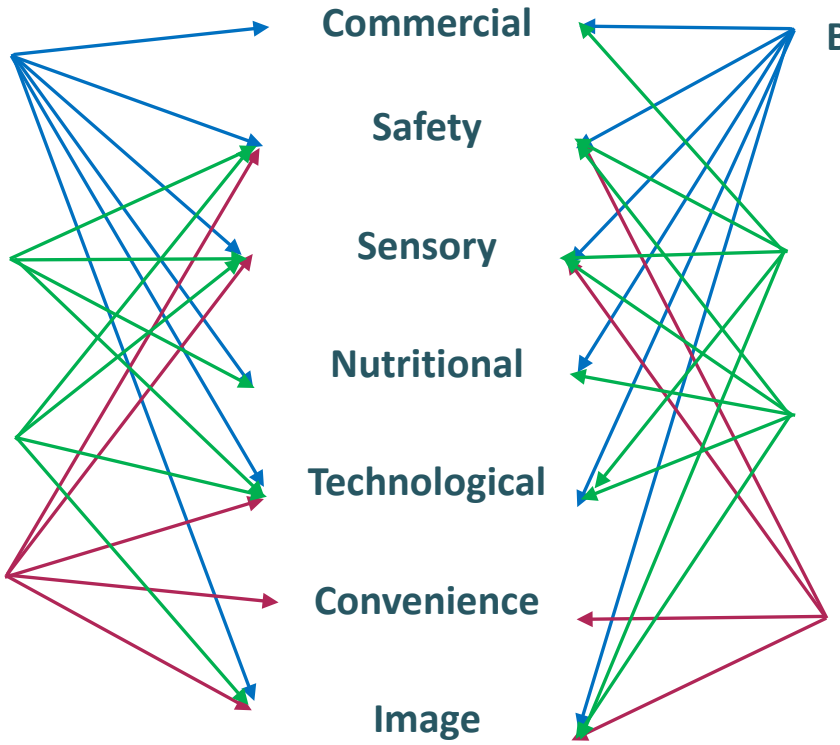
↓

**Drying - Ripening**
*Duration, temperature, fat coating*

↓

**Packaging, slicing**

**Quality attributes**




### Farm cheese made from raw milk

**Breed / dairy cows feeding** *(hay/grazing natural grasslands, low levels of silage and concentrate)*

↓

**Milking – milk collection**
*(hygiene, no transport or mixing)*

↓

**Processing** and **maturation**
*Traditional methods*

↓

**Packaging**
*Whole piece or portions*

- **Quality attributes** of the final products depend on **multiple factors**
- Result from the characteristics of the **raw material** (breed, farming conditions) **and the processing conditions,** including the know-how of the actors

INRAE



*Lebret & Candek-Potokar, 2022 b, Coppa et al., 2022*

# Examples of synergies between production and processing conditions

## 2 - Rearing factors and characteristics of the raw material

### Dry-cured ham

Ham weight

Visual/appearance defects

Thickness of subcutaneous fat

Lipid content, Fatty acid (FA) composition, micro-constituents

Meat ultimate pH

**Factors of variation**

Genotype/breed

Animal health

Pig sex

Age-weight at slaughter / lactation stage

Feeding

Housing-farming system

Slaughtering and carcass refrigeration / milking, collection & storage of milk

### Farm cheese

Protein and fat contents

Proteolysis and lipolysis

Microflora of raw milk

FA composition, micro-constituents

Coagulation ability / acidification

**Flavour**

- Fat : breed and production factors
- Drying and ripening conditions & duration: lipolysis → FA oxidation, volatile compounds → flavour

**Colour and texture**

- Cow farming conditions
- Processing and maturation conditions and duration: micro-constituents → colour; fat melting point → texture

# Synergies between production and processing conditions

- **Synergies** between production and processing factors → progressive development of **typicity**
- **The relative importance** of animal characteristics, farming practices and food processing conditions **depends on** the **quality attribute** and the **product** considered
- Interactions between factors lead to **increased quality variability**
- This variability can be a lever to **differentiate** animal-source foods **within a production system or pre-established specifications** (Geographical Indications; organic)

