Feed Additives as a Key Tool to Enhance Animal Health and Welfare
–
Scientific Perspectives and Practical Implications

Jürgen Zentek

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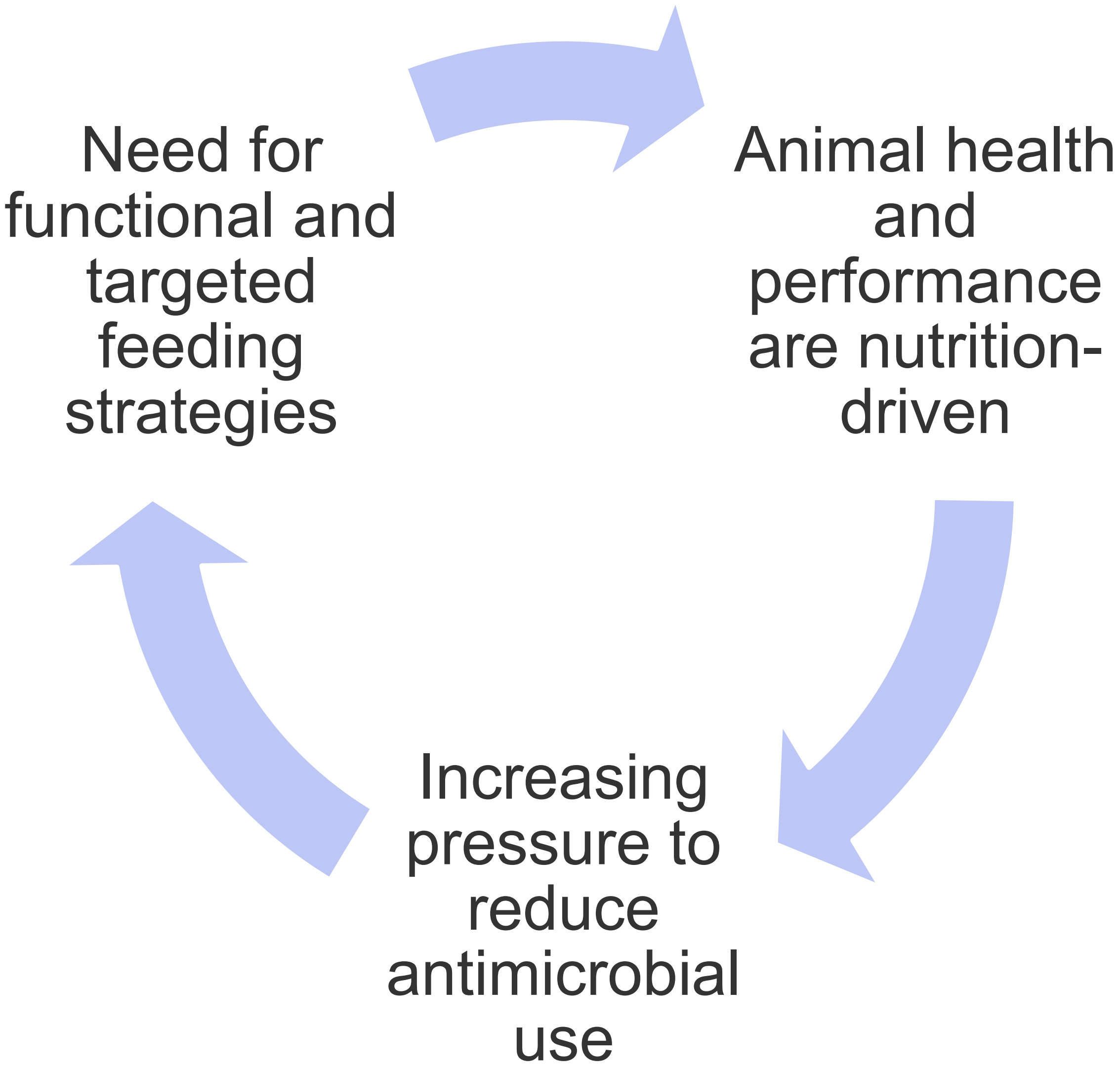
Why Feed Additives Matter



1. The Big Picture: Rethinking Animal Health and Welfare

2. The Gut as a Central Hub
(Linking digestion, microbiome, and immunity)

3. Intervention Points: Feed Additives as Tools

4. Future Directions: From Efficiency to Resilience


NUTRIENT REQUIREMENTS OF SWINE
ANIMAL NUTRITION SERIES
NATIONAL RESEARCH COUNCIL
10
GfE
Empfehlungen zur Energie- und Nährstoffversorgung von Schweinen
2006
SEGES INNOVATION
35th edition
Updated April 2024
Danish nutrient standards
Per Tybirk, Niels Morten Sloth, Thomas Sønderby Bruun & Janni Hales
SEGES Innovation P/S
Danish Pig Levy Fund
Main conclusion
The nutrient standards now include an additional row for growers and finishers that have a particularly good feed conversion ratio. For gilts, phase feeding is now only recommended to obtain the correct balance between backfat thickness and normal behaviour. The minimum concentration of digestible protein in feed for sows in the gestation and insemination units is lowered, and the recommended weight intervals for when the different diets are used have been slightly adjusted. Finally, inclusion of 'Quantum Blue' phytase has been reduced from 400 to 325 FTU at a 100% concentration.
Revisions in 35th edition
The overall improvement in feed conversion ratio and the increase in the production of intact male pigs indicate a significant potential for optimal feed conversion in many herds. Consequently, the standards now also accommodate feed for growers and finishers with a particularly good feed conversion ratio.
Practical experiences and SEGES Innovation trials, as well as international studies, confirm that insufficient protein and lysine concentrations increase the risk of behavioural misconduct, such as tail and ear biting. For gilts, the optimal solution to this is phase feeding with a moderate amino acid deficiency, which results in a slight reduction in gain while still increasing backfat and maintaining a
The Danish feed evaluation system
The Danish feed evaluation system is based on the physiological energy value of nutrients and on the standardised digestibility of these nutrients. In 2002, the old feed unit was replaced by two new feed units: FUgp (feed units for weaned pigs, growers and finishers) and FUsow (feed units for sows).
Tables of composition and nutritional value of feed materials
CVB Feed Table 2019
Chemical composition and nutritional values of feedstuffs
December 2019
CVB for valuable feeding values
Internet: www.cvbdiervoeding.nl

Is it enough?

Health: physiological functionality

Welfare: includes behaviour and mental state

Resilience: ability to cope with stressors

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- Performance (growth, FCR, reproduction) is directly linked to health
  - Healthy gut enables efficient digestion, absorption, and barrier function
  - Disease or inflammation diverts nutrients → reduced performance
- Key concept: Performance is a consequence of health

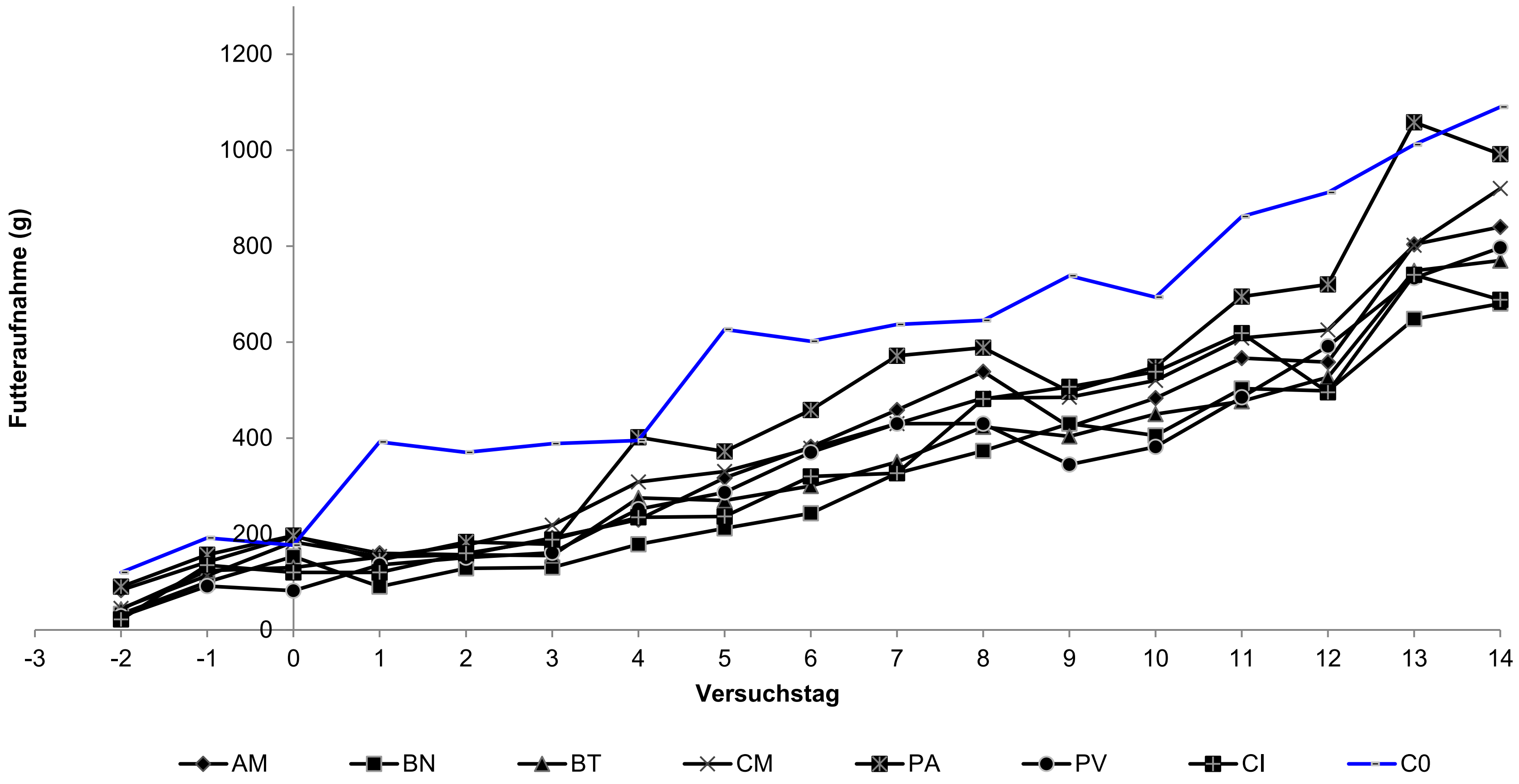
Scientific evaluation

- Biomarkers

I				II
Immune function	Oxidative/ antioxidative indicators	Stress axis	Expression studies	Systems biology
Inflamma-tory indicators	Trolox	Cortico-steroids	Transcriptomes	Meta-omics
Immuno-globulins	ROS	DHEA	miRNAs	Networks
Lympho-cytes	GSH, GSSG	Haema-tology	Holo-biomes	GWAS

https://www.pig333.com/tags/diarrhoea/page_2

Feed intake of piglets after an *Escherichia coli* challenge



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DOI: 10.1002/mbo3.923

ORIGINAL ARTICLE

MicrobiologyOpen WILEY

Longitudinal development of the gut microbiota in healthy and diarrheic piglets induced by age-related dietary changes

Qiaoli Yang[1] | Xiaoyu Huang[1] | Pengfei Wang[1] | Zunqiang Yan[1] | Wenyang Sun[1] | Shengguo Zhao[1] | Shuangbao Gun[1,2]

- Diarrhea = reduction of genes involved in carbohydrate metabolism

AVIAN PATHOLOGY, 2016
VOL. 45, NO. 3, 271–274
http://dx.doi.org/10.1080/03079457.2016.1163521

Taylor & Francis
Taylor & Francis Group

REVIEW

Epidemiologic aspects of necrotic enteritis in broiler chickens – disease occurrence and production performance

Magne Kaldhusdal[a], Sylvie L. Benestad[a] and Atle Løvland[b]

[a]Norwegian Veterinary Institute, Oslo, Norway; [b]Nortura SA, Oslo, Norway

ABSTRACT

Since future conventional broiler production can no longer rely upon in-feed antimicrobials (anticoccidials and antibiotic growth promoters), understanding the most important non-antimicrobial factors influencing occurrence of necrotic enteritis (NE) in poultry will become urgent. Solid population-based data on NE occurrence are scarce. Additionally, data on cholangiohepatitis (CPH) at slaughter is a useful indirect measurement of NE occurrence. Existing data suggest that coccidiosis and nutritional factors are among the most important determinants of NE occurrence. Dietary cereal contents and dietary level of animal proteins can both influence NE occurrence, but cereal composition may be more important because cereals constitute a larger portion of the diet. Losses associated with NE vary depending on the severity of the disease, but data indicate that the farmers' profit may be reduced on average with as much as one third during an epidemic of clinical disease.

ARTICLE HISTORY
Received 15 December 2015
Accepted 24 February 2016

KEYWORDS
Epidemiology; cholangiohepatitis; cereal composition; fishmeal; economic loss

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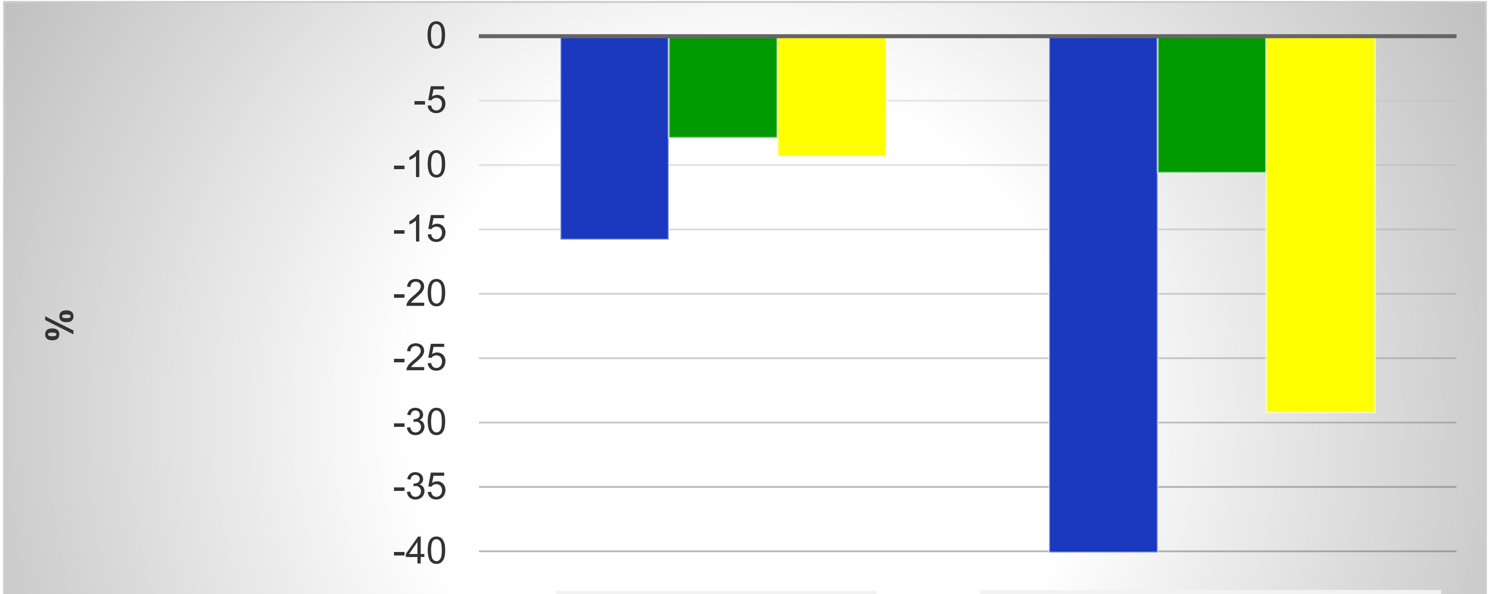
- Meta-analysis from challenge trials with broilers



	Feed intake	Daily weight gain
Clostridium perfringens	-15,8	-40,1
Escherichia coli	-7,9	-10,6
Salmonella spp.	-9,3	-29,2

Remus et al. 2014

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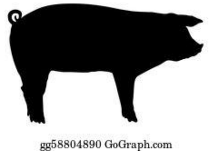
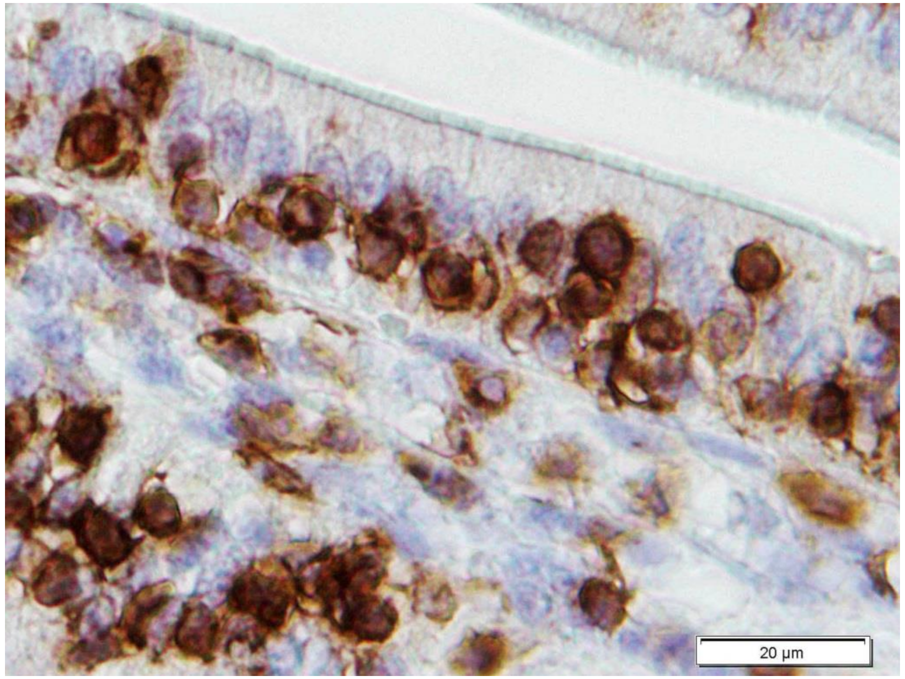
- Largest immune organ
- Interaction with microbiota, diet, environment
- Key role in barrier function and metabolism

