

Evidence-based
decisions in meat
inspection systems:
from routine data and
risk-based meat
inspection into algorithm
and artificial intelligence

Eystein Skjerve

RIBMINS Training School

Parma, June 16 2023

The talk

- Following up and looking back:
 - 1st presentation: Meat inspection and slaughter as learning –based systems
 - 2nd presentation : Methods for comparison of systems
 - 3rd presentation : Interventions in the meat chain: The need to integrate causal inference into planning of interventions.
 - 4th presentation is this one: Some conclusions and future perspectives; Into Artificial intelligence?

The ideology of meat safety

«Documents»

- 1930's; Implementation of the Prescott-Meyer-Wilson maxim has been given the name *longitudinally integrated safety assurance* - LISA.
- 1970's; HACCP

- 1990's»: Internet take-off

: Digitalisation on politic

: 1998; Google r



Adequate protection of the public against food-transmitted diseases of microbial aetiology: Achievements and challenges, half a century after the introduction of the Prescott-Meyer-Wilson strategy of active intervention

- 2000's; Biosensors revolution?

- 2006; Facebook launced openly

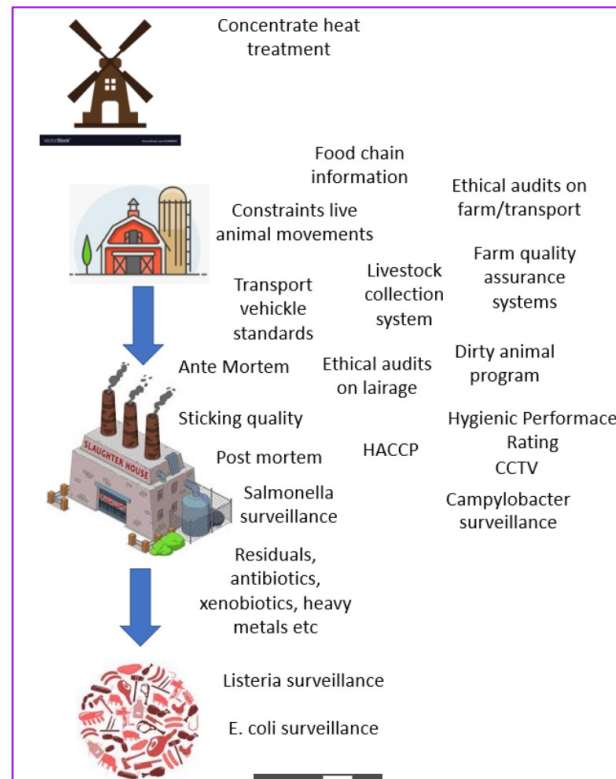
- «Big data»

- 2013; EFSA: Meat Safety Assurance System

“For the most relevant foodborne biological hazards, EFSA has also proposed harmonised epidemiological indicators. The indicators will be useful in the context of the proposed comprehensive meat safety assurance system, enabling the categorisation of farms, flocks or herds and abattoirs according to potential risk and the setting of microbiological targets for carcasses.”

- 2014; IBM Watson

https://www.youtube.com/watch?v=_Xcmh1LQB9I



From Sava Bunic' «Integrated Food Safety Systems and Veterinary Public Health»

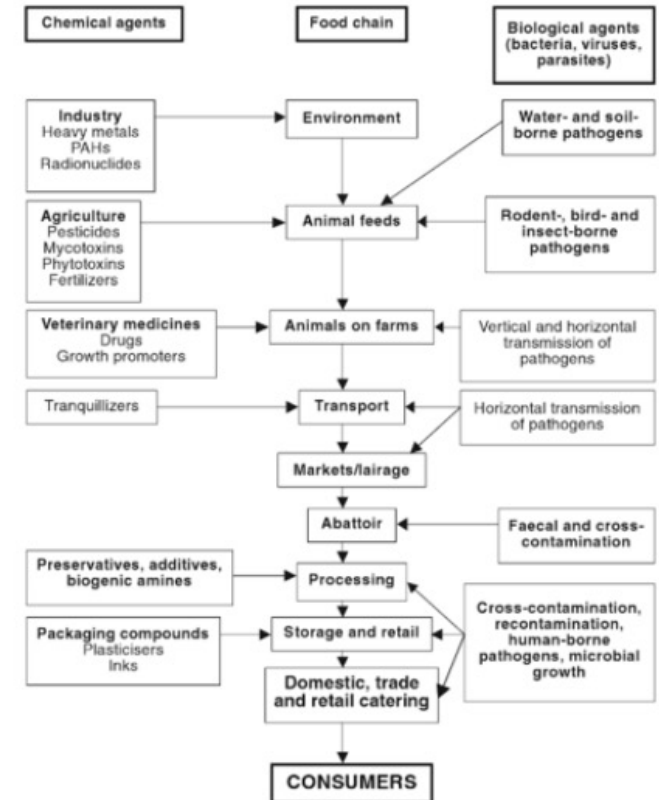


Fig. 1.1. The nature of the food chain and associated hazards.

Learning organisations: KAP - the holy Grail



Contents lists available at ScienceDirect

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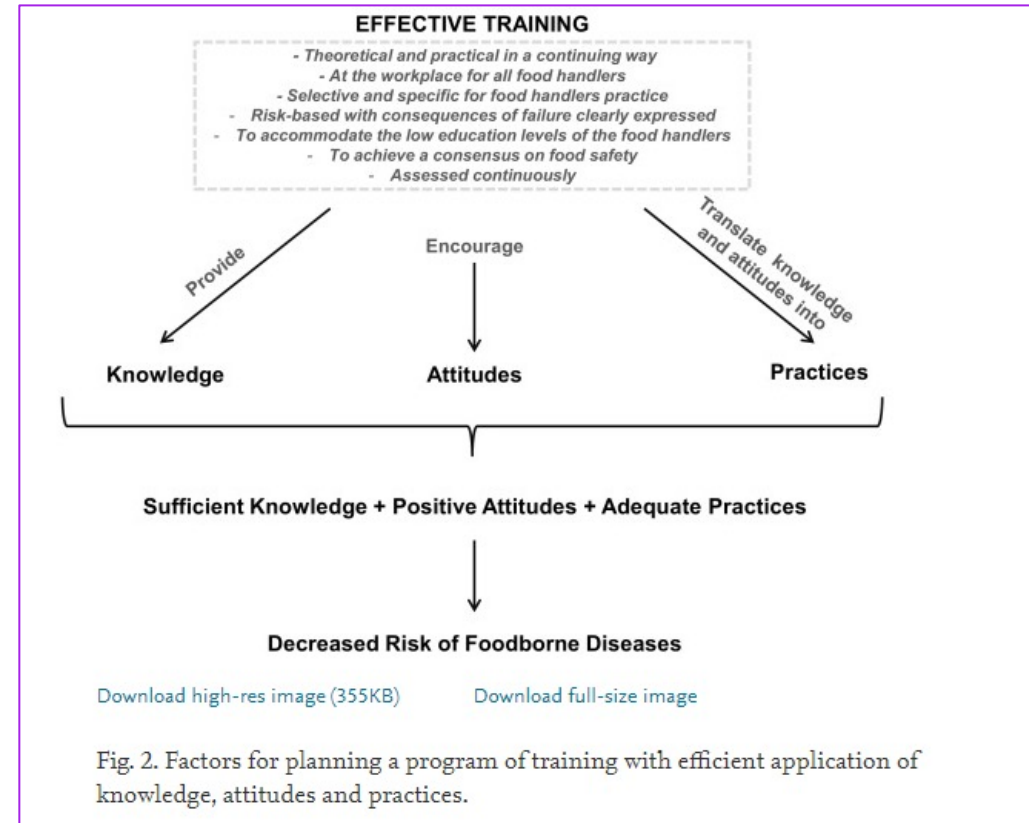
Food Research International

journal homepage: www.elsevier.com/locate/foodres

Review

Knowledge, attitudes and practices of food handlers in food safety: An integrative review