*Lebret & Martin, 2020*
*Prache et al., 2022*
*Lebret & Candek-Potokar, 2022 b*

# Combining production factors to jointly improve pork quality attributes

**Objectives :** improve **sensory** and **nutritional attributes** and **societal image** (feed resources; environmental impacts) by **combining pig genotype and feeding strategies**

→ **improve the quality and sustainability of pork**

- **Two pig genotypes**
  - **Duroc, D** : high sensory quality
  - **Piétrain, P** : standard
- **Two feeding regimens ≠ origin and nature of protein and fat resources**
  - **Roc+, R :** extruded faba beans & linseed, french origin
  - **Control, C:** oilseed meal (incl. imported soybean)

**4 experimental groups** (n=15 female pigs/group): **DR, DC, PR, PC**

*Lebret et al., 2023*
*Gagaoua et al., 2023, 2024*

- ✓ Experimental pigs : 30 to 115 kg (slaughter), individual pen
- ✓ *Ad libitum* feeding, Dlysine:net energy adjusted weekly for each group
- ✓ Growth performance and carcass composition
- ✓ Loin and ham muscles quality traits and biochemical composition
- ✓ Loin sensory analysis (trained panel)
- ✓ Economic indicators
- ✓ Quantification of inputs & outputs and evaluation of the environmental impacts by Life-Cycle Analysis (LCA) using individual data

**Commercial, Technological, Sensory, Nutritional, and Image attributes**

# Combining production factors to jointly improve pork quality attributes

## Results

| | DR | DC | PR | PC | |
|---|---|---|---|---|---|
| **Growth traits and Commercial attributes** | | | | | |
| Average daily gain, g | 989 | 898 | **1052** | **1002** | G***, F** |
| Feed efficiency | 0.34 | 0.33 | **0.38** | **0.37** | G***, F* |
| Carcass weight, kg | 89.4 | **82.2** | **96.7** | **93.8** | G***, F*** |
| Lean Meat Content,% | 60.2 | 60.5 | **61.9** | **61.5** | G** |
| **Technological attributes (loin)** | | | | | |
| pH 24 h | **5.94** | **5.89** | 5.80 | 5.83 | G* |
| Drip loss, % | **3.2** | **3.7** | 4.7 | 4.7 | G** |

Effects of Genotype (G) and Feeding (F) *** : P<0.001; ** : P<0.01; * : P<0.05

- **D vs P pigs**
  ↘ growth performance and carcass leanness
  ↗ technological quality in loin and ham
  (data not shown)

- **R vs C feeding**
  ↗ growth performance

*Lebret et al., 2023*

## Combining production factors to jointly improve pork quality attributes

| | DR | DC | PR | PC | |
|---|---|---|---|---|---|
| **Nutritional attributes (loin)** | | | | | |
| Fatty acid profile C18:2 n-6 : C18:3 n-3 | **6.3** | **20.6** | **7.9** | **21.8** | G***, F*** G x F t |
| **Sensory attributes of loin** (intensity, 0-10) | | | | | |
| Appearance: Marbling | **3.8** | **3.3** | 2.6 | 2.7 | G*** |
| Tenderness | **6.2** | **6.1** | 5.4 | 5.3 | G*** |
| Juiciness | **5.4** | **5.6** | 5.2 | 5.2 | G** |
| Flavour | 5.6 | 5.7 | 5.7 | 5.8 | G* |
| **Economic evaluation** | | | | | |
| Added value (output - feed cost)/kg carcass, € | 1.22 | **1.17** | **1.32** | **1.31** | G***, F t |
| Added value (output - feed cost)/pig, € | 107.2 | **94.2** | **124.5** | 120.3 | G***, F** G x F t |

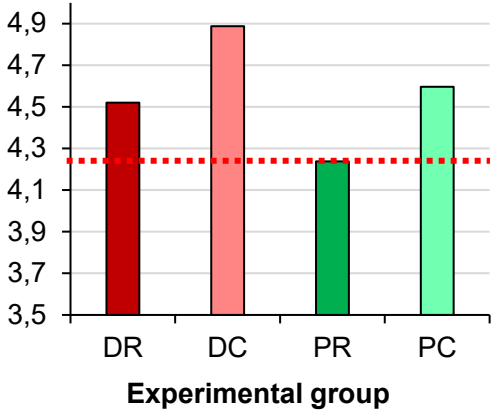
Effects of Genotype (G) and Feeding (F) *** : P<0.001; ** : P<0.01; * : P<0.05; t : P<0.10