- Gut = biggest immune organ
- Largest surface of the body



  - Microbiota
  - Feed antigens
  - Environment

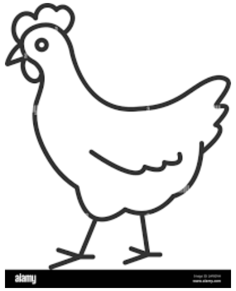


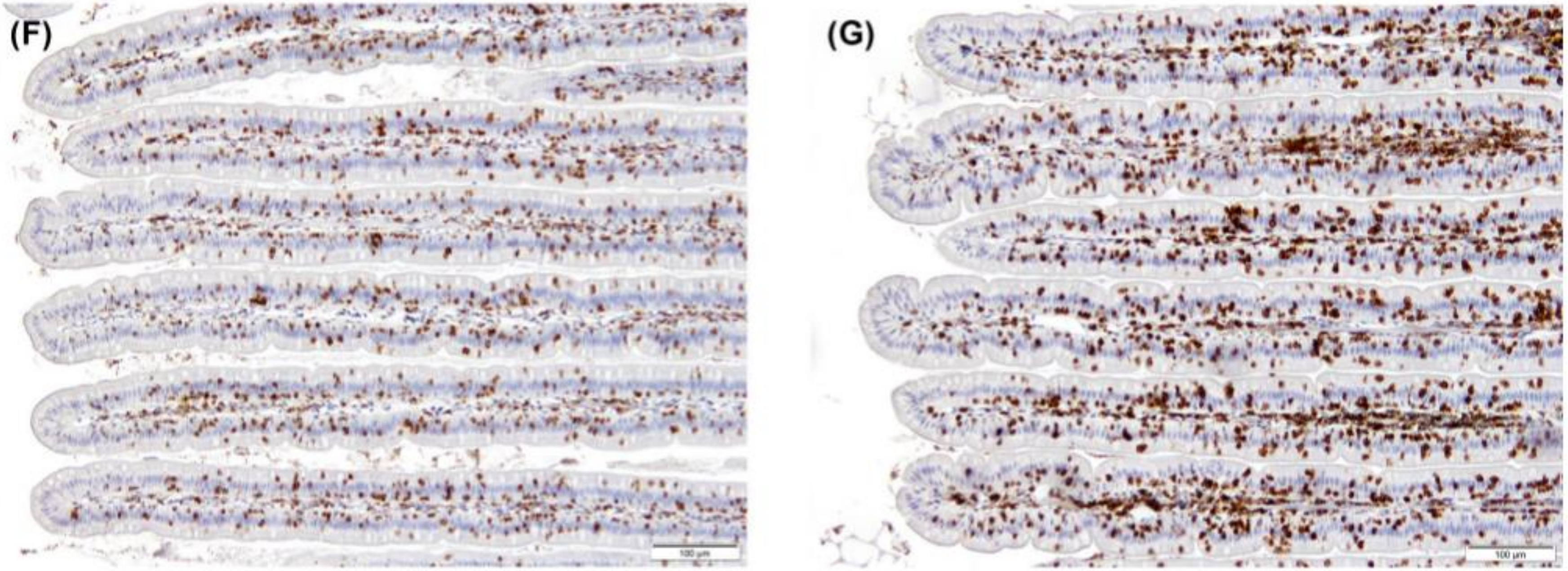
Ferrara 2012

• Gut = same in chicken

CD45+ leukocytes of broilers fed the control diet (F) or the fermented pea diet (G)

- Microbiota
- Feed antigens
- Environment

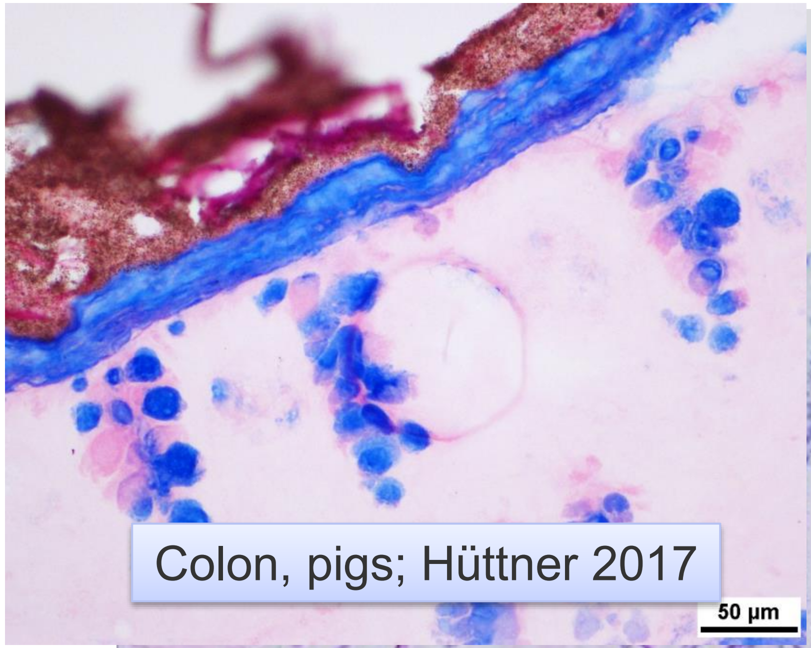




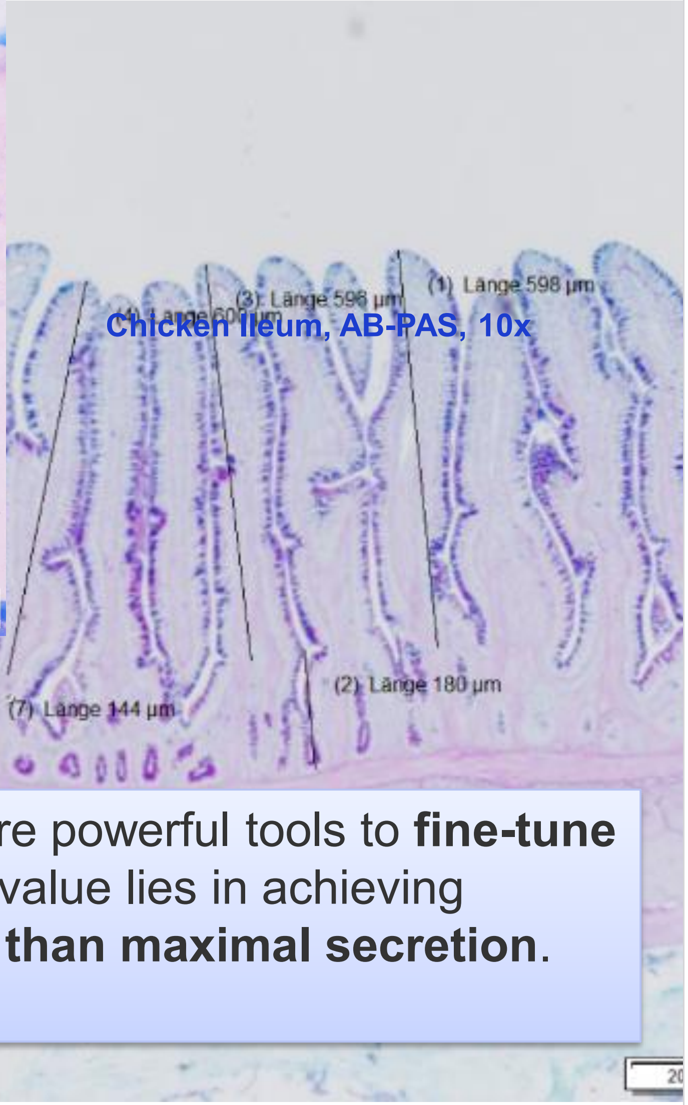
Soybean extraction meal

Peas

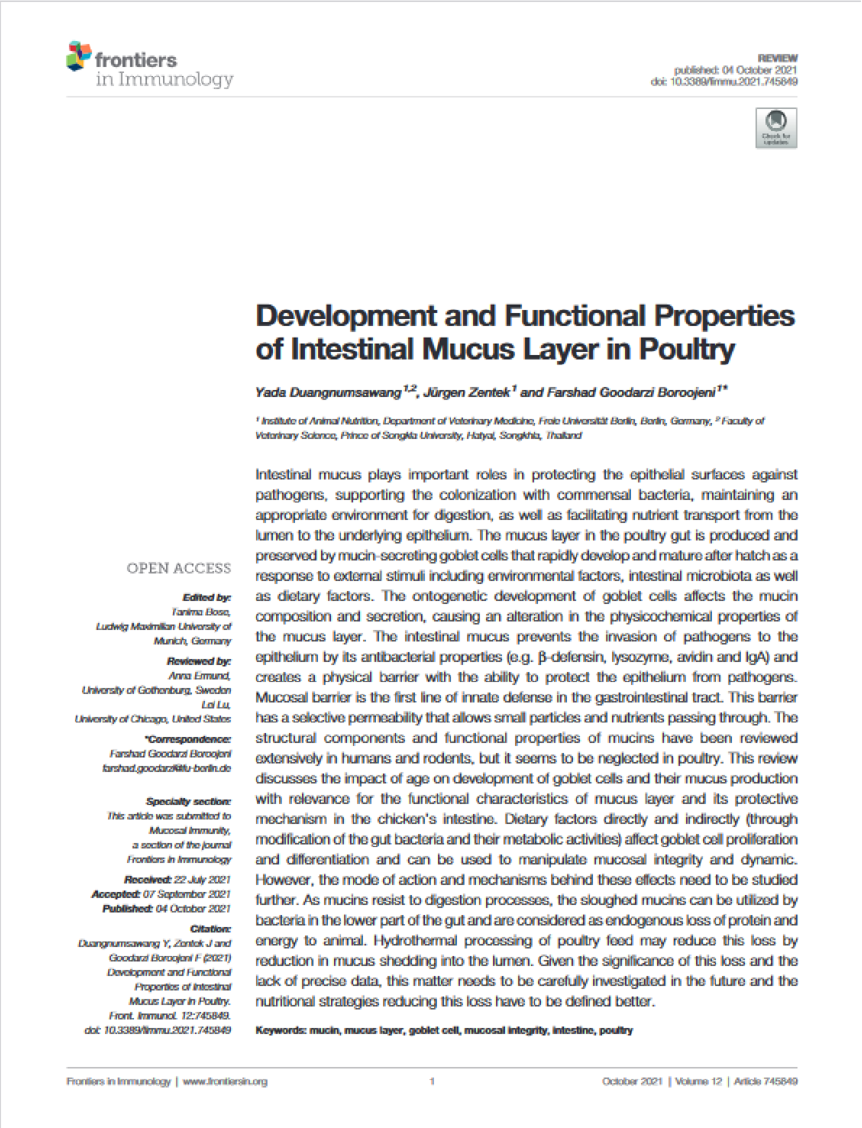
Röhe et al. 2017



Colon, pigs; Hüttner 2017



Conclusion: Feed additives are powerful tools to **fine-tune the mucus barrier**, but their value lies in achieving **functional efficiency rather than maximal secretion**.



frontiers in Immunology

REVIEW
published: 04 October 2021
doi: 10.3389/fimmu.2021.745849

Development and Functional Properties of Intestinal Mucus Layer in Poultry

Yada Duangnumsawang[1,2]*, Jürgen Zentek*[1] *and Farshad Goodarzi Boroojeni*[1*]

[1] *Institute of Animal Nutrition, Department of Veterinary Medicine, Freie Universität Berlin, Berlin, Germany,* [2] *Faculty of Veterinary Science, Prince of Songkla University, Hatyai, Songkhla, Thailand*

Intestinal mucus plays important roles in protecting the epithelial surfaces against pathogens, supporting the colonization with commensal bacteria, maintaining an appropriate environment for digestion, as well as facilitating nutrient transport from the lumen to the underlying epithelium. The mucus layer in the poultry gut is produced and preserved by mucin-secreting goblet cells that rapidly develop and mature after hatch as a response to external stimuli including environmental factors, intestinal microbiota as well as dietary factors. The ontogenetic development of goblet cells affects the mucin composition and secretion, causing an alteration in the physicochemical properties of the mucus layer. The intestinal mucus prevents the invasion of pathogens to the epithelium by its antibacterial properties (e.g. β-defensin, lysozyme, avidin and IgA) and creates a physical barrier with the ability to protect the epithelium from pathogens. Mucosal barrier is the first line of innate defense in the gastrointestinal tract. This barrier has a selective permeability that allows small particles and nutrients passing through. The structural components and functional properties of mucins have been reviewed extensively in humans and rodents, but it seems to be neglected in poultry. This review discusses the impact of age on development of goblet cells and their mucus production with relevance for the functional characteristics of mucus layer and its protective mechanism in the chicken's intestine. Dietary factors directly and indirectly (through modification of the gut bacteria and their metabolic activities) affect goblet cell proliferation and differentiation and can be used to manipulate mucosal integrity and dynamic. However, the mode of action and mechanisms behind these effects need to be studied further. As mucins resist to digestion processes, the sloughed mucins can be utilized by bacteria in the lower part of the gut and are considered as endogenous loss of protein and energy to animal. Hydrothermal processing of poultry feed may reduce this loss by reduction in mucus shedding into the lumen. Given the significance of this loss and the lack of precise data, this matter needs to be carefully investigated in the future and the nutritional strategies reducing this loss have to be defined better.

Keywords: mucin, mucus layer, goblet cell, mucosal integrity, intestine, poultry

OPEN ACCESS

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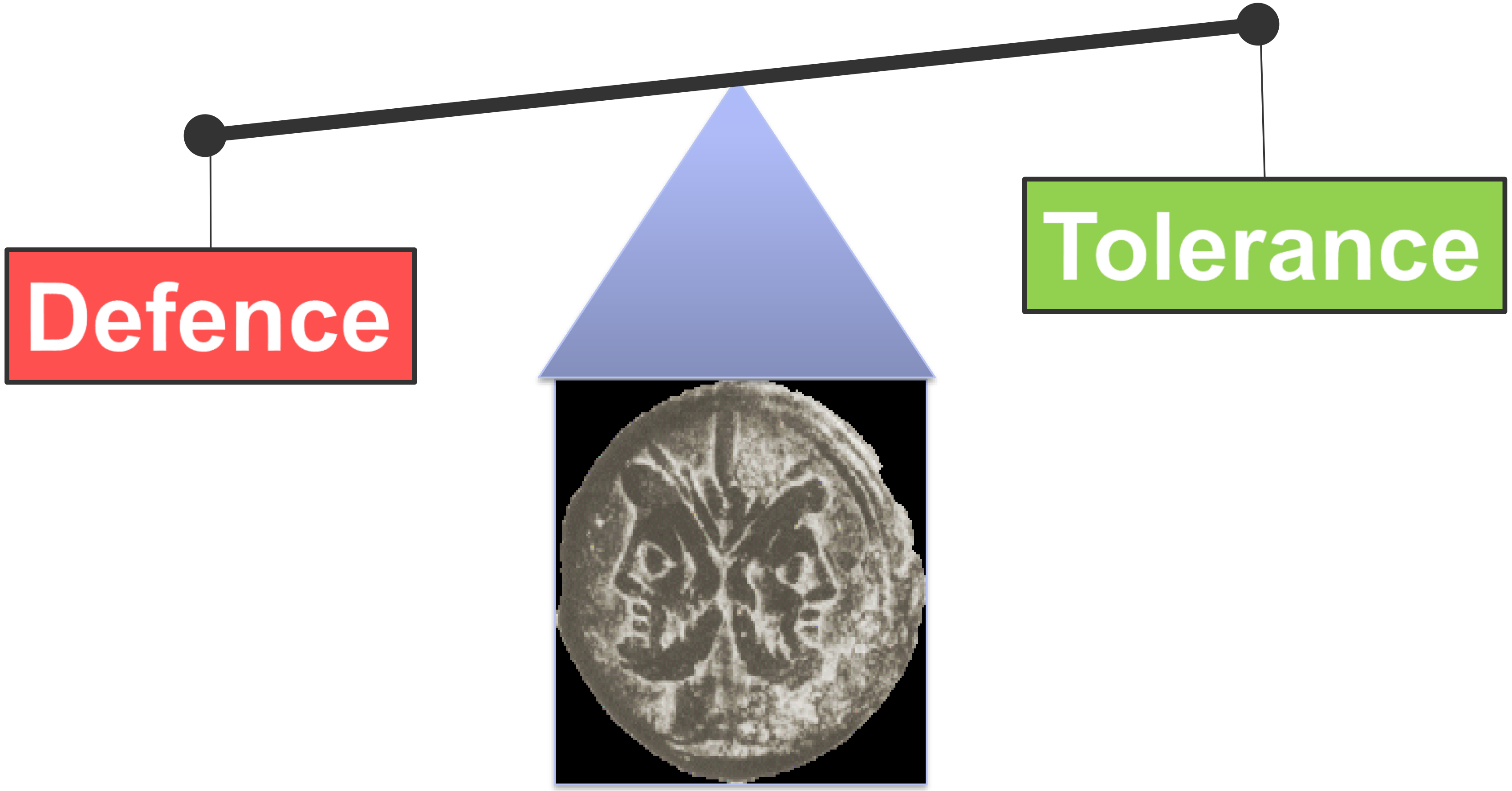
Frontiers in Immunology | www.frontiersin.org 1 October 2021 | Volume 12 | Article 745849

