

High dietary rye levels combined with reduced grinding intensity – an effective concept against higher *Salmonella* prevalence in pork production



J. Kamphues, B. Chuppawa, V. Wilke,
C. B. Hartung, C. Visscher,
A. von Felde¹⁾ and R. Grone¹⁾

Institute for Animal Nutrition at the
University of Veterinary Medicine Hannover, Germany
¹⁾ KWS LOCHOW GMBH, Bergen, Germany



- International Rye Feed Research Meeting, 25th February 2021 -

Salmonella prevalence in pork production – efforts to maintain a high standard of consumer protection

- **Testing of antibody titers in meat juice of slaughtered pigs**
→ category I/ II/ III (very low/ moderate/ high levels)
- **Consequences for the pig producers regarding**
→ time of slaughtering to minimize risks for contamination
- **Implementation of measures (veterinary administration)**
→ including dietary measures at farm level



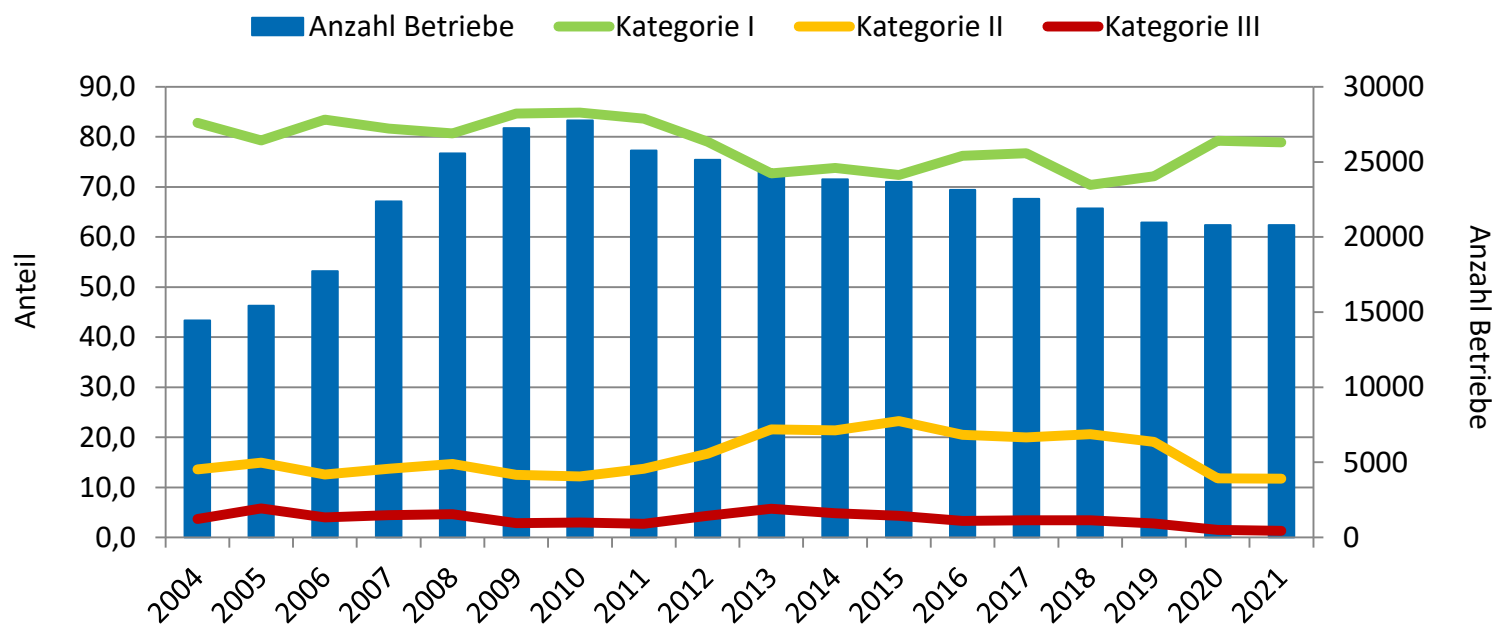
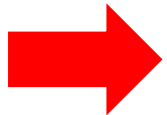


Figure: Results of Salmonella monitoring (meat juice) in slaughtered pigs of Germany (QS-program; data form SPEMANN, 01.02.2021)

Besides optimization of the diet there are lots of hygiene measures need to be respected:

- **Salmonella contamination of pigs entering the fattening unit**
- **Spreading of Salmonella stimulated by „stress“**
- **Intestinal dysbiosis due to antibiotic treatment**
- **Cleaning and disinfection between cycles**
- **Pest control/ rats/ mice/ birds shedding Salmonella**
- **Dust within the technical equipment for climatization**



The diet is only one part within the puzzle „Salmonella“

Salmonella prevalence in pork production in Europe and four different „dietary concepts“ against higher values

- Effects predominantly within the stomach/ small intestine
→ Salmonella entrance/
Salmonella adherence

- Effects within the cranial part, but also in the hindgut
→ Salmonella entrance/
Salmonella elimination

- FERMENTED FEEDS/ DIETS
 - `controlled fermentation`
 - high shares of silage like corn cob mix (CCM) a. s. o.

- COARSER CEREAL GRINDING (share of rough particles ↑)
 - part of cereals (roller mill)
 - resign of pelleting/ granulation

- FEED ADDITIVES
 - organic acids (formic acid...)
 - probiotics (lactic acid producers)
 - prebiotics (lactulose)

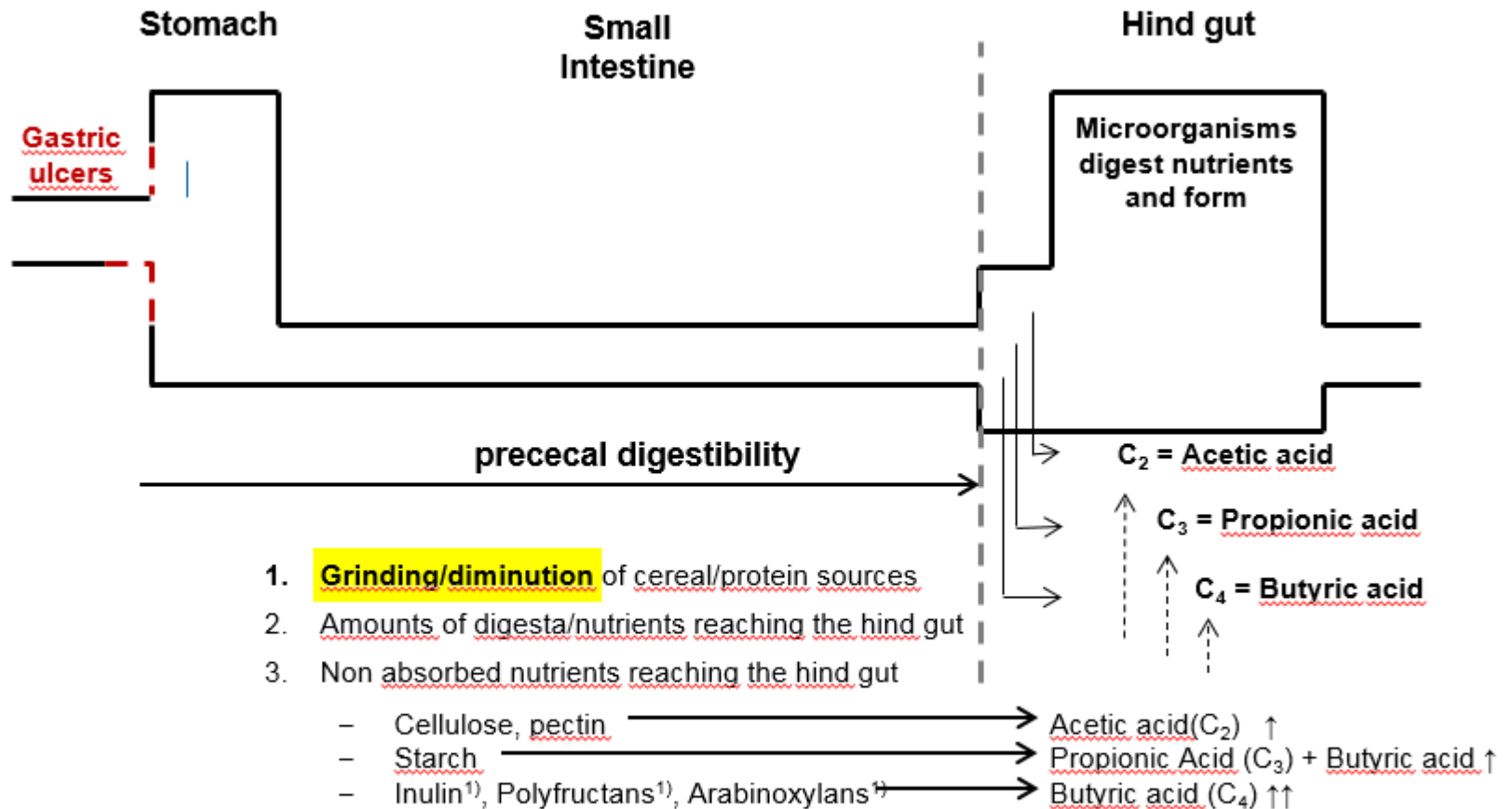
- SPECIFIC FEED MATERIALS
 - `resistant starch` (raw potato!)
 - RYE (fructans/ arabinoxylans)
 - Cereal by-products (bran...)