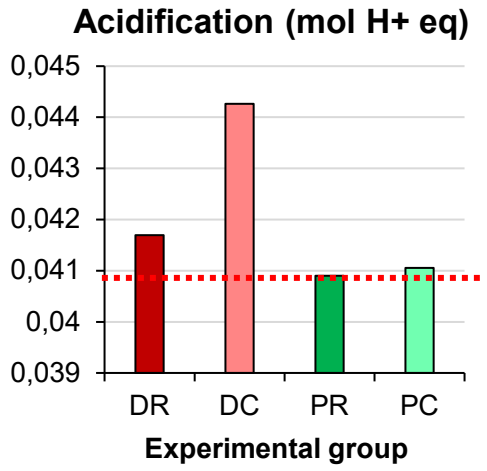
- **D vs P pigs**
  - ↗ sensory and nutritional quality
  - ↘ added value, especially DR pigs
- **R vs C feeding**
  - ↗ nutritional attributes, esp. DR
  - ↗ added value per pig, esp. PR

*Lebret et al., 2023*

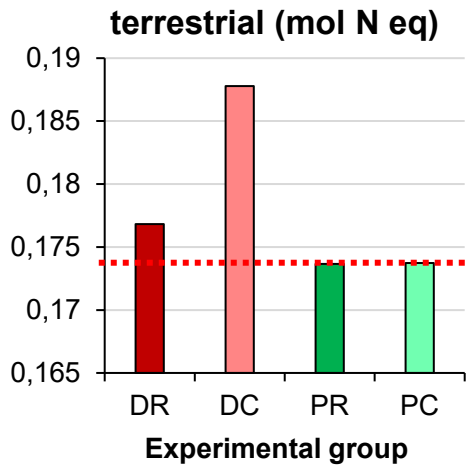
# Combining production factors to jointly improve pork quality attributes

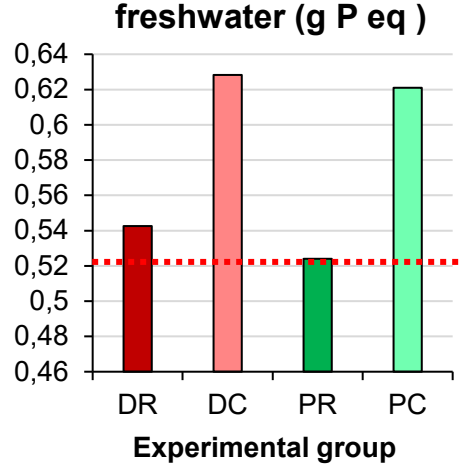
## Environmental impacts of pig production (at farm gate, per kg of live weight)