Laís Mariano Zanin^a, Diogo Thimoteo da Cunha^b, Veridiana Vera de Rosso^c, Vanessa Dias Capriles^c, Elke Stedefeldt^{d,*}



Simple: Dirty animals – dirty meat?

The significance of clean and dirty animals for bacterial dynamics along the beef chain



Sigrun J. Hauge ^{a,*}, Truls Nesbakken ^b, Birgitte Moen ^c, Ole-Johan Røtterud ^a, Sissel Dommersnes ^d, Ole Nesteng ^e, Øyvind Østensvik ^b, Ole Alvseike ^a

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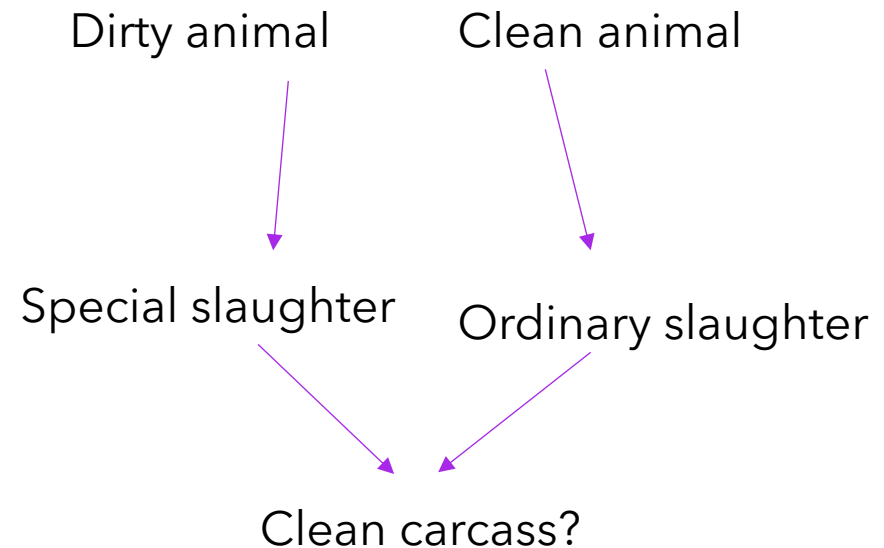
^d *Fatland Jeren AS, Hommersåkn, 250, 4311 Hommersåk, Norway*

^e *Nortura SA, P.O. Box 360 Økern, 0513 Oslo, Norway*

ABSTRACT



This study investigated the bacterial dynamics along the beef chain for clean and dirty cattle in the slaughter and processing lines, using classic quantitative methods and molecular analyses. In addition, the Norwegian national guidelines for Good Hygiene Practices in Norway were evaluated. In these guidelines, cattle presented for slaughter are categorised according to hide cleanliness, resulting in separate processing lines for meat from very dirty animals and reduced prices to farmers. The study was conducted in two commercial abattoirs in Norway. Two groups were compared; 40 visually clean cattle and 40 visually dirty cattle presented for slaughter, with 20 from each group at each abattoir. The same animals were sampled at five sampling sites: hides, carcass surfaces after dehiding, just before chilling, after chilling, and meat trimmings. Meat trimmings were sampled in only one abattoir. Three hundred and sixty samples were collected by swabbing 100 cm² of the brisket area at the first four sampling sites, and sampling 200 g of meat trimmings at the fifth site. The results showed that the hides of dirty cattle had more *Enterobacteriaceae* and higher Aerobic Plate Counts (APC) than visually clean cattle ($P < 0.05$), however there was no significant difference for *Escherichia coli*. For the other sampling sites, there were no differences between the dirty and the clean group. An effect of chilling/drying of the carcass surfaces was demonstrated by the significant reduction in the number of carcasses on which *E. coli* and *Enterobacteriaceae* were detected; from 11% and 39% before chilling to 1% and 16% after chilling, respectively. *Enterobacteriaceae* and *E. coli* were detected in only three and one of the meat trimming samples, respectively. Amplification and sequencing of the 16S rRNA gene from 643 *Enterobacteriaceae* colonies derived from 107 samples demonstrated that *Escherichia/Shigella* were dominant within this family on the hides. However, after dehiding, after grading, and after chilling, the genera *Citrobacter* and *Enterobacter* dominated. The meat trimmings were dominated by the genera *Kluyvera*, *Hafnia*, and unclassified *Enterobacteriaceae*. The relative proportions of *Escherichia/Shigella* were higher for dirty animals than for clean animals, and were higher on hides than from sampling sites further down the chain ($P < 0.05$). The minor differences in contamination on carcass surfaces and meat trimmings between clean and dirty cattle indicate that separate processing lines in Norwegian abattoirs seem to be unnecessary.

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Systematic Review

A Systematic Review on the Effectiveness of Pre-Harvest Meat Safety Interventions in Pig Herds to Control *Salmonella* and Other Foodborne Pathogens

Maria Rodrigues da Costa ¹ , Joana Pessoa ^{2,3,4}, Diana Meemken ^{5,*}  and Truls Nesbakken ⁶