 enhanced efficacy when combinations are implemented

KAMPHUES 2020

The Alimentary Tract of Pigs – a Model

Kamphues et al. 2017



¹⁾ specifically high amounts in rye

What are the main reasons for an increased butyric acid formation in the hindgut of pigs fed increased dietary rye levels? (KAMPHUES et al. 2019)



1. Due to a slightly lower pc digestibility of **starch** increasing amounts of rye will reach the hindgut (~ 25 g/kg rye)
 2. Due to a very low pc digestibility most of the native **fructans** (30 - 60 g/kg rye) will reach the end of the small intestine/the caecum
 3. Due to a very low pc digestibility most of the **arabinoxylans** (80 - 90 g/kg rye) will enter the hindgut, especially the caecum of pigs
- 1.6 - 1.8 higher amounts of organic substances (than in wheat) as well as distinct non-starch-polysaccharides will favour the formation of butyrate in the hindgut!

Butyrate: diverse relationships to the immunological capacity of individuals, selected recent literature

Intestinal barrier ↑
(tight junction protein ↑, protection against LPS-induced damage; (Yan and Ajuwon 2015))

Host defense peptides ↑ (via blocking the histone deacetylase) (Xlong et al. 2016)

Activation of pro-inflammatory cytokines like $\text{TNF}\alpha$, $\text{IL-1}\beta$, IL-6 ; (Liu 2016)

Bacteriostatic effects (Moquet et al. 2016)

Butyrate

Inflammatory reactions ↓, forced mucin production, secretion of antimicrobial peptides (Onrust et al. 2015)

Infectious agents ↓
reduction of colonization and faecal *Salmonella* excretion (Barba-Vitel et al. 2017)

Oxidative stress ↓
inhibition of forced apoptosis (Jiang et al. 2016)

Antibody secretion ↑
sow feeding: higher IgG and IgA in colostrum and milk (Jang et al. 2014)

Kamphues et al. 2017

LAWHON et al. 2002: (Molecular Microbiology 46, 1451 – 1464)



„It is likely then that Salmonella can use the SCFA conditions of the mammalian intestinal tract as **a signal for invasion**.

- **Low total SCFAs** (~ 30 mmol) with a predominance of acetate induce invasion

whereas

- **high total SCFAs** (~ 200 mmol) with greater concentrations of **propionate and butyrate** suppress it.“ !