- Balance



How health starts…

https://www.hypor.com/de/news/hypor-leitfaden-fur-ein-effektives-abferkeKManagement/

Landwirtschaftskammer.de

Bayerische Landesanstalt für Landwirtschaft

- Birth canal + coprophagy = Early microbial colonisation
  - Piglets eat approx. 20 g faeces + litter/d (Sansom & Gleed, 1981)
  - Coprophagy in the first 7 days (Aviles-Rosa et al. 2019):
    - 25 % leucocytes ↗
    - Feed intake ↗
    - Weight gain ↗
    - Final weight: 9.6 kg > Piglets without coprophagy

Sow-piglet-couple

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Animal Science Journal

Animal Science Journal (2016) **87,** 1501–1510 doi: 10.1111/asj.12565

ORIGINAL ARTICLE

Dietary administration of probiotics to sows and/or their neonates improves the reproductive performance, incidence of post-weaning diarrhea and histopathological parameters in the intestine of weaned piglets

Teruo HAYAKAWA,[1] Tomohide MASUDA,[1] Daisuke KUROSAWA[1] and Takamitsu TSUKAHARA[2]

[1]*TOA Pharmaceutical, Sasazuka, Shibuya, Tokyo, and* [2]*Kyoto Institute of Nutrition and Pathology, Ujitawara, Kyoto, Japan*

ABSTRACT

Probiotics have gained considerable attention with respect to their beneficial effects on livestock performance and health. The most significant effects of probiotics on the gut microbiota and the host animals take place when they are included in diets during particularly stressful periods such as weaning and/or at the beginning of the lactation period. The probiotics *Bacillus mesentericus* strain TO-A at 1×10^8 colony forming units (CFU)/g, *Clostridium butyricum* strain TO-A at 1×10^8 CFU/g and *Enterococcus faecalis* strain T-110 at 1×10^9 CFU/g were used. Litter weight at delivery and ratio of return to estrous improved significantly (17% and 24% improvement, respectively) by probiotic administration to sows (0.2% (w/w)). Furthermore, the feed intake of the probiotics-administered sows was greater than that of the control sows during the late lactation period. Post-weaning diarrheal incidence and growth performance was improved by probiotics administration to neonates (0.02% (w/w)), while the combined use of probiotics in sows and their neonates induced the enlargement of villous height and prevented muscle layer thinning in the small intestine of weaning piglets. The administration of probiotics of three species of live bacteria improved the porcine reproductive performance around stressful periods of sows (farrowing) and piglets (weaning). [Corrections added on 26 April 2016, after first online publication: '*Enterococcus faecalis* strain T-100' has been corrected to '*Enterococcus faecalis* strain T-110' in the above paragraph and in the 'Probiotics' section under the Materials and Methods heading.]

Key words: *diarrhea incidence, probiotics, reproductive performance, sow, weaning piglets.*

Performance, diarrhea incidence, and occurrence of *Escherichia coli* virulence genes during long-term administration of a probiotic *Enterococcus faecium* strain to sows and piglets[1]

D. Taras,[2] W. Vahjen, M. Macha, and O. Simon

Institute of Animal Nutrition, Faculty of Veterinary Medicine, Free University Berlin, 14195 Germany

ABSTRACT: As part of an interdisciplinary research project, the performance response of sows and their litters to the probiotic strain *Enterococcus faecium* NCIMB 10415, as well as some health characteristics of the piglets, were studied. Gestating sows (n = 26) were randomly allotted into 2 groups. The probiotic was administered by dietary supplementation to 1 group of sows and their respective litters (probiotic group), whereas the second group (control group) received no probiotic supplementation. The duration of the treatment was nearly 17 wk for sows (d 90 ante partum until d 28 postpartum) and 6 wk for piglets (d 15 to 56). Body weight and feed consumption were recorded weekly. The frequency of 4 toxin and 5 adhesion genes of putative pathogenic *Escherichia coli* was monitored weekly (d 7 to 35) by multiplex PCR assays, and fecal consistency of weaned piglets was studied daily. Probiotic treatment of lactating sows led to an overall preweaning mortality of 16.2% compared with 22.3% in the control group ($P = 0.44$). Animal losses during the first 3 d of the suckling period were decreased in the probiotic group ($P = 0.09$). For piglets (n = 153), which were weaned at 28 d, there were no overall treatment differences in BW gain, feed intake, or feed efficiency. Probiotic supplementation, however, led to nearly a 40% reduction ($P = 0.012$). The actual percentage of piglets with postweaning diarrhea in the probiotic group was 21% compared with 38% in the control group ($P = 0.05$). The study on virulence factors of dominant fecal *E. coli* isolates revealed a high diversity with varying frequency and distribution of each single pathogenicity gene. The 440 isolates carried 29 different pathogenicity gene combinations as well as each of the 9 pathogenicity genes alone. Altogether, isolates with more than 2 pathogenicity genes were quite rare (≤10%), and up until d 28 isolates without any pathogenicity gene occurred most frequently. Depending on the time of sampling, one-third or more of all isolates contained est2 or est1b as single gene or in combination with other pathogenicity genes.

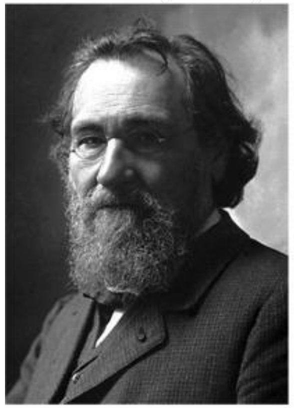
Key words: *Enterococcus faecium* NCIMB 10415, diarrhea, pathogenicity genes, performance, pig, probiotics

 J. Anim. Sci. 2006. 84:608–617

- Eubiosis = Balanced microbial colonization

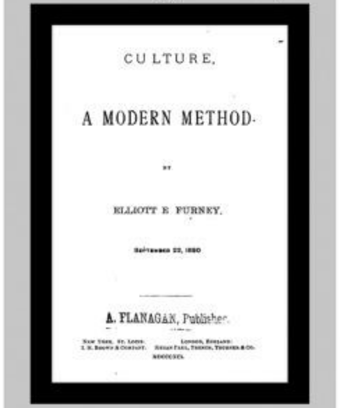
- Dysbiosis = disturbed balance

Élie Metchnikoff (1845–1916)



'Problem[s] … in the digestive tract can only be solved by long-term research on the intestinal flora of humans and animals in the normal and pathological state' (5, p. 932)

Elliott Furney (1848–c1910)

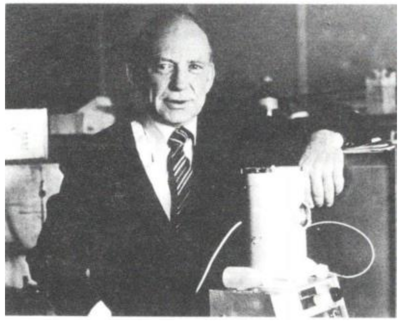


'Eubiosis, living made easy, and Dysbiosis, difficult living' (8, p. 23)

C. Arthur Scheunert (1879–1957)

'I believe that extensive knowledge is to be expected here, and that dysbiosis of the intestinal flora, as I shall call it, may play a decisive role' (9, p. 121)

Hooks KB, O'Malley MA. 2017. Dysbiosis and its discontents. mBio 8:e01492-17. https://doi.org/10.1128/mBio.01492-17



Ernährungsforschung 24, 1979

Sitzung vom 24. November 1959

Vorsitz: Prof. Dr. K. Lohmann.

HAENEL, H. (Potsdam-Rehbrücke): **Makroorganismus und Mikrobiocönose.** Der Stoffwechsel des Makroorganismus kann nicht isoliert betrachtet werden, er steht in ständigen Wechselbeziehungen zu mikroorganismischen Lebensvorgängen. Sie gehen von den Mikrobiocönosen, den mikroskopischen Lebensgemeinschaften der verschiedenen Organe, besonders des Darmes aus. — Es wird über Versuche berichtet, diese Mikrobiocönosen des menschlichen und tierischen Körpers durch selektive Kulturverfahren in einzelne Keimgruppen quantitativ aufzugliedern, Gesetzmäßigkeiten in der Zusammensetzung festzustellen und die Grenzen der „normalen" Zusammensetzung — als Eubiose bezeichnet — von der „gestörten" Zusammensetzung — der Dysbiose — abzugrenzen. — In der Darmflora des Erwachsenen besteht die züchtbare Flora vorwiegend aus anaeroben Lactobacillen und Fäulnisbakterien, konstant begleitet von einer Minderheit anderer Keimarten. Diese Besiedlung ist im ganzen Dickdarm etwa gleich, während die Keimzahlen im Magen und Dünndarm niedriger liegen. Kriterien der Dysbiose sind besonders das Fehlen der anaeroben Lactobacillen unter Zunahme aerober Keime und stärkere Aszension von Dickdarmkeimen in den Dünndarm. Beim

Verhandlungen ärztlicher Gesellschaften 1960

microorganisms

MDPI

Review

Timely Control of Gastrointestinal Eubiosis: A Strategic Pillar of Pig Health

Paolo Trevisi *, Diana Luise, Federico Correa and Paolo Bosi

Department of Agricultural and Food Sciences (DISTAL), University of Bologna, 40127 Bologna, Italy; diana.luise2@unibo.it (D.L.); federico.correa2@unibo.it (F.C.); paolo.bosi@unibo.it (P.B.)
* Correspondence: paolo.trevisi@unibo.it

Abstract: The pig gastrointestinal tract (GIT) is an open ecosystem in which microorganisms and their host are mutually involved and continually adapt to different factors and problems which may or may not be host dependent or due to the production system. The aim of the present review is to highlight the factors affecting the GIT microbial balance in young pigs, focusing on the pre- and post-weaning phases, to define a road map for improving pig health and the production efficiency of the food chain. Birth and weaning body weight, physiological maturation, colostrum and milk (composition and intake), genetic background, environmental stressors and management practices, antibiotic use and diet composition are considered. Overall, there is a lack of knowledge regarding the effect that some factors, including weaning age, the use of creep feed, the composition of the colostrum and milk and the use of antibiotics, may have on the gut microbiome of piglets. Furthermore, the information on the gut microbiome of piglets is mainly based on the taxonomy description, while there is a lack of knowledge regarding the functional modification of the microbiota, essential for the exploitation of microbiota potential for modulating pig physiology.

Keywords: weaning transition; gut microbiota; milk; antibiotic; genetics; diet

Citation: Trevisi, P.; Luise, D.; Correa, F.; Bosi, P. Timely Control of

Enokela *et al. Animal Microbiome* (2026) 8:41
https://doi.org/10.1186/s42523-026-00541-0

Animal Microbiome

REVIEW

Open Access

Towards standardization in pig microbiome research based on a comprehensive twenty-year review

Samuel Onyilokwu Enokela[1,7], Timur Yergaliyev[1,7], Krzysztof Flisikowski[2], Stéphanie Céline Hornburg[3], Henry Reyer[4], Jens Tetens[5], Klaus Wimmers[4], Jürgen Zentek[6] and Amélia Camarinha-Silva[1,7*]

Abstract
The pig microbiome plays a crucial role in animal health, productivity, and meat quality. This comprehensive review analyzed 438 publications on pig microbiome studies from 2003 to 2023, focusing on experimental methodologies, bioinformatic tools, sequencing approaches, and metadata reporting practices. It critically analyzes the variability introduced by different DNA extraction methods, sequencing platforms, and bioinformatics pipelines, emphasizing their impacts on reproducibility and data comparability. We identify critical gaps in metadata reporting, particularly in DNA extraction protocols and bioinformatic workflows. To address these issues, we propose a standardized metadata template for pig microbiome studies, integrating Genomic Standards Consortium guidelines with project-specific criteria. This review provides a framework for developing standardized protocols in pig microbiome research, aiming to improve reproducibility and facilitate cross-study comparisons.

Keywords Metadata, Pig, Standardization, Microbiome

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- Major Bacterial Phyla:

Firmicutes

- Beneficial genera like *Lactobacillus*, *Clostridium*, and *Ruminococcus*
- Fiber degradation, fermentation
- SCFAs, which support gut health

Bacteroidetes

- Breaking down complex polysaccharides
- Key role in energy extraction from feed

Proteobacteria

- Overrepresentation of Proteobacteria (e.g., *Escherichia coli*, *Salmonella*)
- Often associated with dysbiosis and gut inflammation

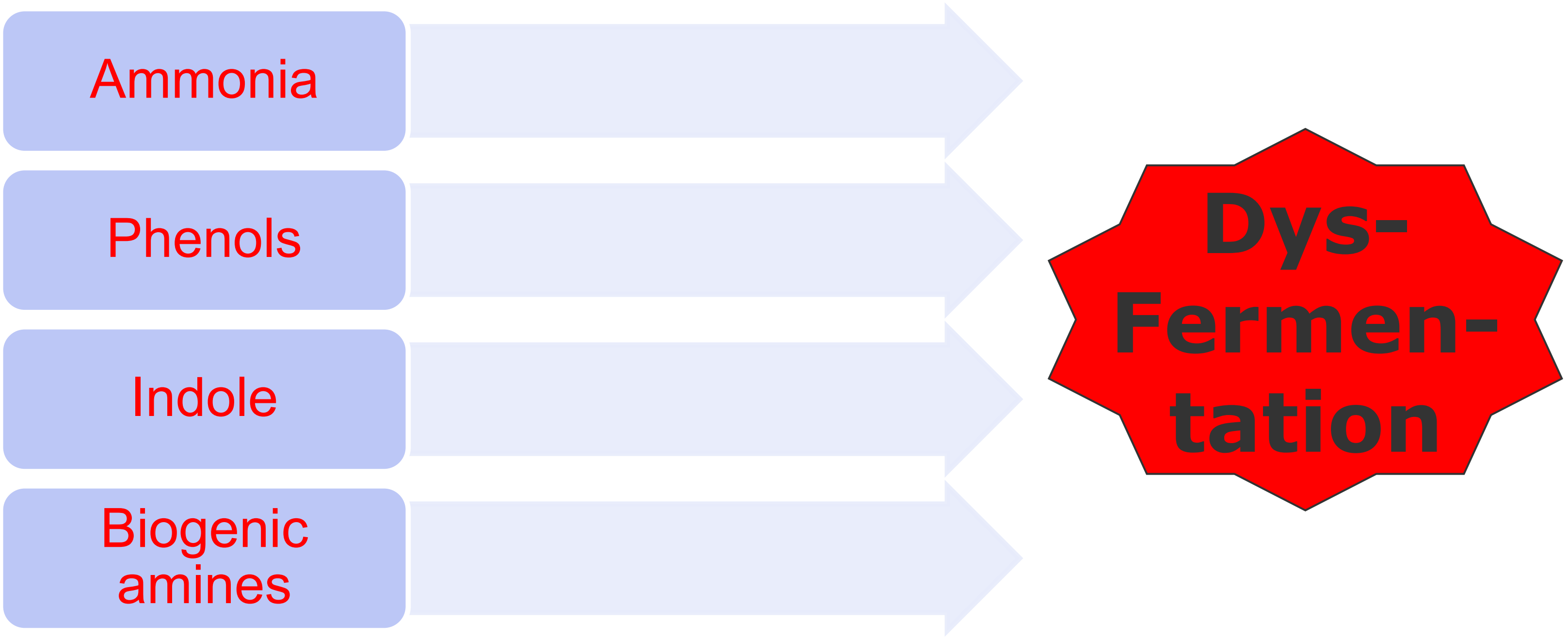
Actinobacteria

- Includes beneficial microbes such as *Bifidobacterium*
- Associated with maintaining gut integrity and outcompeting pathogens

- Higher diversity might be beneficial
- Consider the gut as ecosystem

~ 1000 different species

- Active proteolytic microbial community in the hindgut – what are they doing?
  - *Bacteroides, Clostridium, Fusobacterium, Streptococcus,* and *Enterococcus* spp.