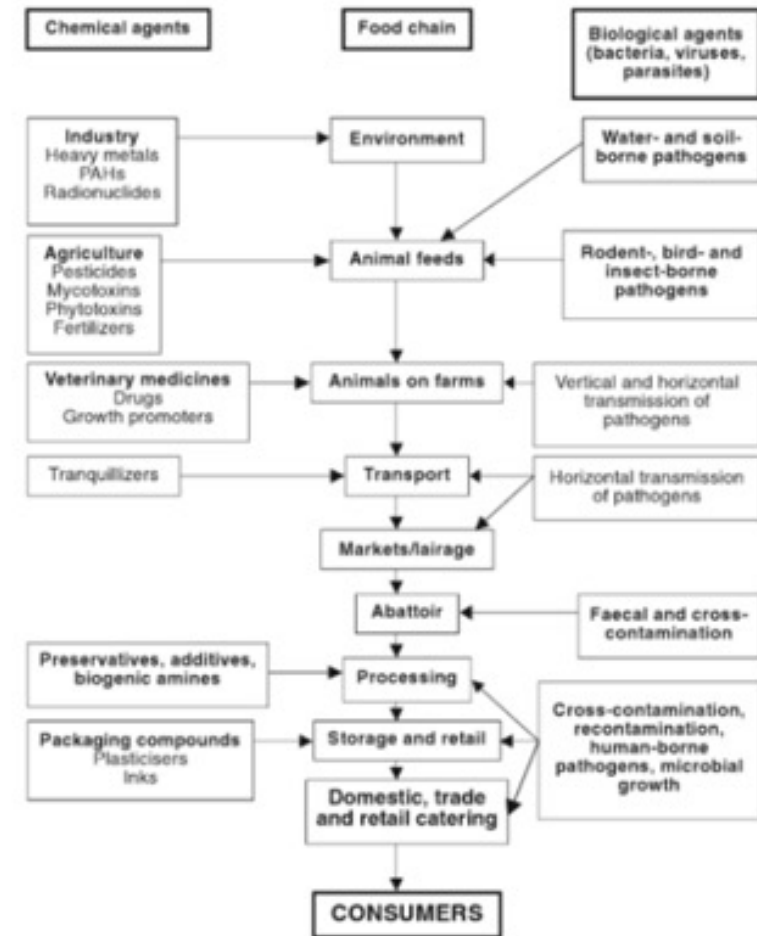
Abstract: This systematic review aimed to assess the effectiveness of pre-harvest interventions to control the main foodborne pathogens in pork in the European Union. A total of 1180 studies were retrieved from PubMed[®] and Web of Science for 15 pathogens identified as relevant in EFSA's scientific opinion on the public health hazards related to pork (2011). The study selection focused on controlled studies where a cause–effect could be attributed to the interventions tested, and their effectiveness could be inferred. Altogether, 52 studies published from 1983 to 2020 regarding *Campylobacter* spp., *Clostridium perfringens*, Methicillin-resistant *Staphylococcus aureus*, *Mycobacterium avium*, and *Salmonella* spp. were retained and analysed. Research was mostly focused on *Salmonella* ($n = 43$ studies). In-feed and/or water treatments, and vaccination were the most tested interventions and were, overall, successful. However, the previously agreed criteria for this systematic review excluded other effective interventions to control *Salmonella* and other pathogens, like *Yersinia enterocolitica*, which is one of the most relevant biological hazards in pork. Examples of such successful interventions are the Specific Pathogen Free herd principle, stamping out and repopulating with disease-free animals. Research on other pathogens (i.e., Hepatitis E, *Trichinella spiralis* and *Toxoplasma gondii*) was scarce, with publications focusing on epidemiology, risk factors and/or observational studies. Overall, high herd health coupled with good management and biosecurity were effective to control or prevent most foodborne pathogens in pork at the pre-harvest level.

Are we
pushing too
far?

Lack of data
to be used in
risk
assessment
and risk
management

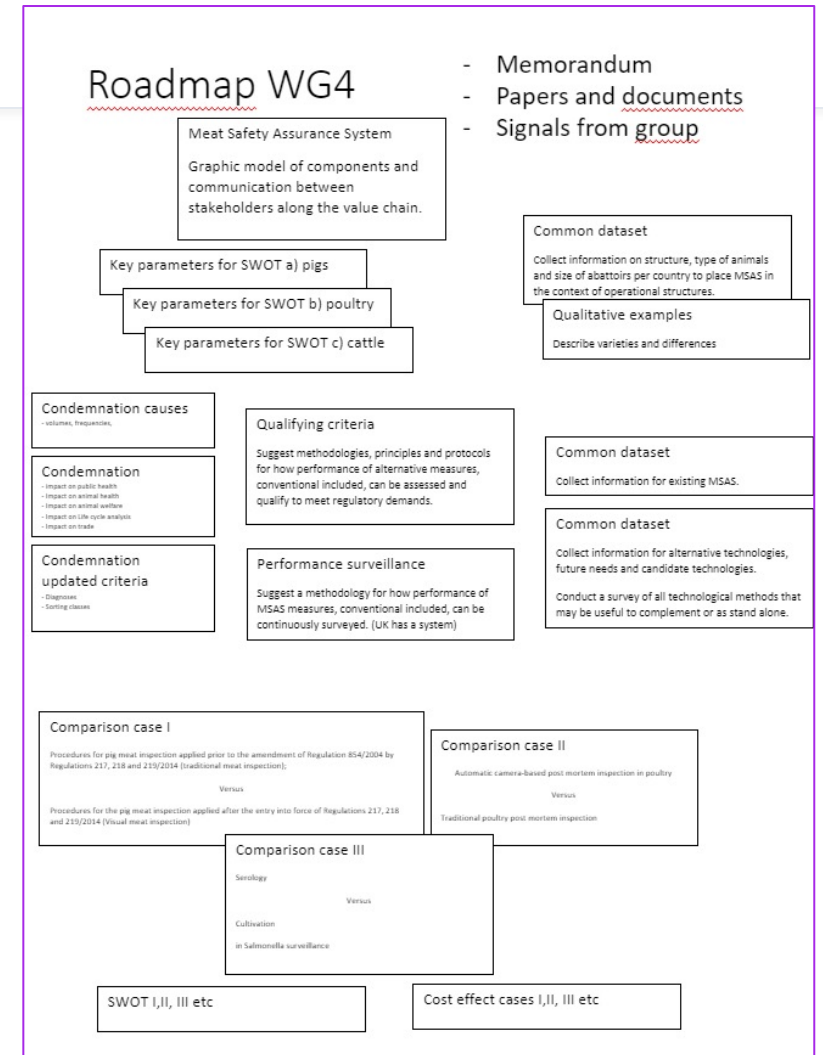
Preharvest data «revolution» ?

- Big data will most likely be used primarily for automatically harvested data, as e.g. sensor technologies
- What about smaller organisations, data harvested from farms and processing units into consumers' kitchens?



Common datasets not available

- We have large amounts of data – most of it is not used
- Where are the data collected
- Who owns the data?
 - Producers
 - Industry
 - Market owners
 - Public sector