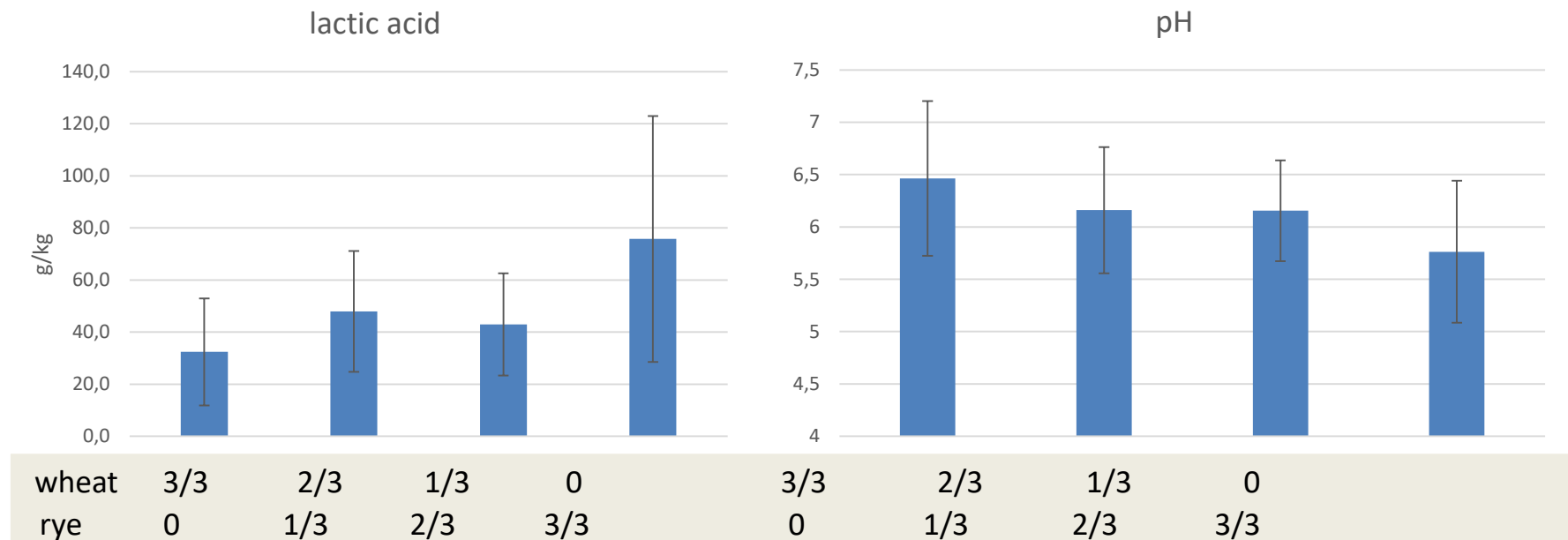
→ in the distal small intestine: Acetate ↑ → Invasion ↑↑↑↑

→ in the cecum/colon: Propionate, Butyrate ↑ → Invasion ↓↓↓↓

Rye – effects within the small intestine

Is there a risk for a too high formation of lactic acid in the small intestine in young pigs fed high rye diets?

⇒ lactic acid ↑ : pH ↓ : activity of amylase?



Lactic acid contents and pH values in the small intestine digesta of young pigs fed diets with increasing shares of rye, substituting wheat (WILKE 2020).