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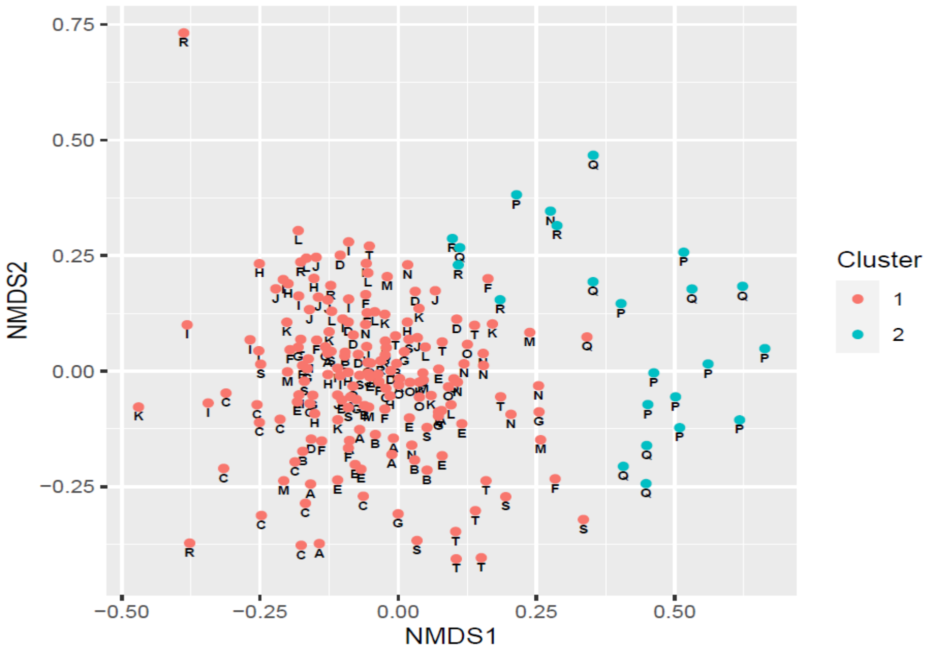

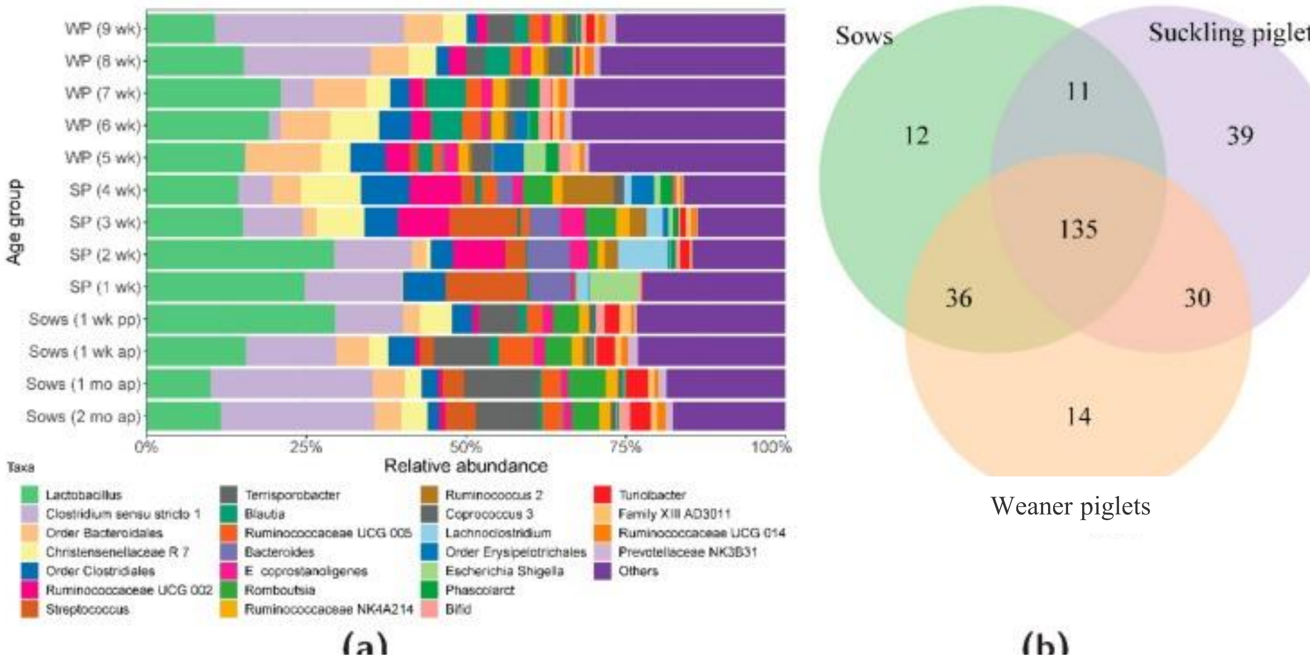

Łukasz Grześkowiak

PLOS ONE

RESEARCH ARTICLE

Characterization of the fecal microbiota of sows and their offspring from German commercial pig farms

Anja Lührmann[1]*, Ksenia Ovadenko[2], Justinus Hellmich[1], Christoph Sudendey[1], Vitaly Belik[2], Jürgen Zentek[1], Wilfried Vahjen[1]

1 Department of Veterinary Medicine, Institute of Animal Nutrition, Freie Universität Berlin, Berlin, Germany, 2 Department of Veterinary Medicine, System Modeling Group, Institute of Veterinary Epidemiology and Biostatistics, Freie Universität Berlin, Berlin, Germany

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Check for updates

microorganisms MDPI

Article

Developing Gut Microbiota Exerts Colonisation Resistance to *Clostridium* (syn. *Clostridioides*) *difficile* in Piglets

Łukasz Grześkowiak *, Temesgen Hailemariam Dadi, Jürgen Zentek and Wilfried Vahjen

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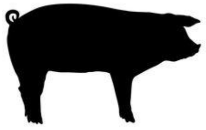
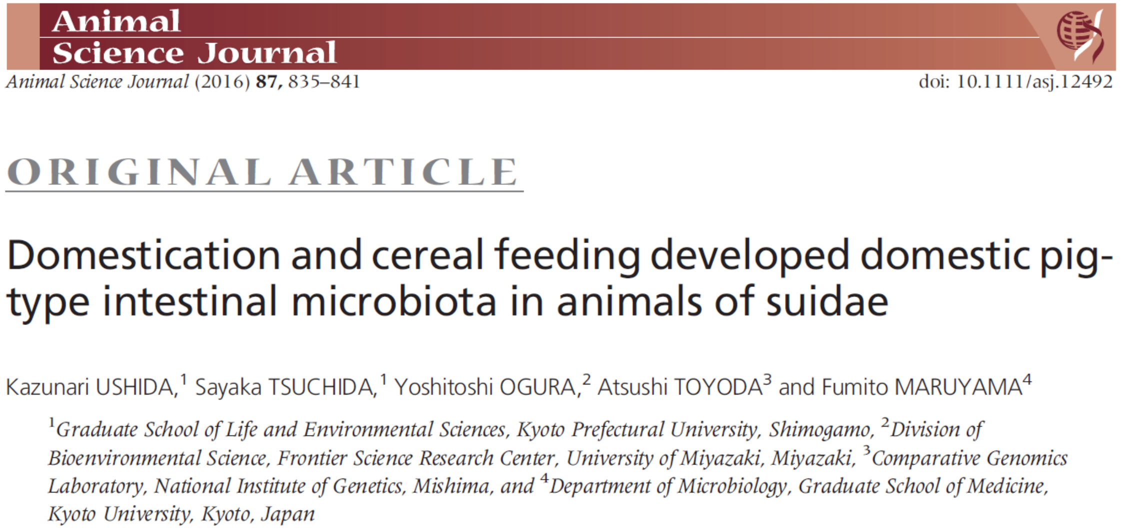


- Wild boar → Bifidobacteria ↗
- Domesticated pigs or wild boar kept in captivity → *Lactobacillus* spp. + *Enterobacteriaceae* ↗

Ushida et al. 2016


Animal Science Journal
Animal Science Journal (2016) **87,** 835–841 doi: 10.1111/asj.12492

ORIGINAL ARTICLE

Domestication and cereal feeding developed domestic pig-type intestinal microbiota in animals of suidae

Kazunari USHIDA,[1] Sayaka TSUCHIDA,[1] Yoshitoshi OGURA,[2] Atsushi TOYODA[3] and Fumito MARUYAMA[4]

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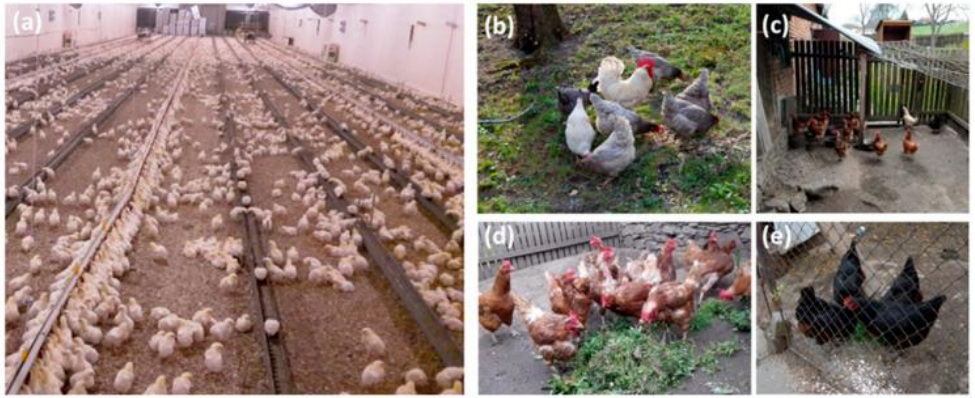

microorganisms

MDPI

Article

Environmental Impact on Differential Composition of Gut Microbiota in Indoor Chickens in Commercial Production and Outdoor, Backyard Chickens

Zuzana Seidlerova, Tereza Kubasova, Marcela Faldynova, Magdalena Crhanova, Daniela Karasova, Vladimir Babak and Ivan Rychlik *

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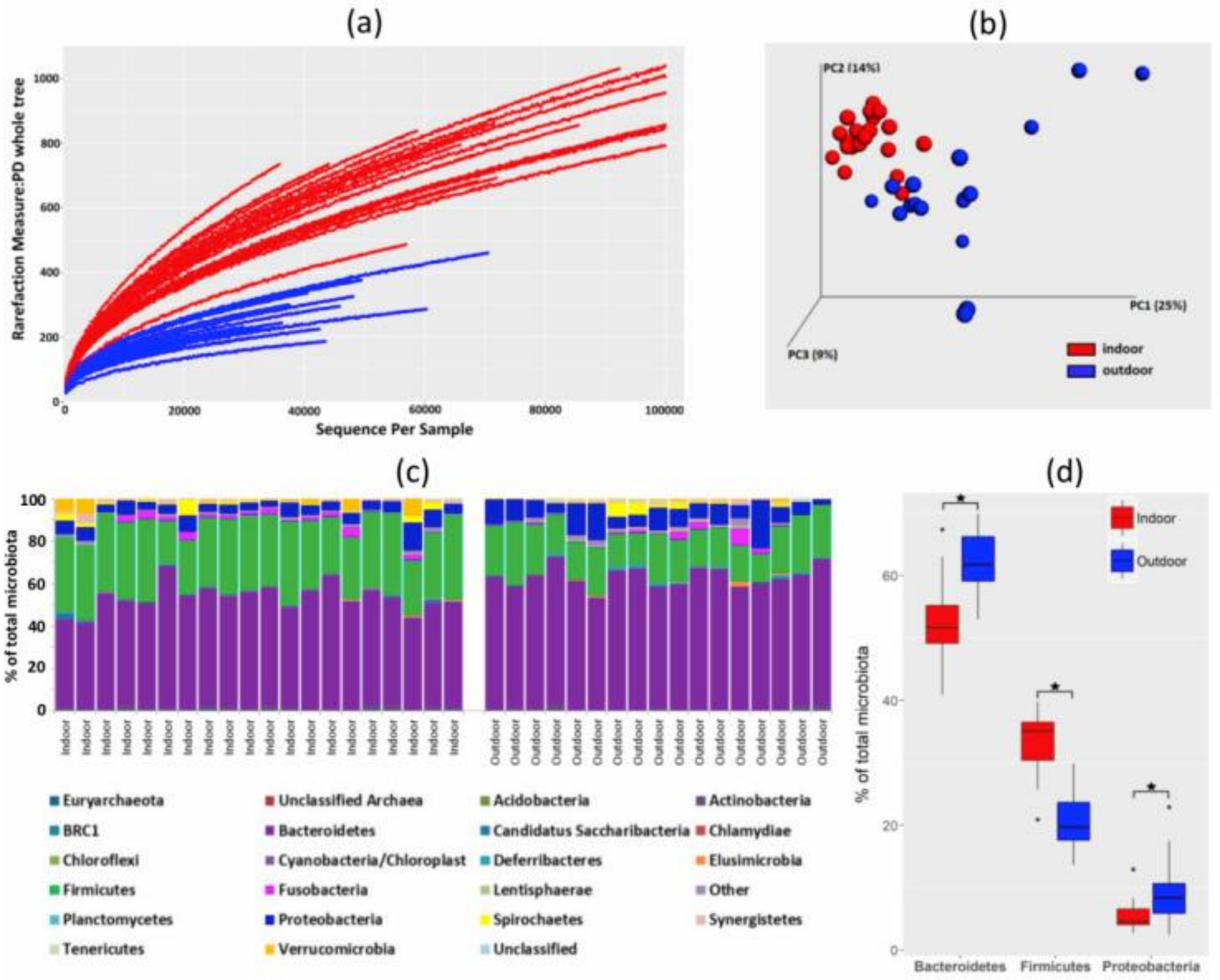

1. The Big Picture: Rethinking Animal Health and Welfare

2. The Gut as a Central Hub
(Linking digestion, microbiome, and immunity)

3. Intervention Points: Feed Additives as Tools

4. Future Directions: From Efficiency to Resilience

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- Improved growth and feed efficiency
- Health and immune modulation
- Potential AMU replacement

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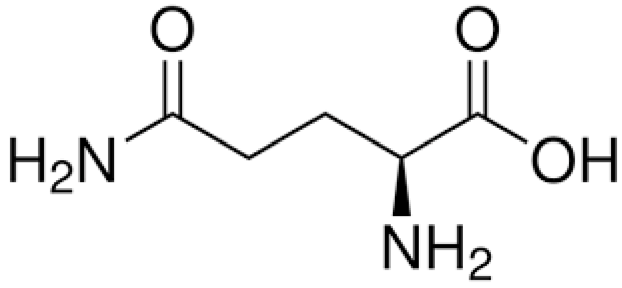
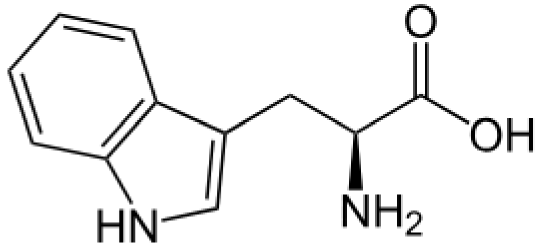
- Functional classification (EU categories)

1. **Technological additives**
2. Sensory additives
3. **Nutritional additives**
4. **Zootechnical additives**
    - Improve animal performance or environment
    - Examples: digestibility enhancers, gut flora stabilizers
5. **Coccidiostats** and histomonostats

Additives	Effects	
	Microbiota	Other effects
Trace elements Cu, Zn	√	Immune system, gut physiology
Acids, salts	√	Diarrhea ↓
Enzymes	√	Digestive physiology ↑
Probiotics	√	Diverse
Non digestible carbohydrates	√	Microbiota, immune system
Phytogenic additives	√	Immune system, digestion

- Amino acids (AAs)
  - Essential for growth
  - Functional roles in gut health
  - Key examples
    - Glutamine
    - Tryptophan





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	Energy substrates	Immunity and health	Antioxidative defense	Protein synthesis
Arginine	Precursor of Creatine	Precursor of Nitric Oxide		• Modulates mTOR activity • Precursor of polyamines
Glutamine	Metabolic fuel for enterocytes	Metabolic fuel for lymphocytes	Precursor of glutathione	Modulates mTOR activity
Glycine			Precursor of glutathione	
Threonine		Rich in immunogloulins and mucins		
Cysteine		Rich in mucins	Precursor of glutathione	
Tryptophane		Critical for macrophage and lymphocyte function		
BCAA/Leucine	Precursor of glutamine			Modulates mTOR activity

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• Glutamine a "miracle amino acid“?

Sow +

Received: 15 January 2022 | Accepted: 23 May 2022
DOI: 10.1002/mrd.23614

REVIEW ARTICLE

Molecular Reproduction & Development

Preweaning performance in intrauterine growth-restricted piglets: Characteristics and interventions

Chris Van Ginneken | Miriam Ayuso | Lieselotte Van Bockstal | Steven Van Cruchten

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Funding information
Agency for Innovation by Technology, Grant/Award 100856; Flanders Innovat Entrepreneurship, Grant/ HBC.2016.0786; Universi Grant/Award Number: G

Abstract
Intrauterine growth restriction (IUGR) is frequently observed in pig production, especially when using highly prolific sows. IUGR piglets are born with low body weight and shape indicative of differences in organ growth. Insufficient uteroplacental nutrient transfer to the fetuses is the leading cause of growth restriction in the pig. Supplementing the sow's gestation diet with arginine and/or glutamine improves placenta growth and functionality and consequently is able to reduce IUGR incidence. IUGR piglets are at higher risk of ...

Translational Animal Science, 2022, 7, 1–9
https://doi.org/10.1093/tas/txac169
Advance access publication 25 December 2022
Sustainable Animal Science and Practices

OXFORD

Impact of dietary supplementation of L-Arginine, L-Glutamine, and the combination of both on nursing performance of multiparous sows

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[‡]METEX NOOVISTAGO, Paris, France
[1]Corresponding author: anna.wessels@fu-berlin.de

ABSTRACT
Dietary supplementation with arginine (Arg) or glutamine (Gln) has been considered as an option to improve nursing performance in reproductive sows. ...