Causal paths

Variable

Straydogs

- exposure
- outcome
- adjusted
- unobserved

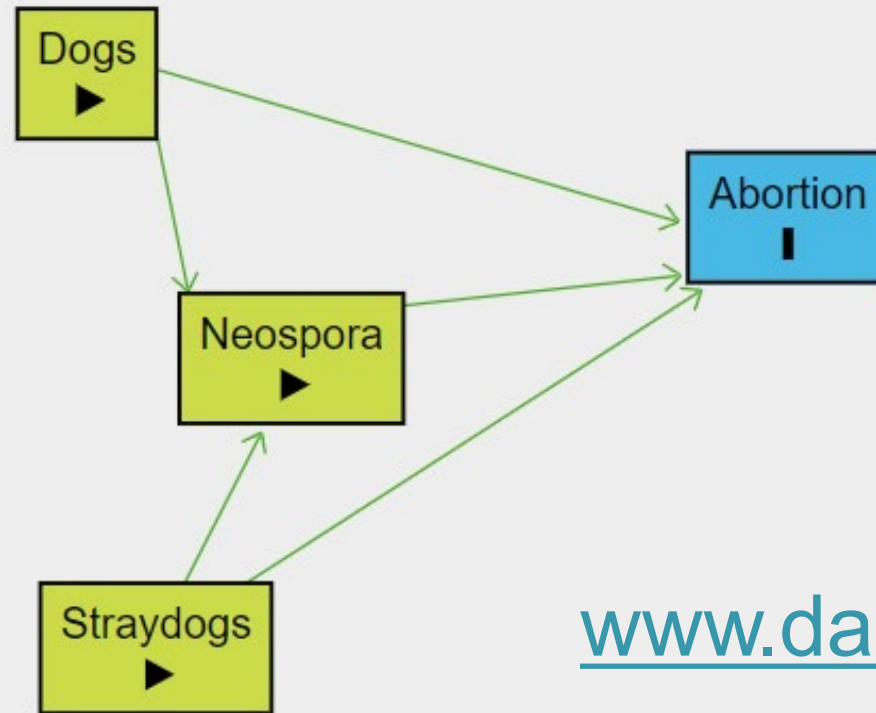
delete

rename

View mode

- normal
- moral graph
- correlation graph
- equivalence class

Model | Examples | How to ... | Layout | Help

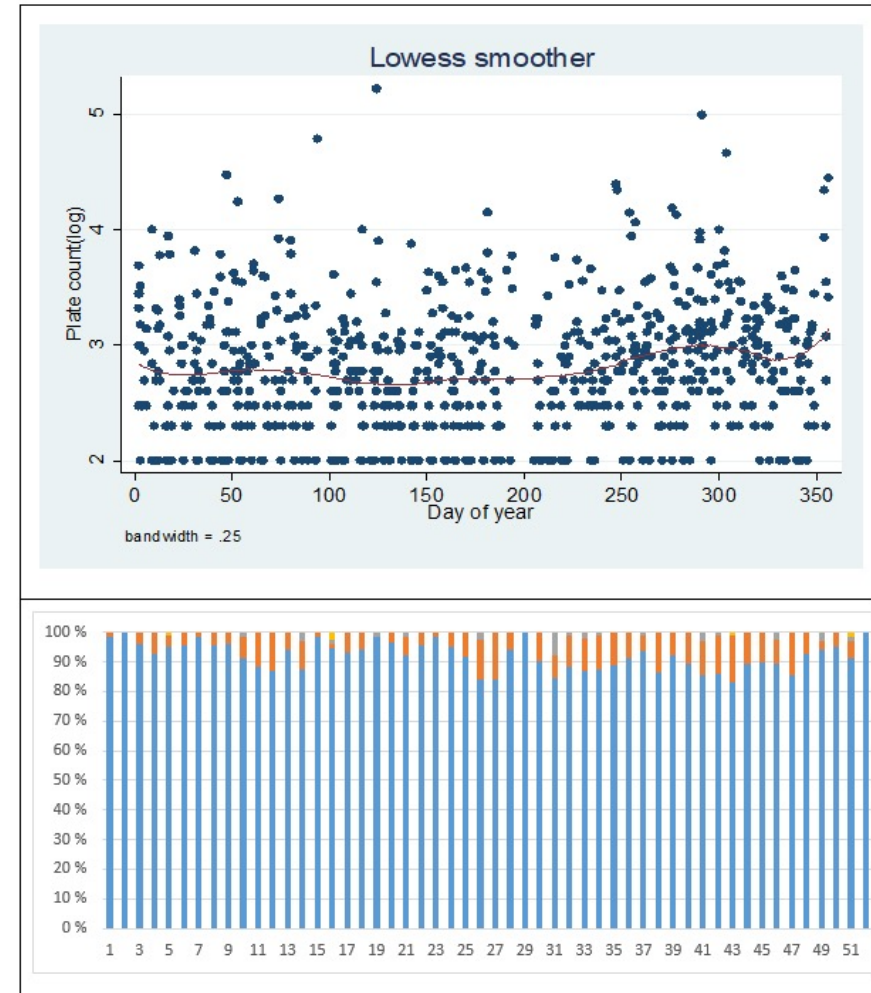


www.dagitty.net

Carcass counts or meat meat cuts - extreme variability

- Obviously meat plant recordings are more reliable
 - Directly influencing public health
 - Can be traced back - If information flow works

Figure 4. Time trends of plate counts (upper) from a meat cut plant during 2012, illustrated with a lowess curve with a bandwidth of 0.25, corresponding to a moving 3 months window. The lower graph shows the weekly trends for *E. coli* in categories (: 0=not detected, 1=<10/cm², 2=10-100/cm², 3=>100/ cm²)



HPR and carcass counts, of course there is a relationship - but what about predictions?

This means that for each percentage of poorer HPR-score, *Enterobacteriaceae* and *E. coli* contamination of carcasses increased by 0.1 log CFU/cm². The models were highly significant (F-statistics: 28.1, 18 DF, p = 0.00005 and 38.99, 18 DF, p = 0.000007). For the *Enterobacteriaceae* regression model, R² was 0.68 (0.69 for cattle and 0.62 for sheep), and 0.61 for *E. coli* (0.62 for cattle and 0.60 for sheep).