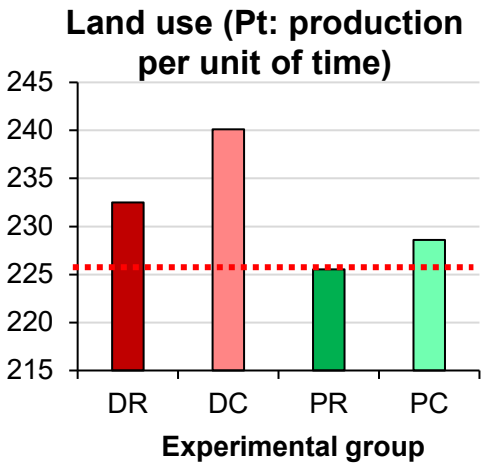


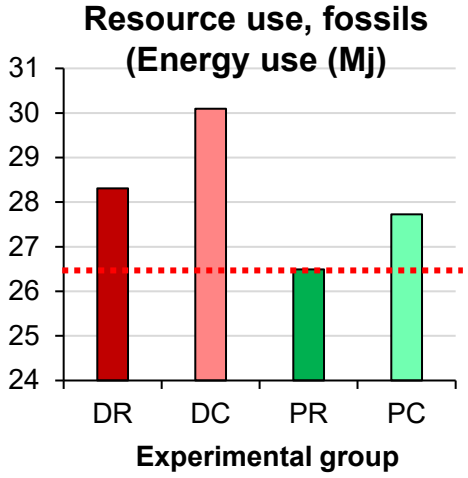



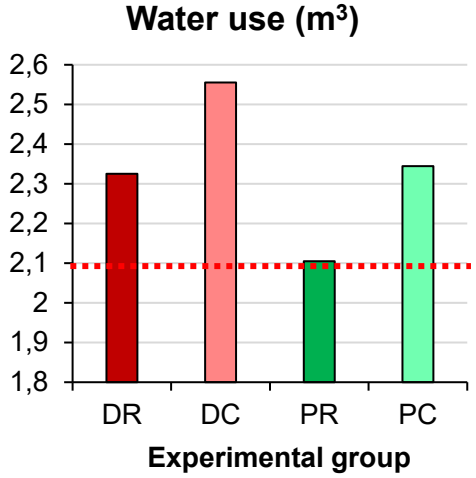

**Eutrophication**




- **D vs P pigs**
  ↗ for all major impact categories
  (mainly due to lower feed efficiency)

- **R vs C feeding strategy**
  ↘ in major impact categories
  lowest impacts for the PR pigs
  (origin of feed resources)

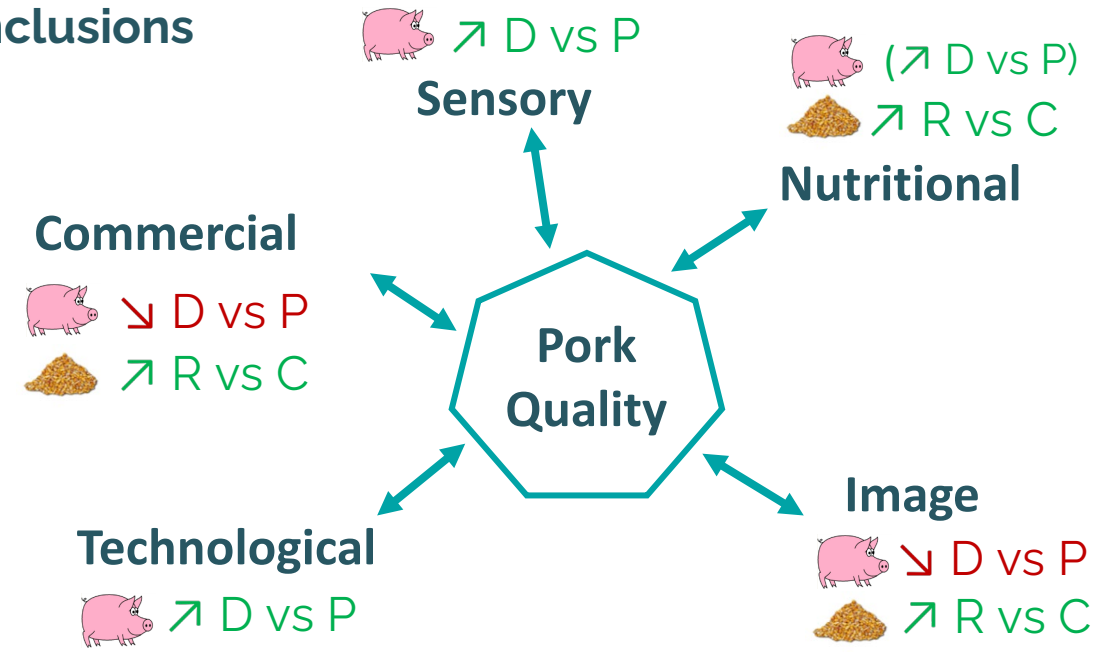
*Gagaoua et al., 2024*



*Gagaoua et al., 2024*

# Combining production factors to jointly improve pork quality attributes

## Conclusions




✓ **Combining D pigs and R feeding strategy**
++ for many quality attributes ***but*** greater environmental impacts and lower added value

✓ **R feeding strategy**
++ to reduce environmental impacts especially in efficient growing pigs