Key words: arginine, glutamine, lactating sow, nursing performance, piglet, weaning homogeneity

PLOS ONE

microorganisms

microorganisms MDPI

Article

Effects of Oral Glutamine Supplementation, Birthweight and Age on Colonic Morphology and Microbiome Development in Male Suckling Piglets

Johannes Schulze Holthausen [1,*], Johannes Schregel [2], Quentin L. Sciascia [2], Zeyang Li [2], Armin Tuchscherer [3], Wilfried Vahjen [1], Cornelia C. Metges [2] and Jürgen Zentek [1]

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Journal of Animal Science, 2025, 103, skaf296
https://doi.org/10.1093/jas/skaf296
Advance access publication 30 August 2025
Non Ruminant Nutrition

OXFORD

Association of glutamine supplementation durin the early suckling period with growth, weaning, lipopolysaccharide induced stress in low birthwe piglets

Quentin Leon Sciascia[†], Johannes Buchallik-Schregel[†,1], Zeyang Li[†,2], Solvig G, Armin Tuchscherer[†], Torsten Viergutz[†], Andreas Höflich[†,‡], Jürgen Zentek[‡], and Cornelia Christiane Metges[†,3]

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Journal of Animal Science, 2025, 103, skaf201
https://doi.org/10.1093/jas/skaf201
Advance access publication 18 June 2025
Metabolism and Metabolomics

OXFORD

Effect of oral glutamine supplementation on growth and glutamine and glucose metabolism in suckling piglets

Quentin L. Sciascia[†], Daria De Leonardis[†], Solvig Görs[†], Andreas Vernunft[†], Anja Eggert[†], Jürgen Zentek[‡], and Cornelia C. Metges[†,1]

[†]Research Institute for Farm Animal Biology (FBN), Nutrition and Metabolism, 18196 Dummerstorf, Germany
[‡]Department of Veterinary Medicine, Institute of Animal Nutrition, Freie Universität Berlin, 14195 Berlin, Germany
[1]Corresponding author: metges@fbn-dummerstorf.de

Abstract
The increase in litter size has led to a higher proportion of low birthweight (LBW) piglets, which are disadvantaged in terms of later growth and organ maturation. ...

Weaner pigs +

TRIENNIAL GROWTH SYMPOSIUM: Important roles for L-glutamine in swine nutrition and production[1,2]

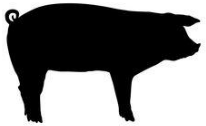
G. Wu,*[3] F. W. Bazer,* G. A. Johnson,* D. A. Knabe,* R. C. Burghardt,* T. E. Spencer,* X. L. Li,* and J. J. Wang*†

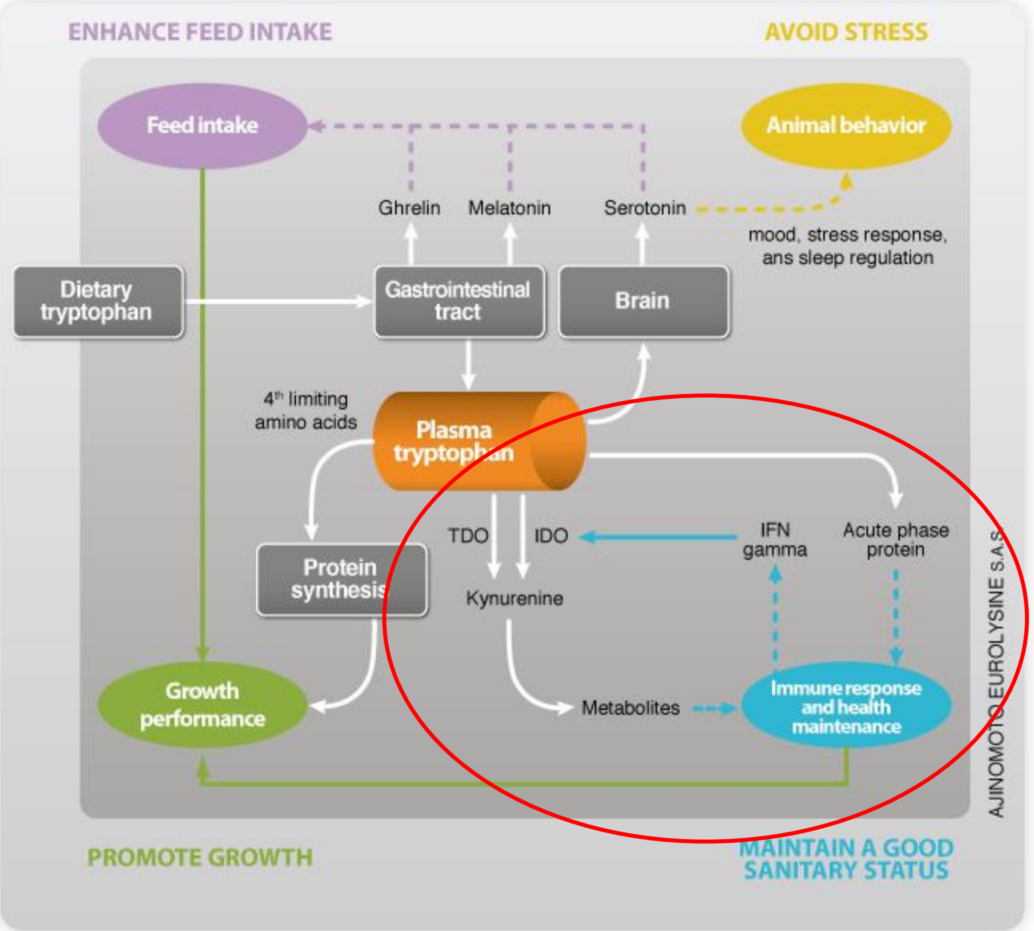
*Departments of Animal Science and of Veterinary Integrative Biosciences, Texas A&M University, College Station 77843; and †State Key Laboratory of Animal Nutrition, China Agricultural University, Beijing, China 100193

ABSTRACT: L-Glutamine (Gln) has traditionally not been considered as a nutrient needed in diets for livestock species or even mentioned in classic animal nutrition textbooks. This is due to previous technical difficulties in Gln analysis and the unsubstantiated assumption that animals can synthesize sufficient ... ide. The exquisite integration of Gln-dependent regulatory networks has profound effects on cell proliferation, differentiation, migration, metabolism, homeostasis, survival, and function. As a result of translating basic research into practice, dietary supplementation with 1% Gln maintains gut health and prevents intestinal dysfunction in low-birth-weight or early-weaned piglets while increasing their growth performance and survival. In addition, supplementing 1% Gln to a corn- and soybean-meal-based diet between d 90 and 114 of gestation ameliorates fetal growth retardation in gilts and reduces preweaning mortality of piglets. Furthermore, dietary supplementation with 1% Gln enhances milk production by lactating sows. Thus, adequate amounts of dietary Gln, a major nutrient, are necessary to support the maximum growth, development, and production performance of swine.

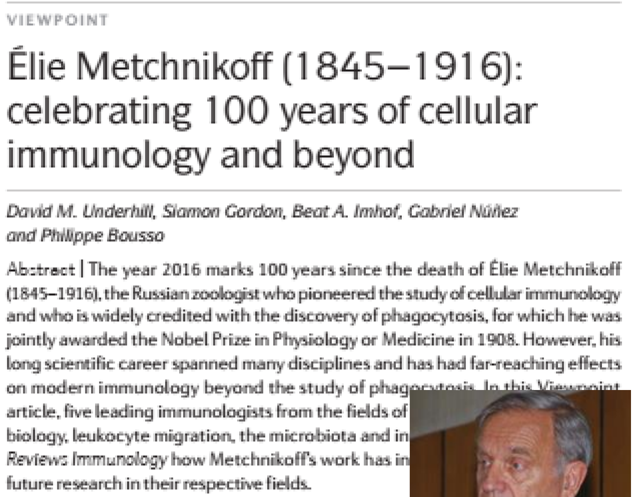
...on, growth, physiology, requirement

- Trp Supplementation @ Gut Health:
  - Support of intestinal morphology (Koopmans et al., 2006)
  - Fewer symptoms of colitis in piglets (Kim et al., 2010)





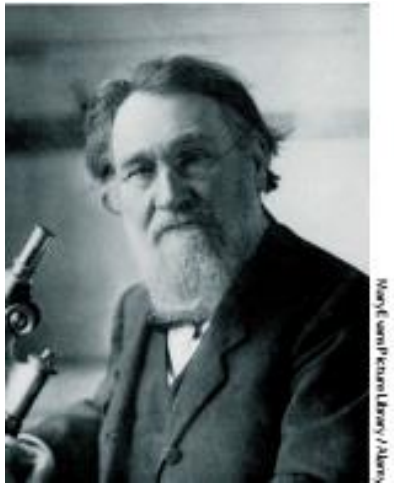
- **Probiotics**
  - Microorganisms
  - Bacteria and yeasts
- **Prebiotics**
  - Carbohydrates that cannot be digested by th
    body's own enzymes
  - Fermentable substrate for the intestinal micr
  - = Feed materials


VIEWPOINT

Élie Metchnikoff (1845–1916): celebrating 100 years of cellular immunology and beyond

David M. Underhill, Siamon Gordon, Beat A. Imhof, Gabriel Núñez and Philippe Bousso

Abstract | The year 2016 marks 100 years since the death of Élie Metchnikoff (1845–1916), the Russian zoologist who pioneered the study of cellular immunology and who is widely credited with the discovery of phagocytosis, for which he was jointly awarded the Nobel Prize in Physiology or Medicine in 1908. However, his long scientific career spanned many disciplines and has had far-reaching effects on modern immunology beyond the study of phagocytosis. In this Viewpoint article, five leading immunologists from the fields of … biology, leukocyte migration, the microbiota and in… *Reviews Immunology* how Metchnikoff's work has in… future research in their respective fields.




Critical Review

Dietary Modulation of the Human Colonic Microbiota: Introducing the Concept of Prebiotics

Bilder: https://www.editions-tredaniel.com/marcel-roberfroid-auteur-4217.html; https://www.reading.ac.uk/food/our-staff/glenn-gibson; http://www.bio-kult.com/userfiles/file/1756_what_exactly_are_probiotics.pdf

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- Effects of probiotics and diarrhoea prophylaxis in piglets

Proceedings of the Nutrition Society (2007), **66**, 260–268 DOI:10.1017/S0029665107005484

Nutritional management of gut health in pigs around weaning

Jean-Paul Lallès[1]*, Paolo Bosi[2], Hauke Smidt[3] and Chris R. Stokes[4]
[1]*INRA, UMR1079, Rearing Systems, Animal and Human Nutrition, F-35590 Saint-Gilles, France*
[2]*Diproval, University of Bologna, Reggio Emilia, Italy*
[3]*Laboratory of Microbiology, Wageningen University, Wageningen, The Netherlands*
[4]*Veterinary Pathology Infection & Immunity, University of Bristol, Langford, UK*

Early weaning of piglets is often accompanied by a severe growth check and diarrhoea. It is well established that this process is multi-factorial and that post-weaning anorexia and under-nutrition are major aetiological factors. Gastrointestinal disturbances include alterations in small intestine architecture and enzyme activities. Recent data indicate transiently-increased mucosal permeability, disturbed absorptive–secretory electrolyte balance and altered local inflammatory cytokine patterns after weaning. These responses appear to operate according to two distinct temporal patterns, an acute response followed by a long-lasting adaptation response. Pigs coexist with a diverse and dense commensal microbiota in their gastrointestinal tract. Most of these microbes are beneficial, providing necessary nutrients or protection against harmful pathogens for the host. The microbial colonisation of the porcine intestine begins at birth and follows a rapid succession during the neonatal and weaning period. Following the withdrawal of sow's milk the young piglets are highly susceptible to enteric diseases partly as a result of the altered balance between developing beneficial microbiota and the establishment of intestinal bacterial pathogens. The intestinal immune system of the newborn piglet is poorly developed at birth and undergoes a rapid period of expansion and specialisation that is not achieved before early (commercial) weaning. Here, new insights on the interactions between feed components, the commensal microbiota and the physiology and immunology of the host gastrointestinal tract are highlighted, and some novel dietary strategies are outlined that are focused on improving gut health. Prebiotics and probiotics are clear nutritional options, while convincing evidence is still lacking for other bioactive substances of vegetable origin.

Pig: Weaning: Diet: Intestine

Journal of Animal Physiology and Animal Nutrition
DOI: 10.1111/j.1439-0396.2012.01284.x

REVIEW ARTICLE

Gastrointestinal health and function in weaned pigs: a review of feeding strategies to control post-weaning diarrhoea without using in-feed antimicrobial compounds

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1 Department of Animal Science, University of Manitoba, Winnipeg, MB, Canada,
2 Animal Research Institute, School of Veterinary and Biomedical Sciences, Murdoch University, Murdoch, WA, Australia, and
3 Animal Research and Development, Department of Agriculture and Food, South Perth, WA, Australia

Keywords
Antimicrobial growth promoters, pigs, dietary protein level, dietary protein source, organic acids, prebiotics, probiotics, post-weaning diarrhoea, trace minerals

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*Authors have made equal contribution to this paper.

Received: 2 June 2011;
accepted: 23 January 2012

Summary

For the last several decades, antimicrobial compounds have been used to promote piglet growth at weaning through the prevention of subclinical and clinical disease. There are, however, increasing concerns in relation to the development of antibiotic-resistant bacterial strains and the potential of these and associated resistance genes to impact on human health. As a consequence, European Union (EU) banned the use of antibiotics as growth promoters in swine and livestock production on 1 January 2006. Furthermore, minerals such as zinc (Zn) and copper (Cu) are not feasible alternatives/replacements to antibiotics because their excretion is a possible threat to the environment. Consequently, there is a need to develop feeding programs to serve as a means for controlling problems associated with the weaning transition without using antimicrobial compounds. This review, therefore, is focused on some of nutritional strategies that are known to improve structure and function of gastrointestinal tract and (or) promote post-weaning growth with special emphasis on probiotics, prebiotics, organic acids, trace minerals and dietary protein source and level.

Kavanova *et al. BMC Microbiology* (2025) 25:8
https://doi.org/10.1186/s12866-024-03711-9
BMC Microbiology
RESEARCH Open Access

In vitro characterization of lactic acid bacteria and bifidobacteria from wild and domestic pigs: probiotic potential for post-weaning piglets

Katerina Kavanova[1,2*], Iveta Kostovova[1], Monika Moravkova[1], Tereza Kubasova[1] and Magdalena Crhanova[1]

Abstract

Background Gastrointestinal diseases in weaned piglets are a frequent cause of high morbidity and mortality in domestic pigs. The use of antibiotics is problematic due to increasing antibiotic resistance in bacterial populations, for which reason the use of suitable probiotics is highly recommended to maintain animal health and welfare.

Results In this study, 57 strains of biologically safe lactic acid bacteria (LAB) and bifidobacteria originating from the gastrointestinal tract (GIT) of pigs were identified and characterized in terms of their probiotic properties for potential use in weaned piglets. These strains were divided into two sets based on their origin – from the GIT of wild boars ($n=41$) and from the GIT of domestic pigs ($n=16$). Strains obtained from wild boars exhibited greater taxonomic diversity compared to isolates from domestic pigs. While searching for coding sequences (CDS) encoding bacteriocins and bile salt hydrolases (BSH), no significant difference was detected between the two tested groups. On the other hand, CDS encoding adhesinlike factors were more frequent in the dataset isolated from wild boars than in the dataset obtained from domestic pigs. Moreover, more CDS encoding carbohydrateactive enzymes (CAZymes) were carried in the genomes of strains obtained from wild boars. Utilization of important selected carbohydrate substrates, such as starch, D-raffinose, D-mannose, Dcellobiose and gentiobiose, was confirmed by API testing. Antimicrobial activity against at least one of the five tested pathogens was found in 51% of wild boar strains but in none of the isolates from domestic pigs.

Conclusion This suggests that the intestinal microbiota of wild boars could serve as a promising source of probiotics for domestic pigs.

Keywords Probiotics, Wild boars, Domestic pigs, Antimicrobial activity, CAZymes, Carbohydrate utilization

2007 2012 2025

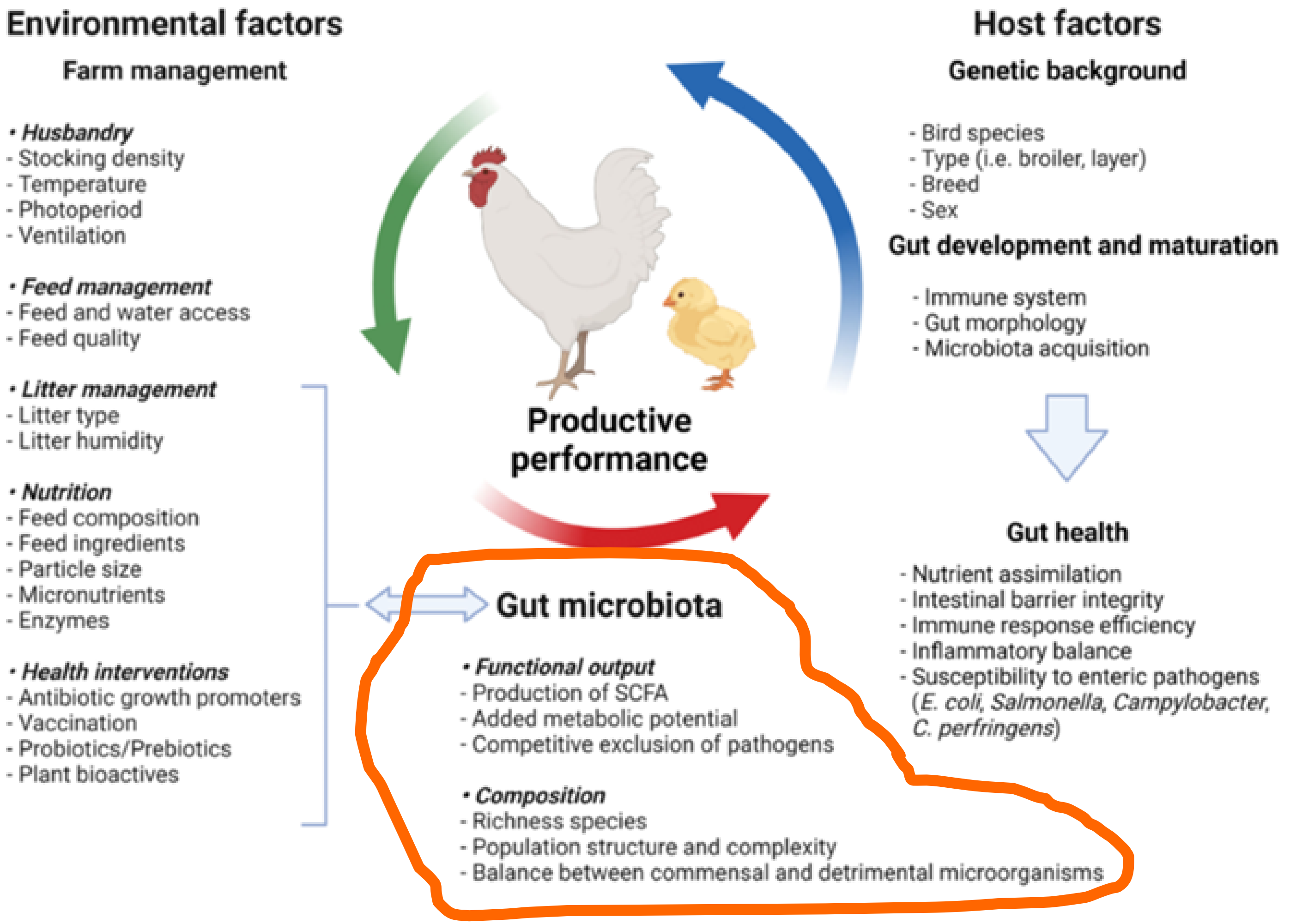


Figure 1. Factors affecting the gut microbiota composition modified according to Carrasco et al. [21] (figure was created with BioRender.com, accessed on 15 December 2021).