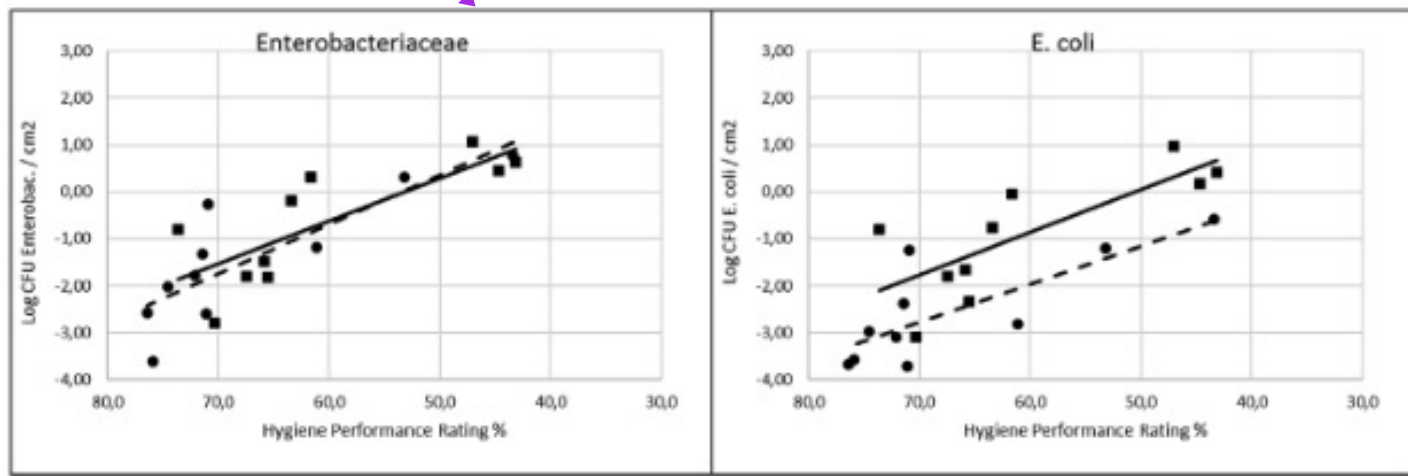
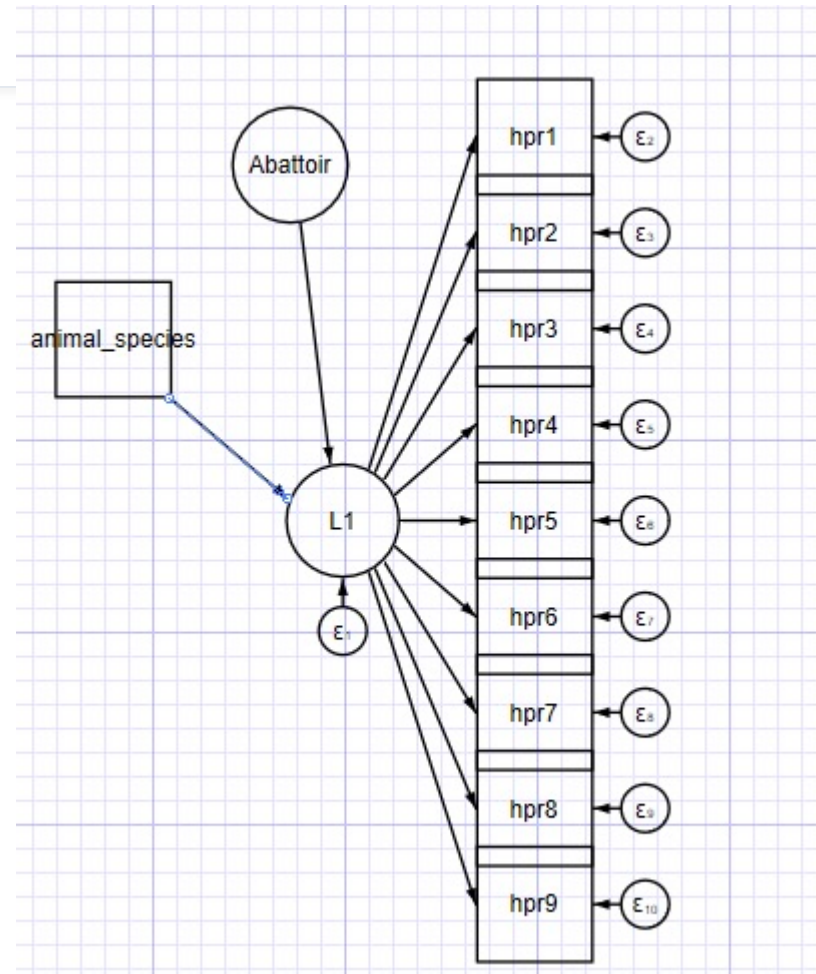
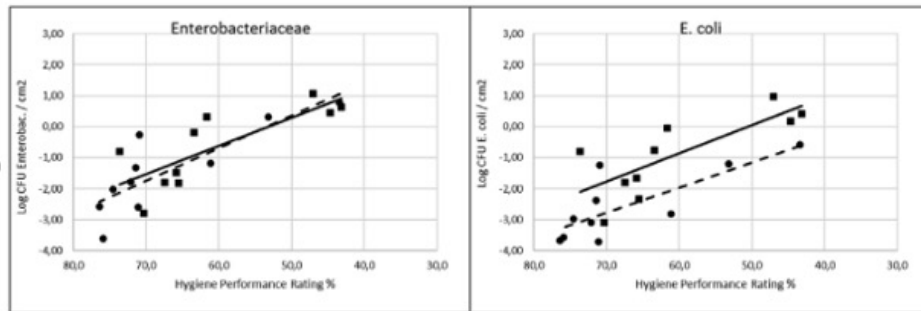


Fig. 3. The relationship between HPR results on the x-axis and microbiological carcass hygiene on the y-axis. The mean of log/cm² Enterobacteriaceae (graph to the left) and *E. coli* (to the right) on cattle (dots) and sheep carcasses (squares). The dashed line showed the regression line for cattle and the solid line for sheep. NB: The x-axis is reversed, with low hygienic scores to the right, high to the left of the x-axis.

HPR - hygiene as a latent (non-measured variable)

Table 1. Associations between HPR scores and counts of Enterobacteriaceae and E. coli using a standardized method in analysing counts. Results are shown for the overall score, and the latent variable created by the structural equation model. Further results are given for to levels of reliability of the predictor variable (0.8, 0.9). Coefficients with 95% CI and corresponding coefficient of determination is given for each model.

Predictor	<i>Enterobacteriaceae</i>	<i>E. coli</i>
Overall score	-0.099 (-0.133- -0.066) R ² =0.68	-0.101 (-0.141- -0.061) R ² =0.61
Latent variable from SEM (reliability=1.0)	-0.165 (-0.215- -0.113) R ² =0.72	-0.174 (-0.230- -0.118) R ² =0.70
Latent variable from SEM; reliability=0.9	-0.182 (-0.231- -0.134) R ² =0.79	-0.194 (-0.248- -0.140) R ² =0.78
Latent variable from SEM; reliability=0.8	-0.206 (-0.244- -0.166) R ² = 0.89	-0.217 (-0.263- -0.172) R ² =0.87



Complexity: Risk assessments

Assessment of the Risk to Public Health due to Use of Antimicrobials in Pigs—An Example of Pleuromutilins in Denmark

Lis Alban^{1*}, Johanne Ellis-Iversen², Margit Andreassen³, Jan Dahl¹ and

¹Risk Assessment Group, Department for Food Safety and Veterinary Issues, Danish Agriculture, Copenhagen, Denmark, ²National Food Institute, Technical University of Denmark, Kongens Lyngby, Denmark, ³Danish Association of the Veterinary Pharmaceutical Industry, Copenhagen, Denmark, ⁴Dept Parasites and Fungi, Statens Serum Institut, Copenhagen, Denmark

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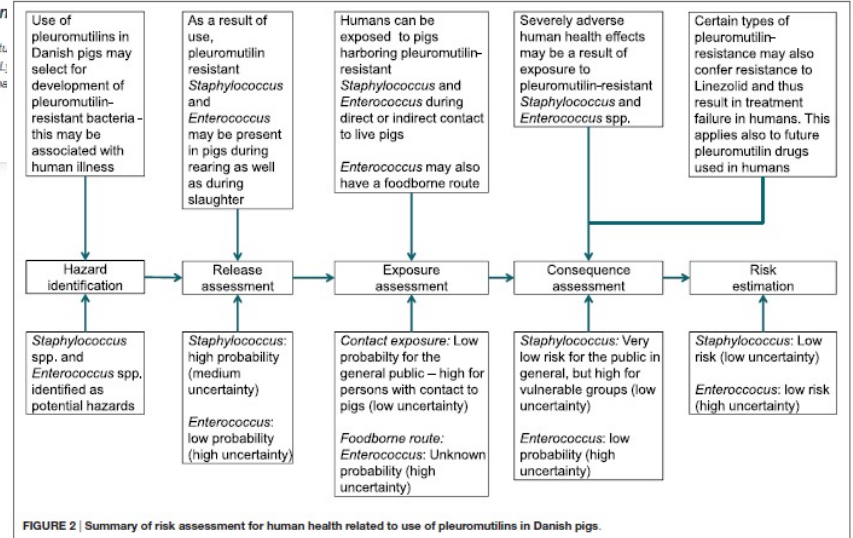


FIGURE 2 | Summary of risk assessment for human health related to use of pleuromutilins in Danish pigs.