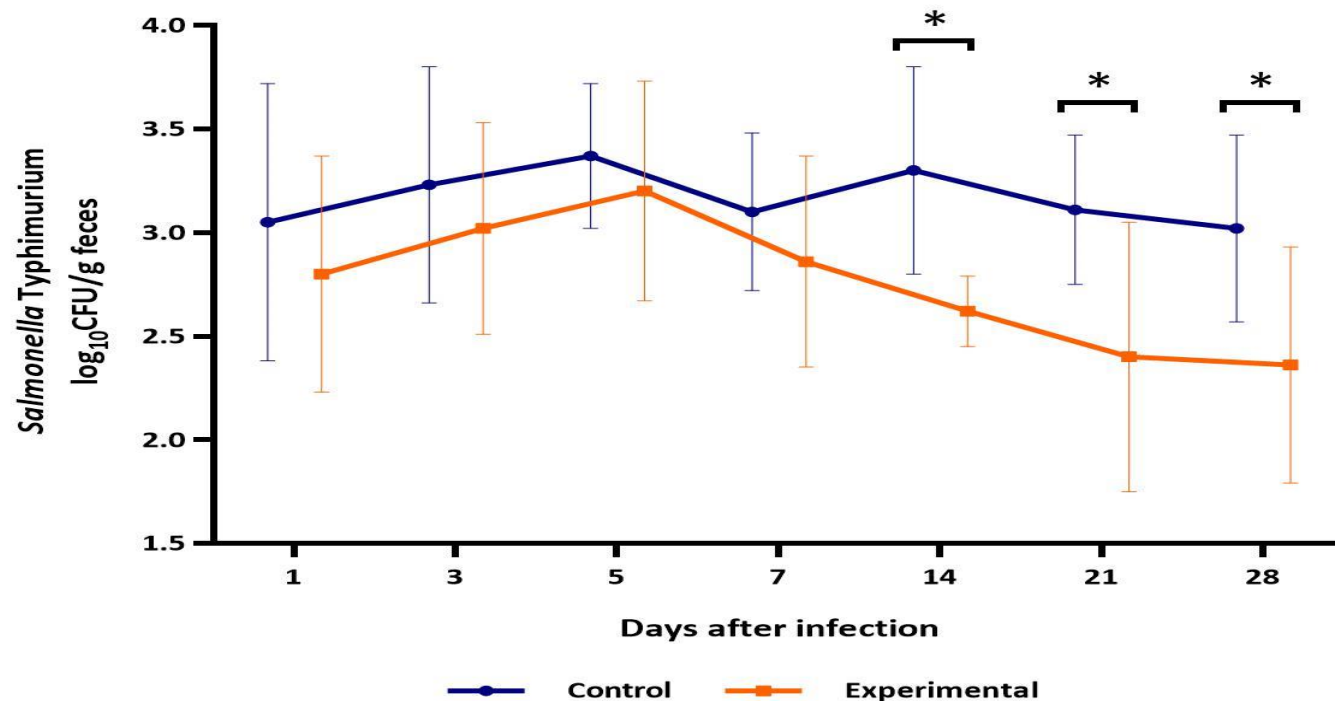
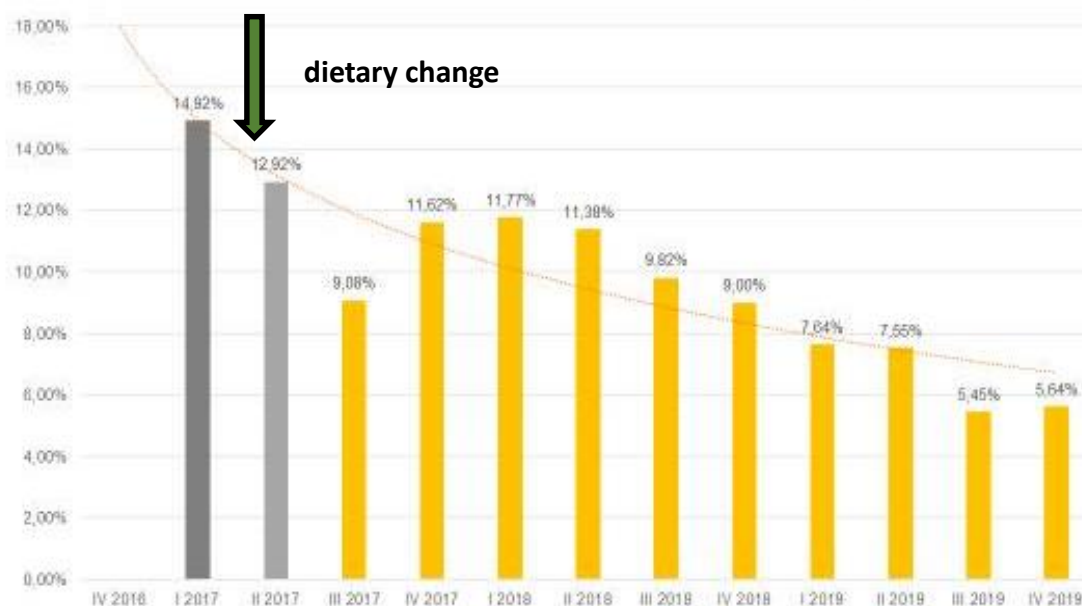


Figure: Counts of *Salmonella* (log₁₀ CFU/g fecal sample) of piglets fed different diets after an experimental oral infection with *S. Typhimurium*. Means of bacterial counts between the control (69 % wheat) and experimental (69 % rye) groups differed significantly (* $p < 0.05$; Chuppawa et al. 2020)