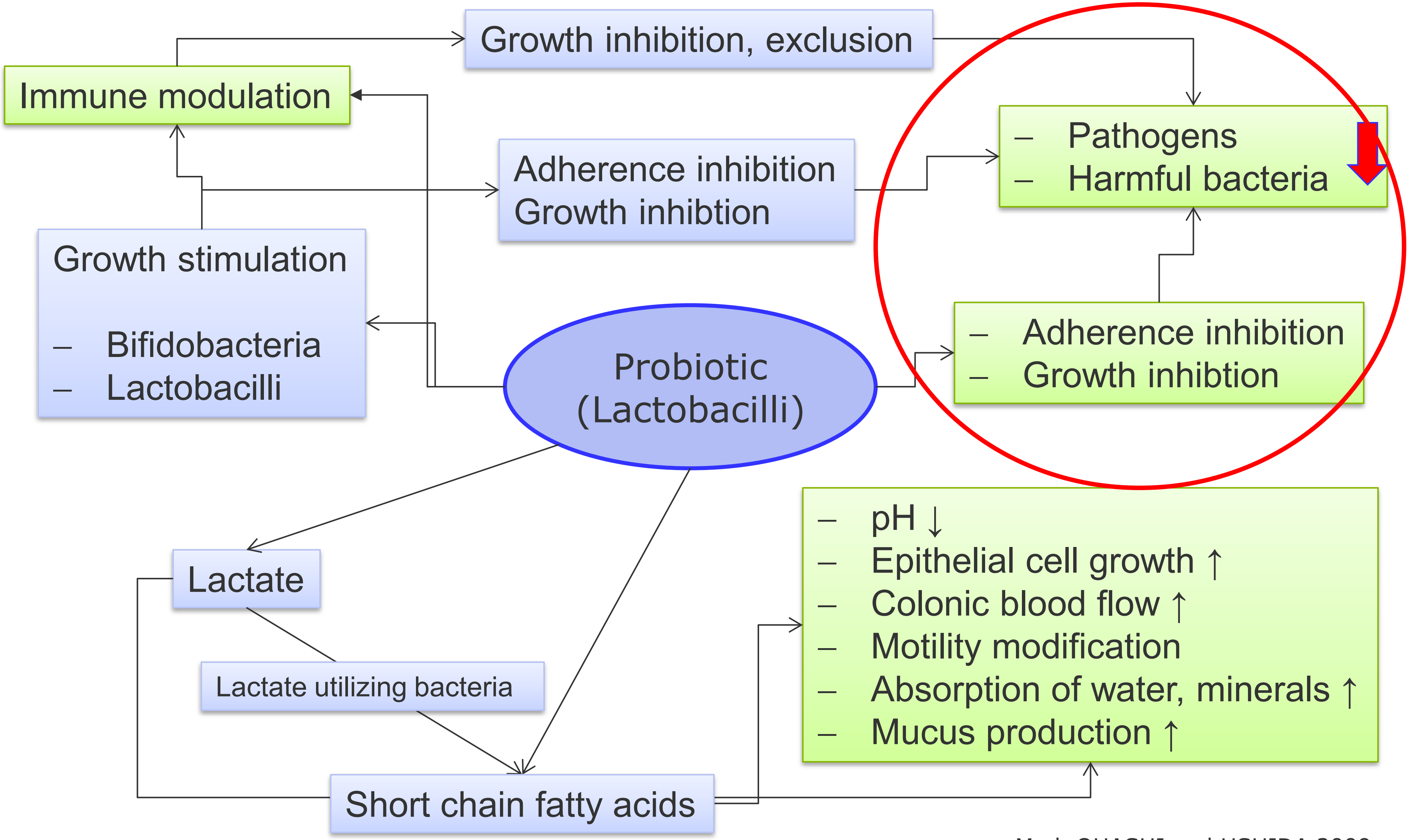
microorganisms MDPI

Review

Probiotics, Prebiotics, and Phytogenic Substances for Optimizing Gut Health in Poultry

Awad A. Shehata [1,2,*], Sakine Yalçın [3], Juan D. Latorre [4], Shereen Basiouni [5], Youssef A. Attia [6], Amr Abd El-Wahab [7,8], Christian Visscher [7], Hesham R. El-Seedi [9,10,11], Claudia Huber [12], Hafez M. Hafez [13], Wolfgang Eisenreich [12] and Guillermo Tellez-Isaias [4,*]

Abstract: The gut microbiota has been designated as a hidden metabolic 'organ' because of its enormous impact on host metabolism, physiology, nutrition, and immune function. The connection between the intestinal microbiota and their respective host animals is dynamic and, in general, mutually beneficial. This complicated interaction is seen as a determinant of health and disease; thus, intestinal dysbiosis is linked with several metabolic diseases. Therefore, tractable strategies targeting the regulation of intestinal microbiota can control several diseases that are closely related to inflammatory and metabolic disorders. As a result, animal health and performance are improved. One of these strategies is related to dietary supplementation with prebiotics, probiotics, and phytogenic substances. These supplements exert their effects indirectly through manipulation of gut microbiota quality and improvement in intestinal epithelial barrier. Several phytogenic substances, such as berberine, resveratrol, curcumin, carvacrol, thymol, isoflavones and hydrolyzed fibers, have been identified as potential supplements that may also act as welcome means to reduce the usage of antibiotics in feedstock, including poultry farming, through manipulation of the gut microbiome. In addition, these compounds may improve the integrity of tight junctions by controlling tight junction-related proteins and inflammatory signaling pathways in the host animals. In this review, we discuss the role of probiotics, prebiotics, and phytogenic substances in optimizing gut function in poultry.



Mod. OHASHI and USHIDA 2009

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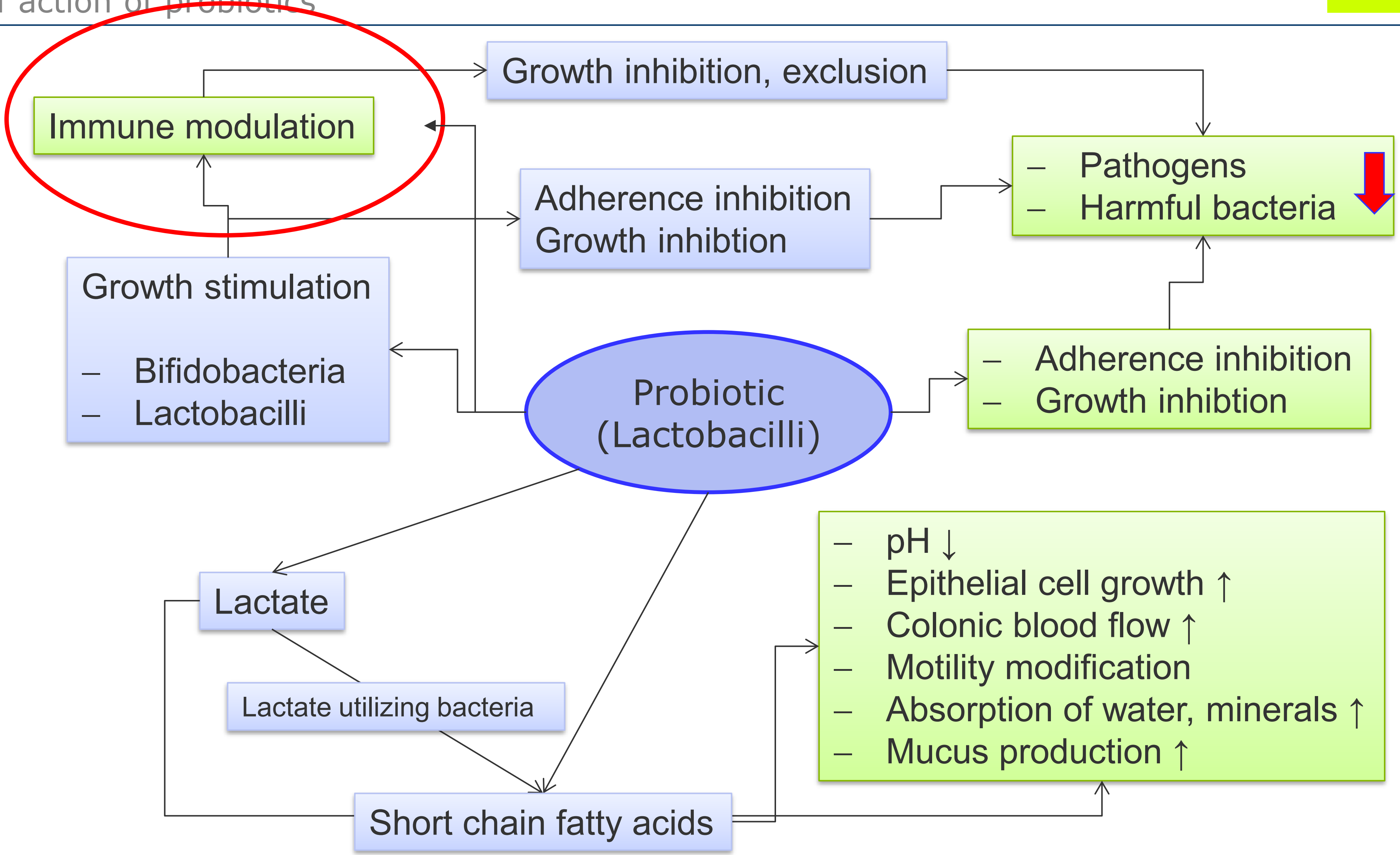
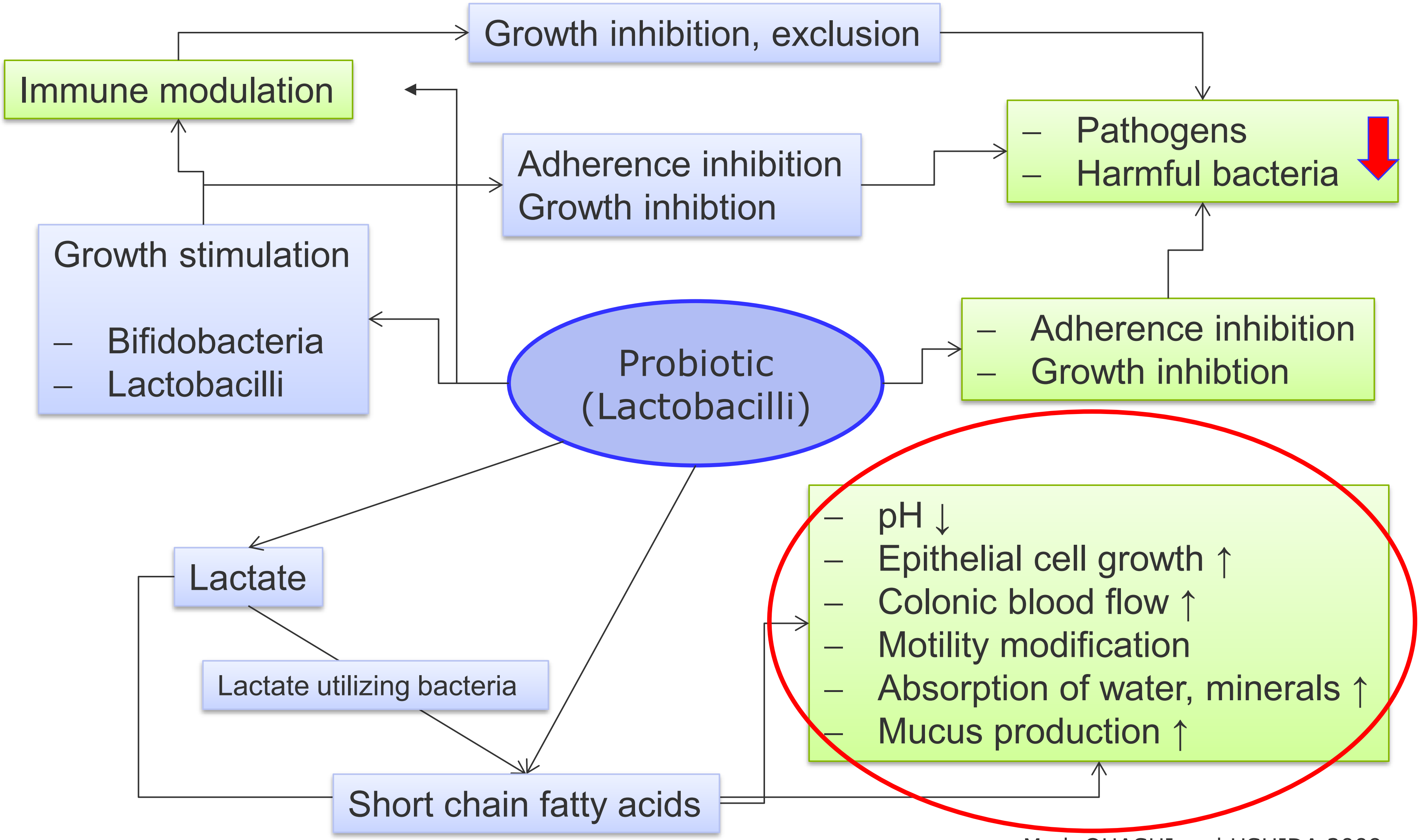
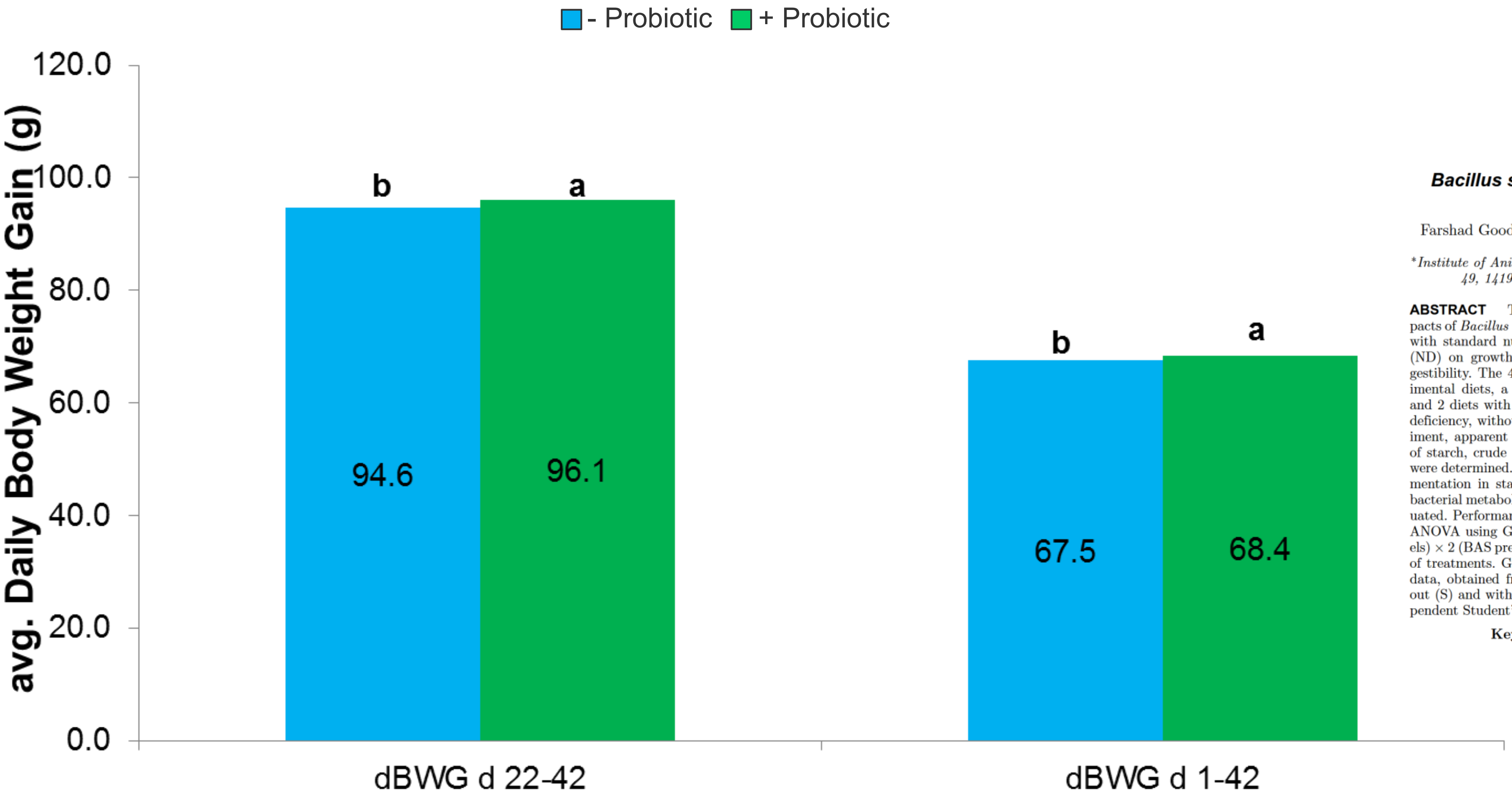