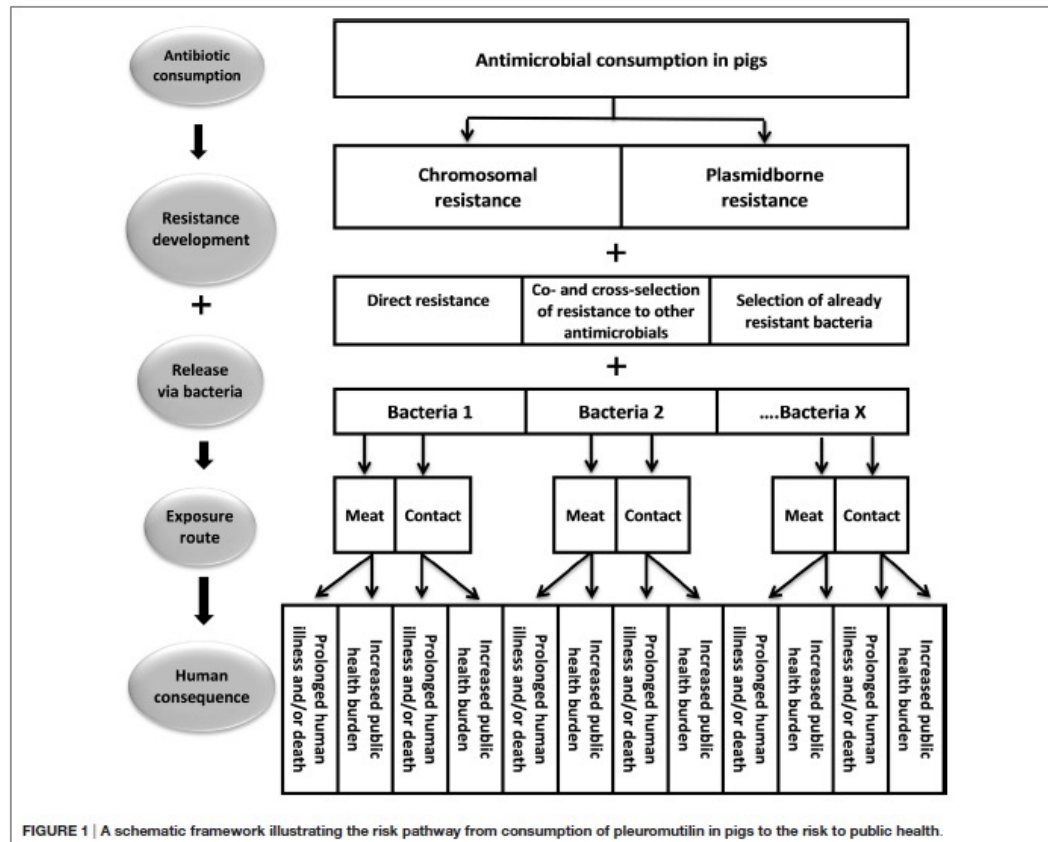


FIGURE 1 | A schematic framework illustrating the risk pathway from consumption of pleuromutilin in pigs to the risk to public health.

Risk Estimate

The current risk for human health-associated consumption of pleuromutilins in Danish swine was assessed as low under the current conditions. This is an increase compared to the previous assessment conducted in 2010, where a very low risk was found (7). A summary of the different elements of the risk assessment is presented in Figure 2.

The consumption of pleuromutilins in Denmark is low compared to other European countries (9) and has not changed

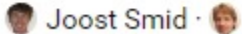
Complex networks

A Biotracing Model of Salmonella in the Pork Production Chain

February 2012 · Journal of food protection 75(2):270-80

DOI: 10.4315/0362-028X.JFP-11-281

Source · [PubMed](#)

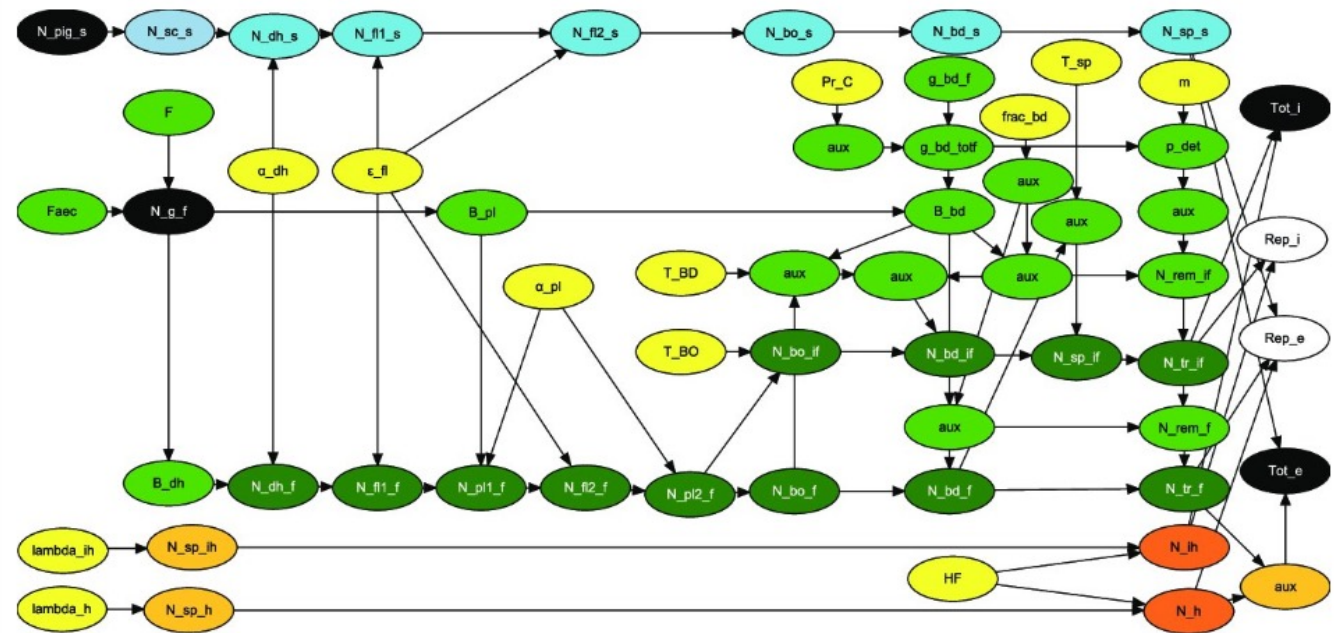
 Joost Smid · Lourens Heres · Arie H Havelaar · A Pielaat