- **Combining genetics and relocation of feed resources: win-win strategy towards more sustainable production of quality pork** – but still room for improvements
- **Synergies** but also **antagonisms** between quality attributes
- Needs for **multidimensional analyses** to **characterize trade-offs** between quality attributes



*Lebret et al., 2023, Gagaoua et al. 2024*

# Farming practices in organic systems and quality attributes - Pork

**Organic farming**

- Principles (EU regulations 2018): practices that respect the **environment, health and animal welfare**

➢ Organic pigs: better to **avoid surgical castration of males, but risks for**

- **agonistic behaviours** (mounting, agressions)
- **pork boar taint:** undesirable odours or flavours, mainly due to
  - androstenone : mostly genetic effects
  - **skatole**: mostly **feeding** and **husbandry conditions**

**Feeding strategy for non-castrated males in organic farming to improve various quality attibutes**

**Comparison of the effects of two feeding strategies for organic non castrated pigs** (Piétrain crossbreeds)

- **control** (=organic specifications) (n=37)
- **Bio+**: local raw materials, rich in fibres (faba bean; forages) and omega-3 fatty acids (n=40)

**on growth and carcass traits, technological, nutritional, sensory and image quality attributes of pork**

*Van Baelen et al., 2024a, 2024b*

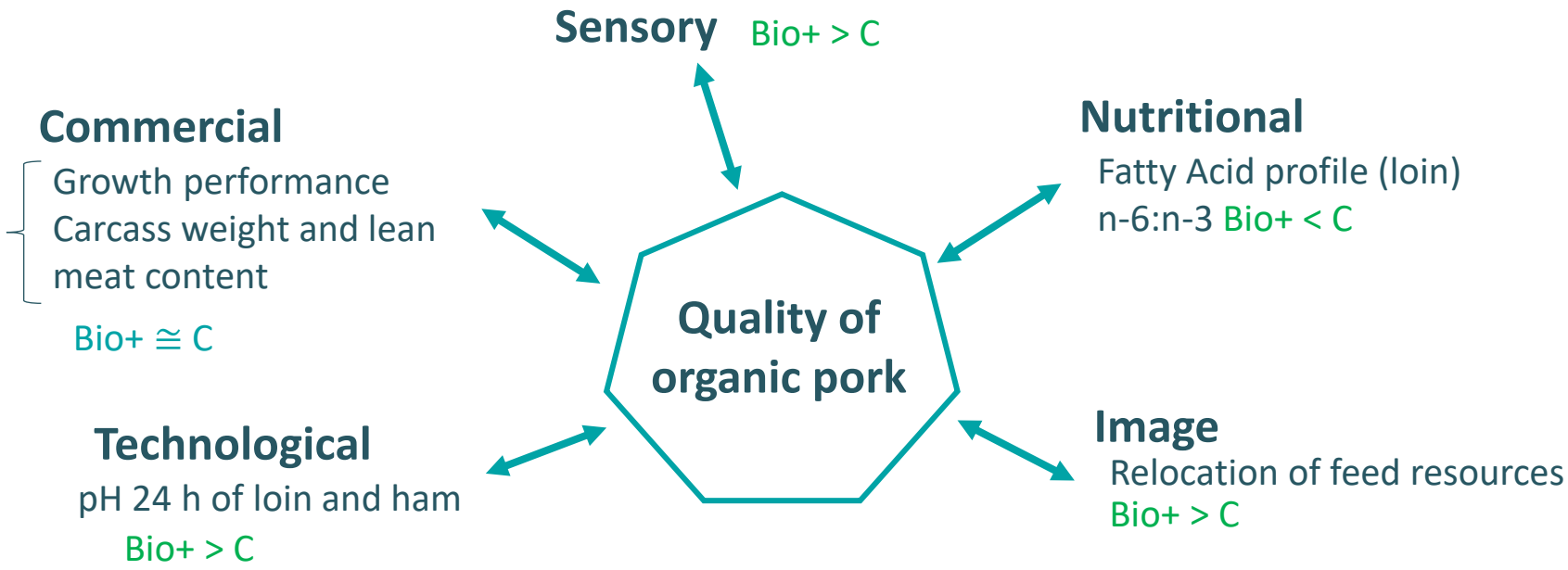
# Farming practices in organic systems and quality attributes - Pork