Mod. OHASHI and USHIDA 2009



Mod. OHASHI and USHIDA 2009



***Bacillus subtilis* in broiler diets with different levels of energy and protein**

Farshad Goodarzi Boroojeni,[*,1] W. Vahjen,[*] K. Männer,[*] A. Blanch,[†] D. Sandvang,[†] and J. Zentek[*]

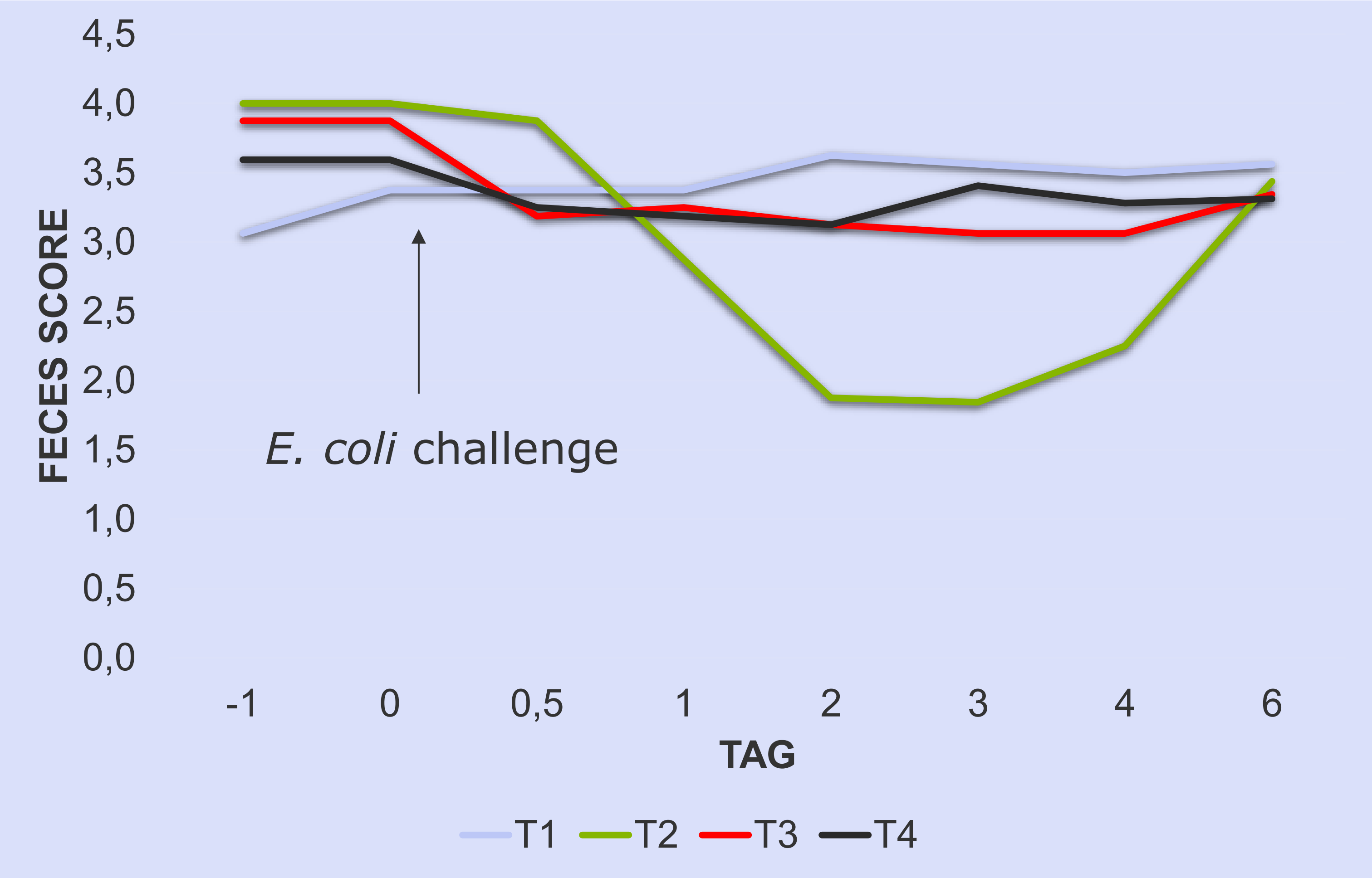
[*]*Institute of Animal Nutrition, Department of Veterinary Medicine, Freie Universität Berlin, Königin-Luise-Str. 49, 14195 Berlin, Germany; and* [†]*Chr. Hansen A/S, Bøge Allé 10-12, 2970 Hørsholm, Denmark*

ABSTRACT The present study evaluated the impacts of *Bacillus subtilis* (BAS) inclusion in broiler diets with standard nutrient content or nutrient deficiency (ND) on growth performance (GP) and nutrient digestibility. The 42 d experiment consisted of 6 experimental diets, a diet with standard nutrient content, and 2 diets with different levels of energy and protein deficiency, without or with BAS. At the end of experiment, apparent ileal digestibility coefficients (AIDC) of starch, crude protein (CP), and gross energy (GE) were determined. Furthermore, impacts of BAS supplementation in standard diets on gut histomorphology, bacterial metabolic activity, and composition were evaluated. Performance and AIDC data were subjected to ANOVA using GLM procedure with a 3 (nutrient levels) × 2 (BAS presence/absences) factorial arrangement of treatments. Gut histomorphology and microbiology data, obtained from broilers fed standard diets without (S) and with BAS (SB), were assessed by an independent Student's *t*-test. The ND in diets was effective enough to cause nutritional stress and negatively affect performance. Inclusion of BAS in both types of diet improved GP, which was due to the fact that adding BAS in these diets led to improvements in AIDC of CP, starch, and GE ($P \leq 0.05$). Comparing only 2 experimental groups, S and SB, revealed no impact on bacterial composition and metabolism in the ileum and cecum, except a reduction in ileal lactobacilli number for SB group. Adding BAS to standard diet reduced crypt depth (CD) and increased villus length to CD ratio in the duodenum, whereas it had no impact on other histomorphological variables in the duodenum, jejunum, and ileum. In conclusion, supplementation of broiler diets with probiotic BAS can positively affect growth performance and nutrient digestibility and this positive impact might even be more pronounced in nutrient-deficient diets. However, the extent of the alleviating ability of BAS in nutrient-deficient diets as well as the biological mechanisms for such a phenomenon needs to be studied further.

Key words: *Bacillus subtilis*, nutritional stress, probiotic, growth promoter, histology

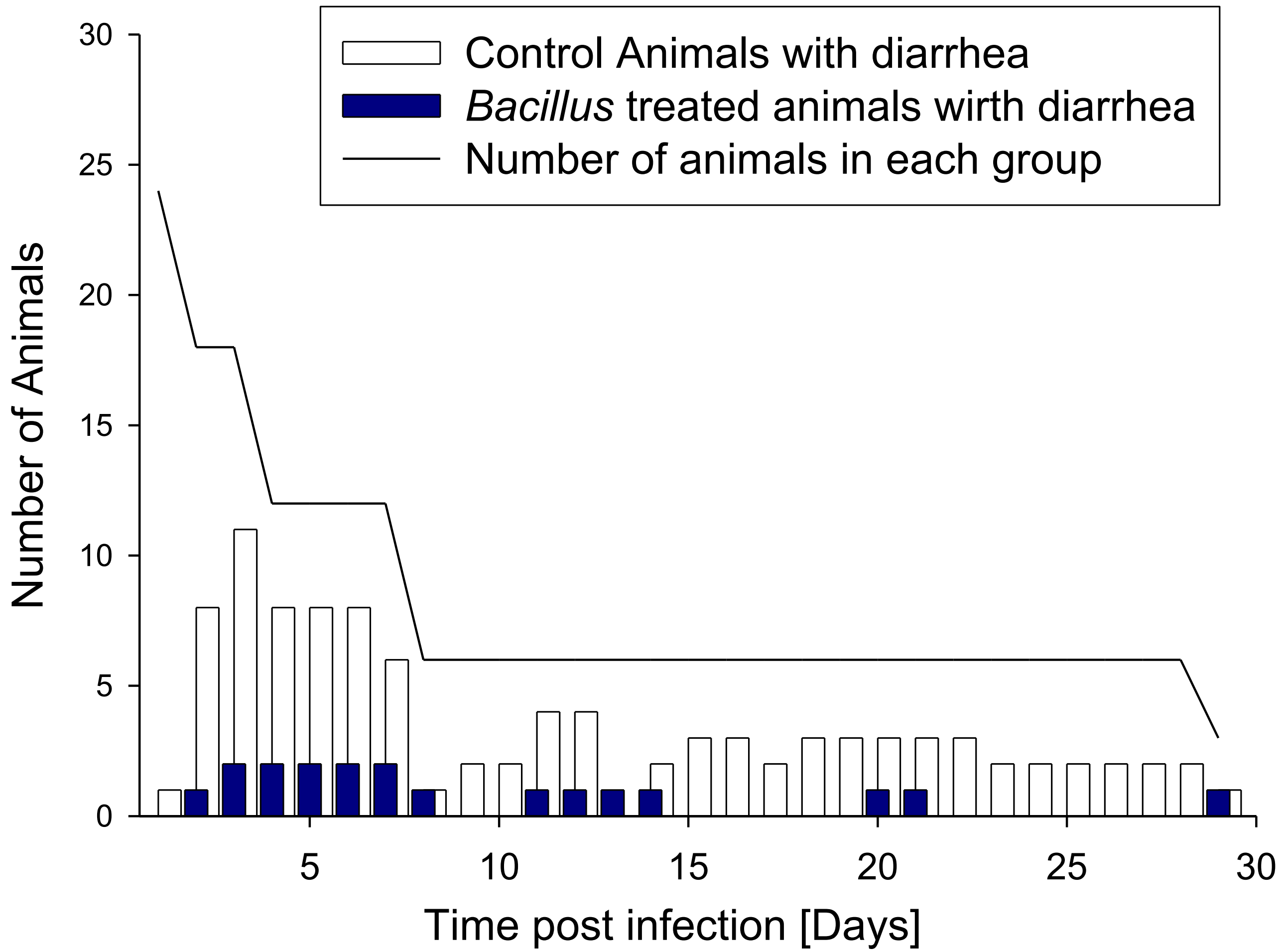
2018 Poultry Science 97:3967–3976
http://dx.doi.org/10.3382/ps/pey265

Escherichia coli



Score 1 = Diarrhea; 5 = Hard feces

Salmonella and diarrhea in piglets



Scharek-Tedin et al. 2013

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animals

MDPI

Article

Effect of Feed Additives as Alternatives to In-feed Antimicrobials on Production Performance and Intestinal *Clostridium perfringens* Counts in Broiler Chickens

Silje Granstad [1,*], Anja B. Kristoffersen [1], Sylvie L. Benestad [1], Siri K. Sjurseth [1], Bruce David [2], Line Sørensen [3], Arnulf Fjermedal [4], Dag H. Edvardsen [5], Gorm Sanson [3], Atle Løvland [2] and Magne Kaldhusdal [1]

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2 Nortura SA, P.O. Box 360 Økern, 0513 Oslo, Norway; robert.bruce.david@nortura.no (B.D.); atle.lovland@nortura.no (A.L.)
3 Felleskjøpet Fôrutvikling AS, Nedre Ila 20, 7018 Trondheim, Norway; line.sorensen@fkf.no (L.S.); gorm.sanson@fkf.no (G.S.)
4 Fiskå Mølle AS, Fiskåvegen 1010, 4120 Tau, Norway; arnulf.fjermedal@fiska.no
5 Norgesfôr AS, Torggata 10, 0181 Oslo, Norway; dag.henning.edvardsen@norgesfor.no
* Correspondence: silje.granstad@vetinst.no

Figure 1: Score = 1

Figure 2: Score = 2

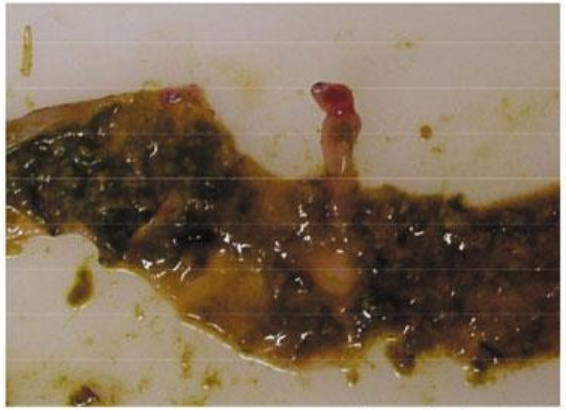

Figure 3: Score = 3

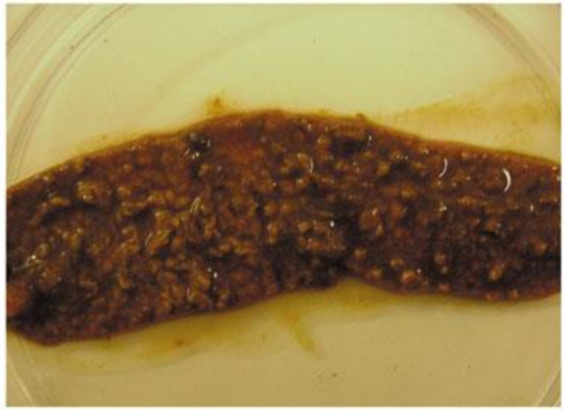

Figure 4: Score = 4

http://www.poultryhub.org/wp-content/uploads/2012/06/Necrotic-enteritis-lesions.jpg

Animals 2020, 10(2), 240; https://doi.org/10.3390/ani10020240 animals

MDPI

Article

Effect of Feed Additives as Alternatives to In-feed Antimicrobials on Production Performance and Intestinal *Clostridium perfringens* Counts in Broiler Chickens

Silje Granstad [1,*], Anja B. Kristoffersen [1], Sylvie L. Benestad [1], Siri K. Sjurseth [1], Bruce David [2], Line Sørensen [3], Arnulf Fjermedal [4], Dag H. Edvardsen [5], Gorm Sanson [3], Atle Løvland [2] and Magne Kaldhusdal [1]

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Narasin had a strong *C. perfringens* reducing effect

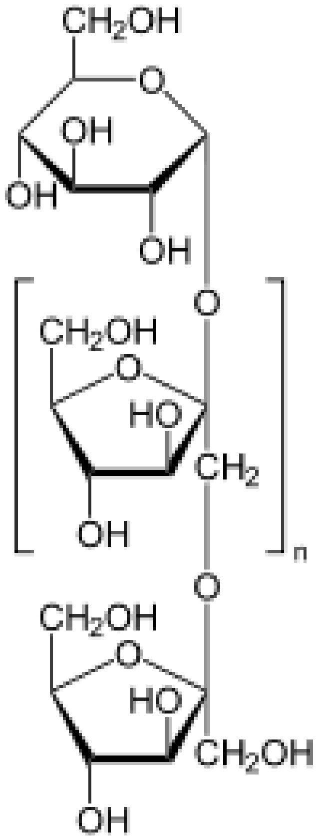
Also effective

- *Bacillus subtilis* probiotic strain
- Short- and medium-chain fatty acids
- *Saccharomyces cerevisiae*

Animals 2020, 10(2), 240; https://doi.org/10.3390/ani10020240

- Inulin
  - Extraction from Jerusalem artichoke, chicory or artichoke
  - Heterogeneous structure
  - Chain length 3 to 60

Wikipedia



Journal of
Animal Physiology and Animal Nutrition

DOI: 10.1111/jpn.12666

REVIEW ARTICLE

Review on the effects of potential prebiotics on controlling intestinal enteropathogens *Salmonella* and *Escherichia coli* in pig production

T. H. T. Tran[1,2], N. Everaert[1,2] and J. Bindelle[1,2]

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2 AgricultureIsLife, TERRA, Gembloux Agro-Bio Tech, University of Liege, Gembloux, Belgium