Figure

Caption

Fig. 4. BBN of the Salmonella in pork slaughter chain. The different colors (only visible in the online version of the article) represent the dynamics of Salmonella coming from

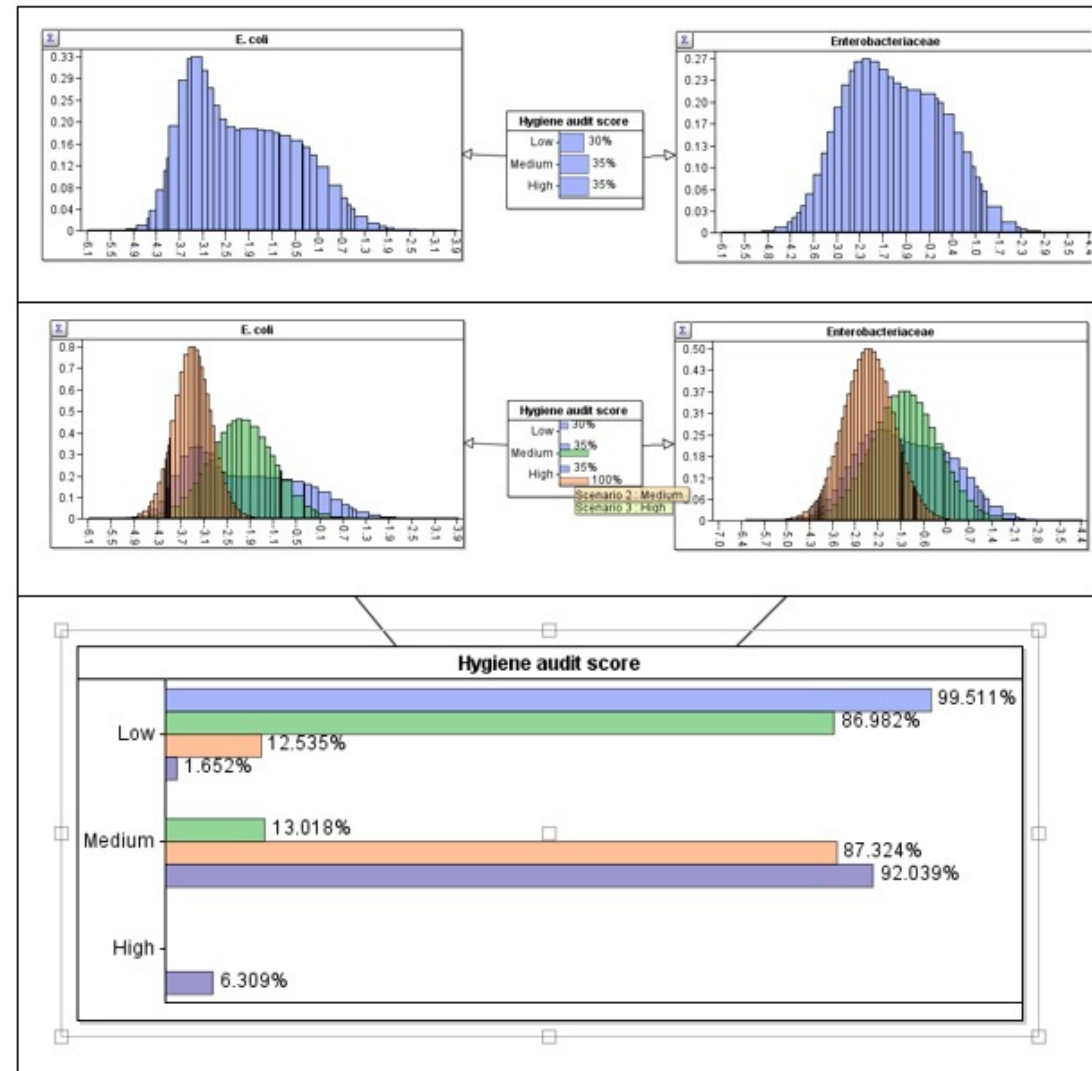
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Decision analyses

- Bayesian networks represents a graphical technique easily (??) understood
- BN can send information forward and backward

Figure 5. A decision oriented system using a Bayesian network, showing the probability distribution without any HPR information (upper), and with HPR information (middle). The lower graph gives probability distributions of three levels of hygiene scores (low, medium, high) for scenarios with inputs for Enterobacteriaceae (log units) 1, 0, -1, -1.5 and E. coli (log units) 0.5, -0.5, -1.5, -2) per cm².



The Industry and Public Sector



Norsk Kylling markerer byggestart i Orkanger

Tirsdag 11.juni 2019 ble grunnsteinen for Norsk Kylling sitt nye slakteri og foredlingsanlegg lagt ned på tomten i Orkanger. Det fremtidsrettede anlegget vil være banebrytende innen energibruk og nye løsninger, og vil utgjøre starten i etableringen av en næringsmiddelklynge i området

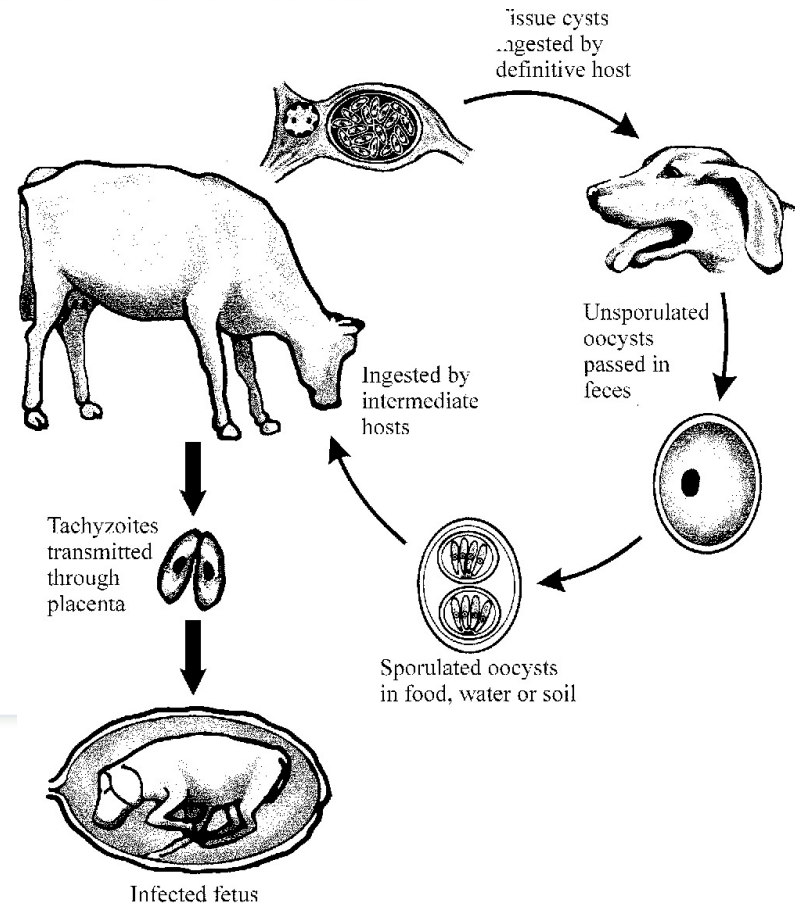
REMA 1000-leder Ole Robert Reitan, Norsk Kylling-leder Kjell Stokbakken, ordfører i Orkdal, Oddbjørn Bang, og næringspolitisk talsperson i Høyre, Linda Hofstad Helleland, var alle med på å markere byggestart på det fremtidsrettede anlegget. Samfunnsansvar, kvalitet, dyrevelferd og innovative energiløsninger var sentrale temaer i åpningstalene.