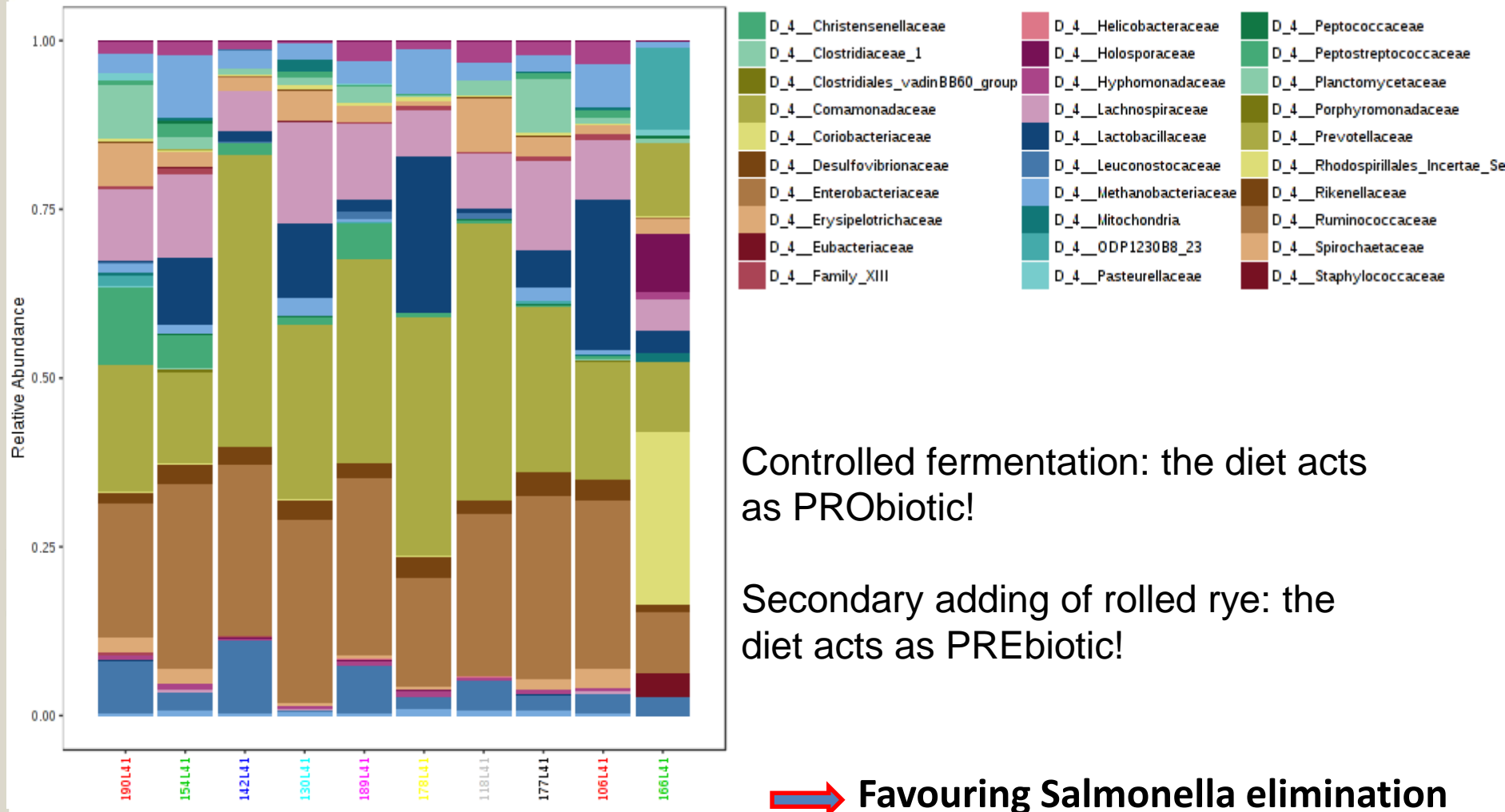
Salmonella prevalence (%) in pigs (n= 117455) of 9 farms



23.02.2021

**The development of Salmonella prevalence in slaughtered pigs after dietary changes in 2017
- ≥ 40 % rye and coarse grinding – in the field study in Germany (KWS / von Felde 2020)**

The microbiom of **colonal** contents of young pigs fed a fermented diet, after fermentation rolled rye was added to increase the particles' size in the diet (BUNTE et al. 2019)



It is not a „dream“, but there are real chances to overcome the Salmonella story in pork production by „dietary measures“:

- **„controlled fermentation“ of a rye based final liquid diet**
 - high lactic acid concentration (> 5% of DM!) plus lactic acid producers (10^{10} /g)
 - favouring Salmonella elimination before / at the entrance
- **add to the fermented part of the liquid diet not only protein feeds**
 - ~ 15% of rye ground/ cracked in a roller mill only
 - marked effects on hind gut microbiota (Bifido-bacteria ↑)
- **minimized use of antimicrobials in young pigs**
 - stabilized intestinal microbiota preventing settlement
 - reduced numbers of „seeders“ within groups
- **in future times: effective concepts for the piglet producing units!**
 - minimizing the infection / contamination of piglets
 - protection of the fattening units instead of treatment

Summary / conclusions

- **Science based concept regarding the specific properties of rye due to its typical NSPs favouring butyric acid formation**
- **Field studies confirm the expectations regarding use of rye and lower grinding intensity (→ decrease of Salmonella antibody titers)**
- **Experimental studies – including artificial infection – have demonstrated significant effects of rye at „challenge conditions“**
- **Combining the ideas of specific feed materials like rye and a more coarse diet as well as of fermentation - the best!**
- **Favouring the diversity and activity of hindgut microbiota is desired – inspite of slightly increased energy losses**