Positive effect
Negative effect

**Loin & ham colour**
Lightness Bio+ < C

**Boar taint compounds in backfat**
Androstenone Bio+ ≥ C
Skatole Bio+ < C

**Sensory analyses of loin (trained panel)**
Red colour Bio+ > C
Marbling
Tendreness, juiciness
Odour, Flavour
Aromatic persistence
} Bio+ ≅ C
No boar taint for Bio+ or C pork




➢ **Within specifications of organic farming, feeding for non-castrated male pigs is a lever to jointly improve various quality attributes**

*Van Baelen et al., 2024a, 2024b*

# Farming practices in organic systems and quality attributes - Lamb

## Organic (O) vs conventional (C) farming on carcass and meat quality in pasture-fed lambs

Positive effect - Negative effect

### Sensory

Flavour intensity O > Conv - or O > C
depending on countries or consumers
Risk of off-flavours (skatole, indole)
**O > C**

### Nutritional

Fatty Acid profile
n-6: n-3
O < C

**Lamb quality**

### Commercial

Carcass fatness (insufficient)
Soft fat
O > C

*Lourenco et al 2007,*
*Kocak et al 2016*
*Prache et al 2011, 2022*

- **Differences due to more white clover in organic grasslands**
  (higher lipids and n-3 FA, less advanced ruminal bioydrogenation, rich in rapidly degradable proteins)

- **Antagonisms between meat quality attributes**
- **Solutions : supplement with condensed tannins to reduce the risks of off-flavours**

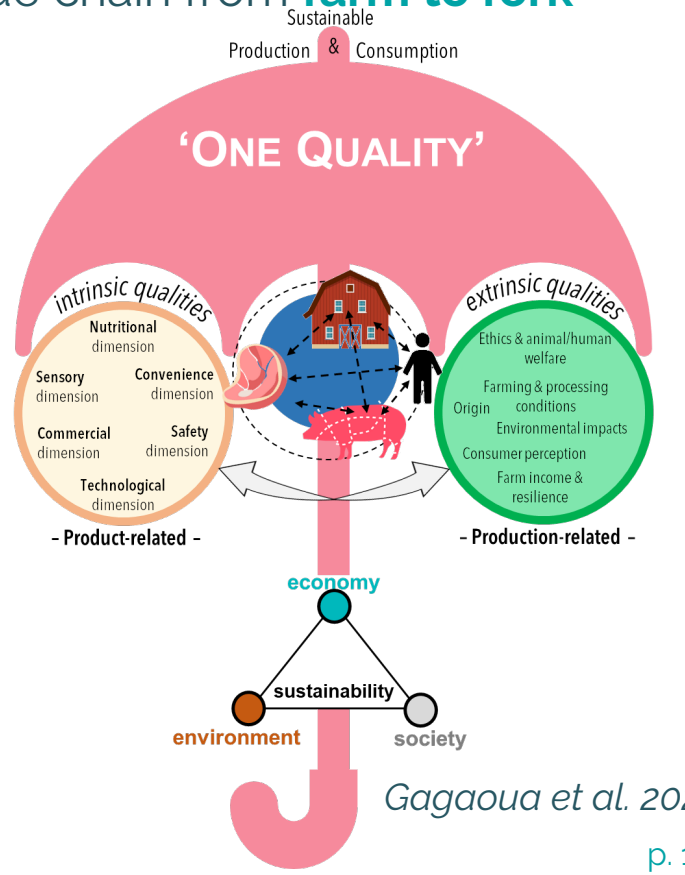
# Conclusions and Perspectives


## Quality of animal-source foods

- **Many attributes**, both product-related (intrinsic) and production/processing-related (extrinsic)
- Results from **various and interconnected factors** along the value chain from **farm to fork**
- **Synergies** but also **antagonsims** between quality attributes

➢ Better **characterize the synergies and antagonisms between the multiple quality attributes** by multidimensional analyses to allow **stakeholders**, including **consumers** to make **informed choices** according to their **quality priorities**

**= Integrated approach: One Quality combining quality and sustainability dimensions**




*Gagaoua et al. 2024*

# Thank you for your attention!

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