- Industries will be reluctant to share their data
- Public data sharing will be limited by GDPR
- Other, commercial actors will dominate the arena in food safety and food quality
 - Industrial systems have more freedom and more efficient than public systems – and will be able to integrate databases

Do not forget the biology!

Neospora also known as Neospora caninum is **single celled parasitic organism that can affect cattle, particularly pregnant cattle, where it can result in abortion**. The disease affects cattle worldwide, and once infected, cattle remain infected for life, making the disease very difficult to eradicate. 4. nov. 2020

Neospora is not zoonotic, but Neospora affects zoonoses as it is linked to pre-harvest management and contact between cattle and dogs



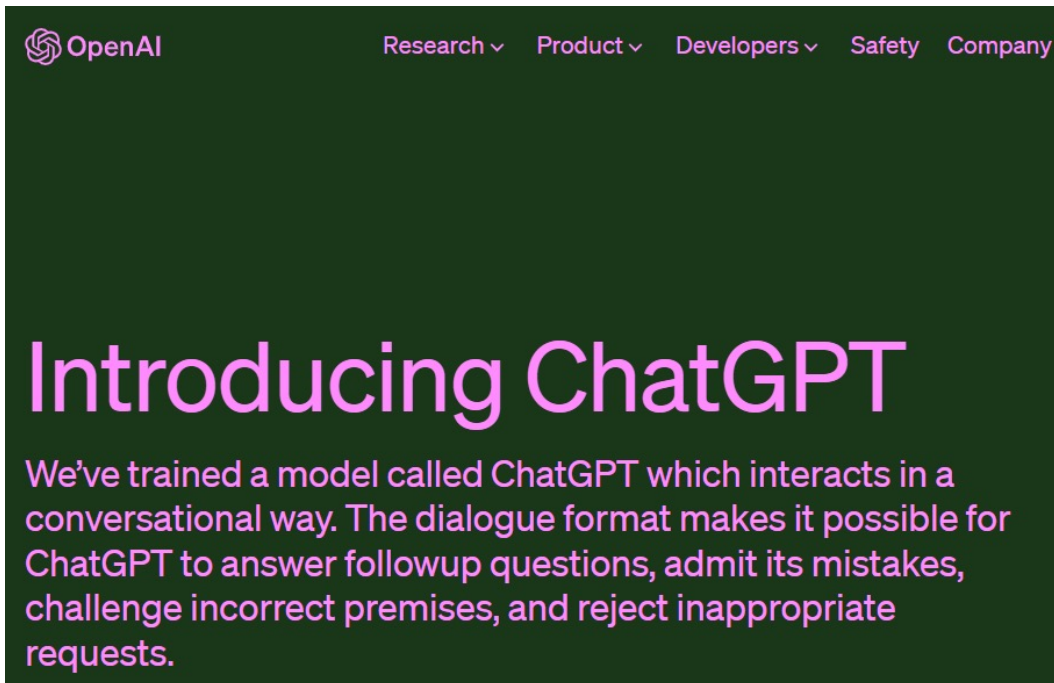
The status

1. Very few European countries have real pre-harvest systems to collect data to be used in quality assurance
2. Temptation to move towards automatic data harvesting – are these data relevant and reliable?
3. Ownership of data is controversial
4. Sharing of data difficult due to GDPR and commercial interests
5. CHALLENGES WILL BE LINKED TO DEALING WITH EXTREME VARIABILITIES IN VERY DIVERSE MEAT CHAINS IN EUROPE

The future - into the green shift

- Reduced meat consumption in Europe
- Stress on the industry linked to pressure from
 - Sustainability and climate
 - «Green Deal»
 - Animal welfare
- Authorities and industries under pressure to change food systems into circular food chains

And the World was never to be the same again; algorithms and Artificial Intelligence (AI)



The screenshot shows the OpenAI website with a dark green background. At the top left is the OpenAI logo. To its right are navigation links: Research, Product, Developers, Safety, and Company. The main heading is "Introducing ChatGPT" in large, light purple font. Below it is a paragraph in the same color: "We've trained a model called ChatGPT which interacts in a conversational way. The dialogue format makes it possible for ChatGPT to answer followup questions, admit its mistakes, challenge incorrect premises, and reject inappropriate requests."

OpenAI

Research Product Developers Safety Company

Introducing ChatGPT

We've trained a model called ChatGPT which interacts in a conversational way. The dialogue format makes it possible for ChatGPT to answer followup questions, admit its mistakes, challenge incorrect premises, and reject inappropriate requests.

NG describe the relationship between surface microbial counts and slaughter hygiene

The relationship between surface microbial counts and slaughter hygiene is significant and plays a crucial role in ensuring food safety and preventing the spread of pathogens. Slaughter hygiene refers to the practices and measures implemented during the slaughtering and processing of animals to maintain cleanliness and minimize the risk of contamination.

Surface microbial counts are a measure of the total number of microorganisms present on the surfaces of equipment, tools, and facilities in the slaughterhouse environment. These microorganisms can include bacteria, fungi, viruses, and other pathogens. High surface microbial counts indicate a higher level of contamination and increase the likelihood of pathogens being transferred to the meat during processing.

Proper slaughter hygiene practices aim to reduce and control surface microbial counts in the slaughterhouse. This includes maintaining a clean and sanitized environment, implementing effective cleaning and disinfection protocols, and ensuring the use of appropriate personal protective equipment (PPE) by workers.

By controlling surface microbial counts, slaughter hygiene practices help minimize the risk of foodborne illnesses and ensure the safety of the meat products. Pathogens such as Salmonella, Escherichia coli (E. coli), Campylobacter, and Listeria monocytogenes are commonly associated with slaughterhouse contamination. These pathogens can cause serious illnesses in humans if consumed through contaminated meat.

Regenerate response



Will AI save us

- May not be of much help in our area, due to lack of transparency of data, limited sharing of data - and:
- Huge variability of data
- Even advanced AI systems will not give reliable predictions on specific units as animals and herds.

Am I a bit pessimistic?