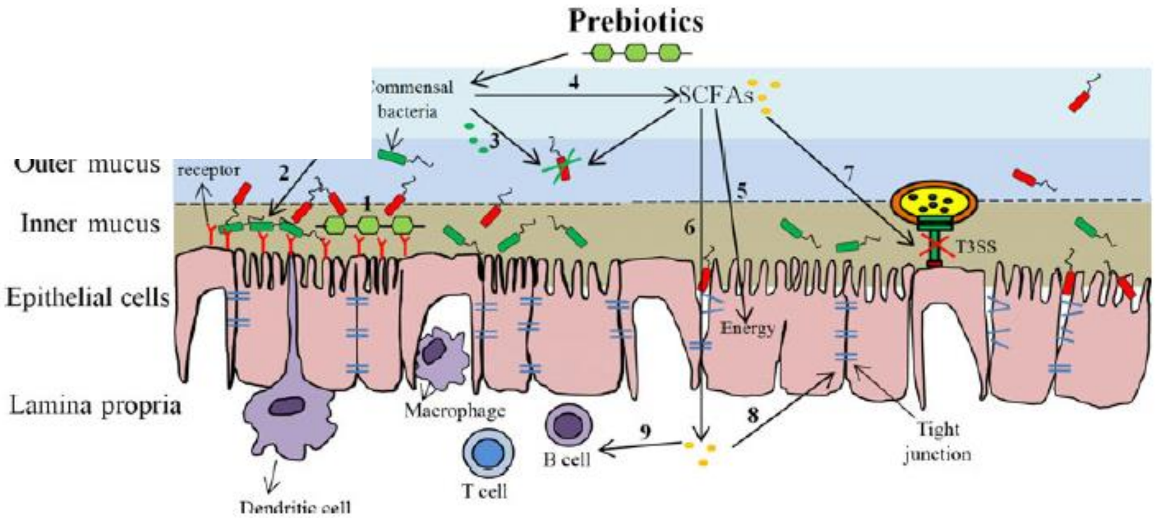

Fig. 2 Schematic representation of the mechanisms of prebiotics against pathogen infection: coating of the host surface receptors by adhesin analogs (1), or by commensal bacterial biofilm formation (2); bacteriocins (3) or short-chain fatty acids (SCFAs) (4) produced by favourable bacteria (3); use of SCFAs as energy source for epithelial cells (5) and metabolic regulation (6); inhibition of the type-III secretion system (T3SS) (7); improvement of tight junction, mucin production (8) or immunomodulation (9) (based on the figures in reviews of Sansonetti (2004) and Kalita et al. (2014)). [Colour figure can be viewed at wileyonlinelibrary.com]

FREIE UNIVERSITÄT BERLIN

Journal of Animal Physiology and Animal Nutrition

DOI: 10.1111/j.1439-0396.2012.01284.x

REVIEW ARTICLE

Gastrointestinal health and function in weaned pigs: a review of feeding strategies to control post-weaning diarrhoea without using in-feed antimicrobial compounds

J. M. Heo[1,2,*], F. O. Opapeju[1,*], J. R. Pluske[2], J. C. Kim[3], D. J. Hampson[2] and C. M. Nyachoti[1]

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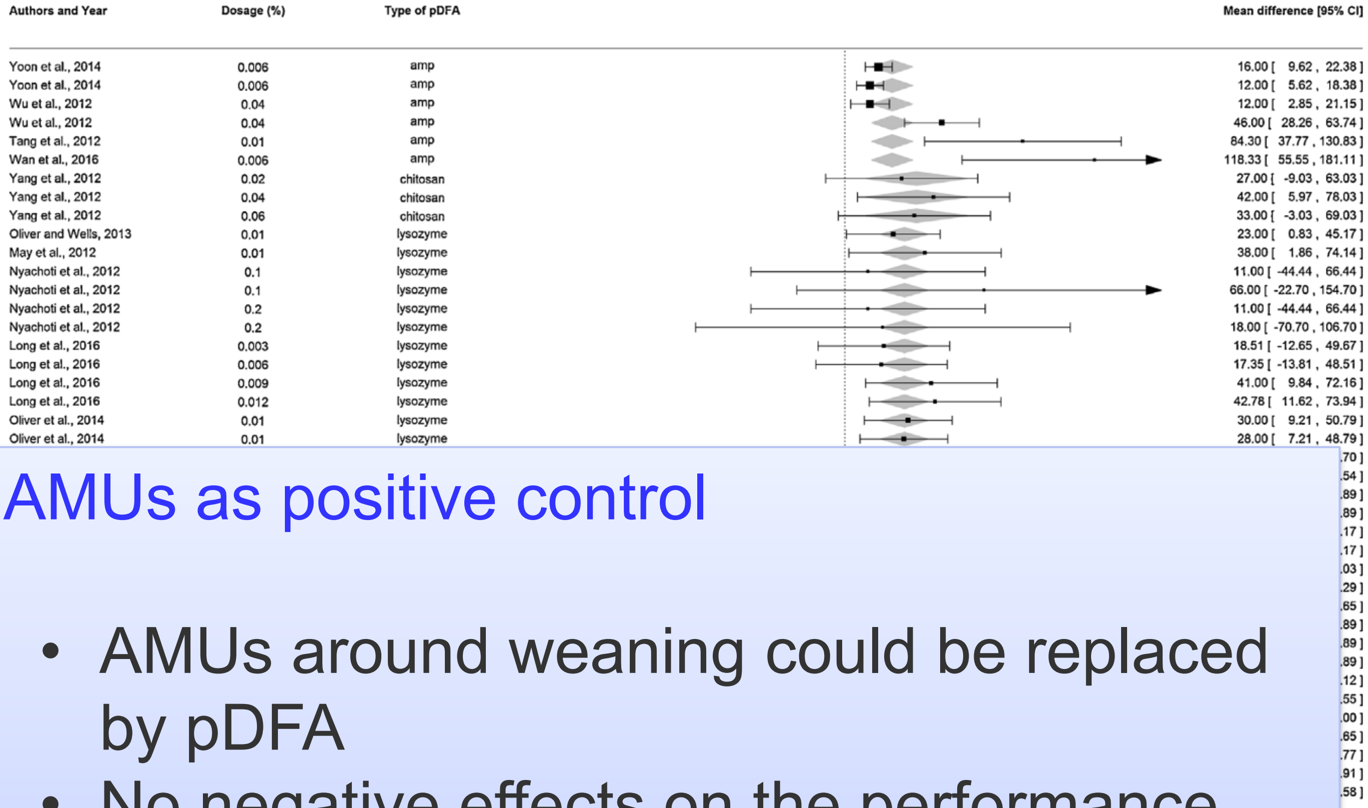
2 Animal Research Institute, School of Veterinary and Biomedical Sciences, Murdoch University, Murdoch, WA, Australia, and
3 Animal Research and Development, Department of Agriculture and Food, South Perth, WA, Australia

- Establishing a more stable and diverse microbiota
- *Lactobacillus* and *Bifidobacterium* spp. ↑
- Reduced ammonia content in the colon

- Plant-based bioactives
- Antimicrobial and anti-inflammatory
- Improve nutrient utilisation



- AMUs as positive control
  - AMUs around weaning could be replaced by pDFA
  - No negative effects on the performance indicators

Fig. 2. This forest plot shows the results of the mixed effects meta-analysis with type of potential dietary feed additive (pDFA) as fixed effect. For the average daily weight gain (ADG, in g) the mean difference estimate (black square symbol) with corresponding 95% confidence interval (95% CI; black bar) between the treatment group with pDFA and the negative control group is shown. Whenever a 95% CI exceeded the plot limits of (−150; 150), this was indicated by an arrow. Per pDFA the summary estimate based on the model is shown in grey, with the outer edges of the polygon indicating the 95% CI limits.

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ELSEVIER

Potential dietary feed additives with antibacterial effects and their impact on performance of weaned piglets: A meta-analysis

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ARTICLE INFO

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Keywords:
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Dietary feed additives
Piglets
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ABSTRACT

This meta-analysis evaluated the use of potential dietary feed additives (pDFA) with antibacterial effects and their impact on the perfomance of weaned piglets. Twenty-three peer-reviewed in vivo studies, comprising 50 trials, were identified between January 2010 and January 2017. The pDFA in these studies could be grouped in 5 classes: antimicrobial peptides, chitosan, lysozyme, medium chain fatty acids/triglycerides and plant extracts. Mixed-effect meta-analyses with type of pDFA as fixed effect were performed for the growth parameters 'average daily gain' (ADG) and 'feed conversion ratio' (FCR), which are the two most important and used economic performance parameters for farmers.

For each class of pDFA, results of the meta-analysis showed significantly higher average daily gain in the group with pDFA compared to the negative control group, while no significant difference with the positive control group was observed. Furthermore, a positive effect on FCR was found, i.e. significantly less feed was needed to gain 1 kg of body weight in the group with pDFA compared to the negative control group. No significant differences with positive control groups were observed for each class of pDFA, except for plant extracts, where the FCR was also significantly reduced in the treatment group. These results suggest that pDFA could reduce the use of antimicrobials without significant negative effects on performance indicators.

Phytogenic feed additives

- Herbs, spices, plant extracts

Table 3
Apparent ileal digestibility of la
pooled samples of 12 hens per d

Items	Uni
Pooled replicates	n°
Body weight	g
Dry matter (ileum digesta)	%
Apparent ileal digestibility	
Crude protein	%
- Alanine	%
- Arginine	%
- Aspartic acid	%
- Cysteine	%
- Glutamic acid	%
- Glycine	%
- Histidine	%
- Isoleucine	%
- Leucine	%
- Lysine	%
- Methionine	%
- Phenylalanine	%
- Proline	%
- Serine	%
- Threonine	%
- Tyrosine	%
- Valine	%
- Total amino acids	%
Crude fat	%
Crude ash	%
Calcium	%
Phosphorus	%

p-values of $p < 0.05$ indicate s
indicate a trend.

RNA sequencing

- Antimicrobial properties (pancreas, follicles) ↗
- Mineralization processes
- Improved cleavage of carbohydrates, peptides, and lipids in the follicle, indicating improved nutrient utilisation for the developing embryo

105 (2026) 106219
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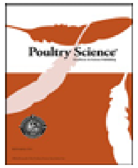


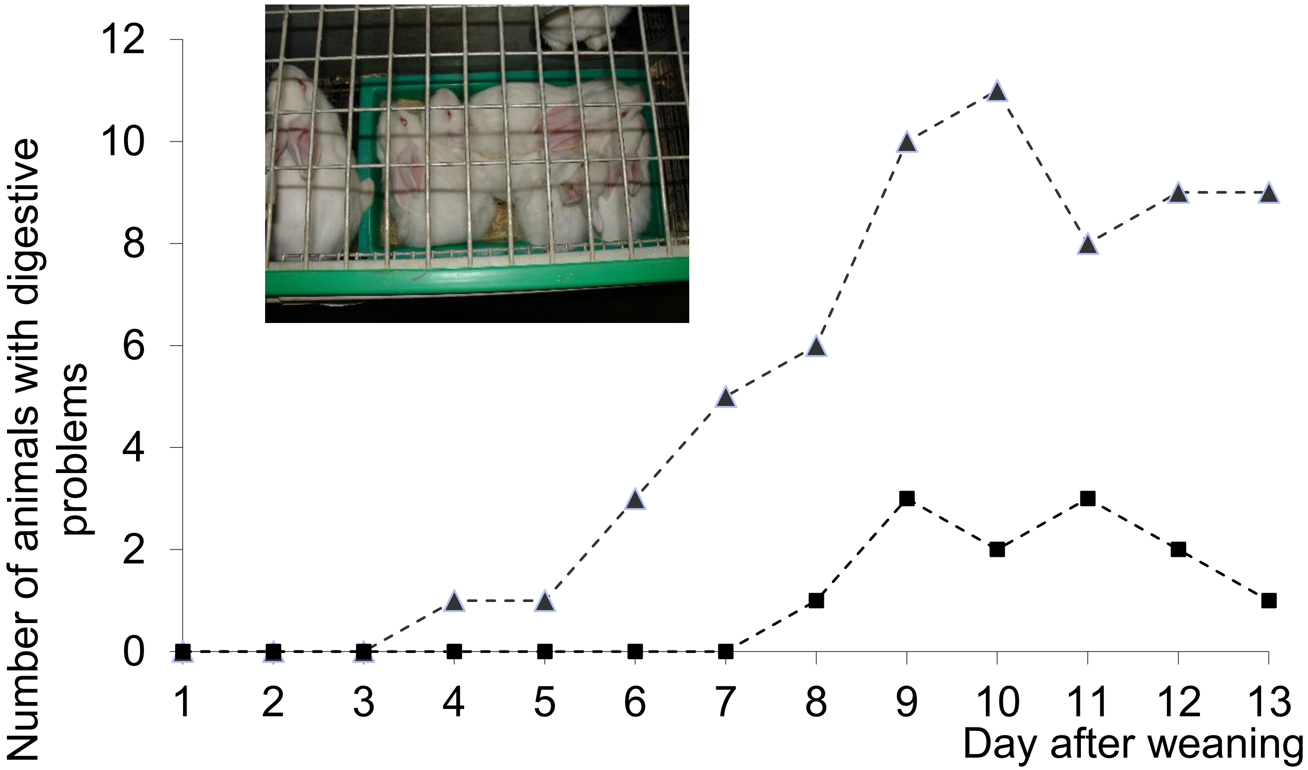
follicle, and
tive

ljul [a],

provements and potentially possess humoral
on, and excretion, warranting further inves-
a wide array of active ingredients with anti-
ning them as a promising alternative to in-
This study investigates how a phytogenic
ise with quillaja bark influences reproductive
hens. A four-week trial with Lohmann Brown
150 mg/kg phytogenic supplement to assess
($n = 24$), and gene expression in pancreas,
ng hens showed a significant increase of 3.84
trends for improved egg weights ($p = 0.053$)
s. Complementary RNA sequencing analyses
with antimicrobial properties (pancreas, fol-
Results suggest improved cleavage of carbo-
trient utilisation for the developing embryo.
nt digestibility of laying hens and promotes
d nutrient availability in eggs, potentially
hytogenic feed supplement can enhance the
expression of antibacterial proteins involved in innate immune responses.

Phytogenic supplement for weaned rabbits

Post weaning deaths: Control group: 3 animals; Experimental group: 1 animal



Krieg et al. 2009

n= 40 / group; ■ + phyt. Additive; ▲ control

9

- Postbiotics

  - Bioactive microbial metabolites (e.g., SCFA, peptides, cell components)
  - Antimicrobial & anti-inflammatory effects
  - Modulate immunity and microbiota activity
  - High stability
  - Key concept: targeted, consistent gut health modulation

Journal of Ethnopharmacology 261 (2020) 113073

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ELSEVIER

Lythrum salicaria L. herb and gut microbiota of healthy post-weaning piglets. Focus on prebiotic properties and formation of postbiotic metabolites in *ex vivo* cultures.

Temesgen H. Dadi[a], Wilfried Vahjen[a], Jürgen Zentek[a], Matthias F. Melzig[b], Sebastian Granica[c], Jakub P. Piwowarski[a,b,c,*]

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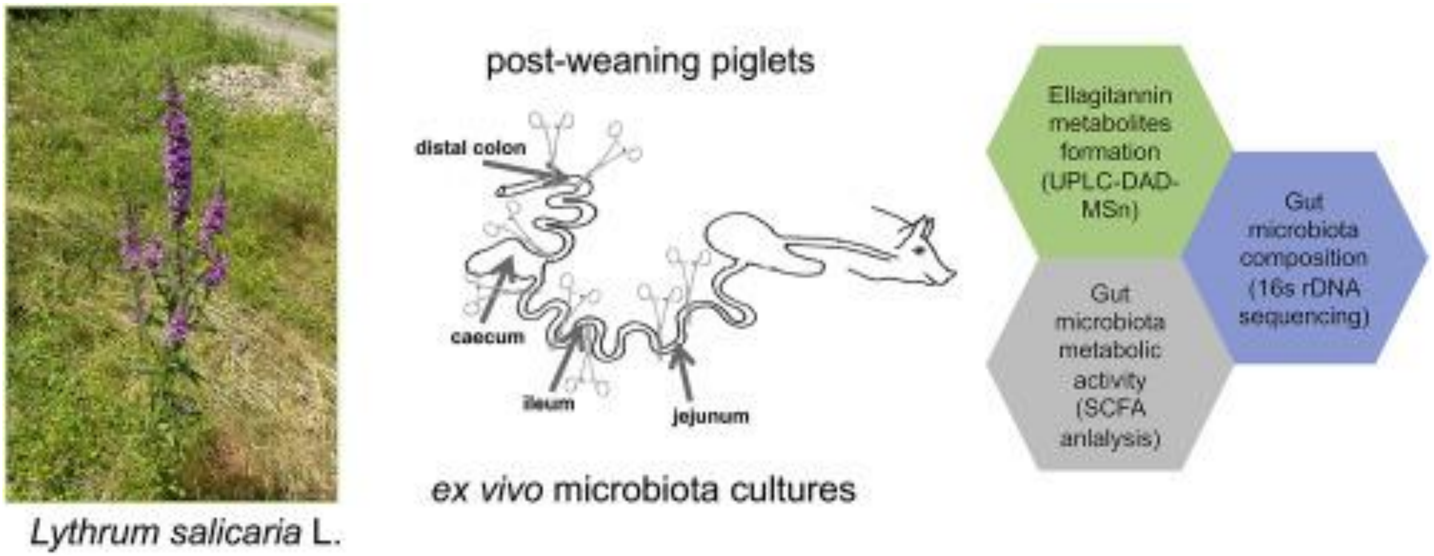

JOURNAL OF NATURAL PRODUCTS

pubs.acs.org/jnp

Article

Lythrum salicaria Ellagitannins Stimulate IPEC-J2 Cells Monolayer Formation and Inhibit Enteropathogenic *Escherichia coli* Growth and Adhesion

Sebastian Granica, Wilfried Vahjen, Jürgen Zentek, Matthias F. Melzig, Karolina A. Pawłowska, and Jakub P. Piwowarski*

Cite This: J. Nat. Prod. 2020, 83, 3614−3622

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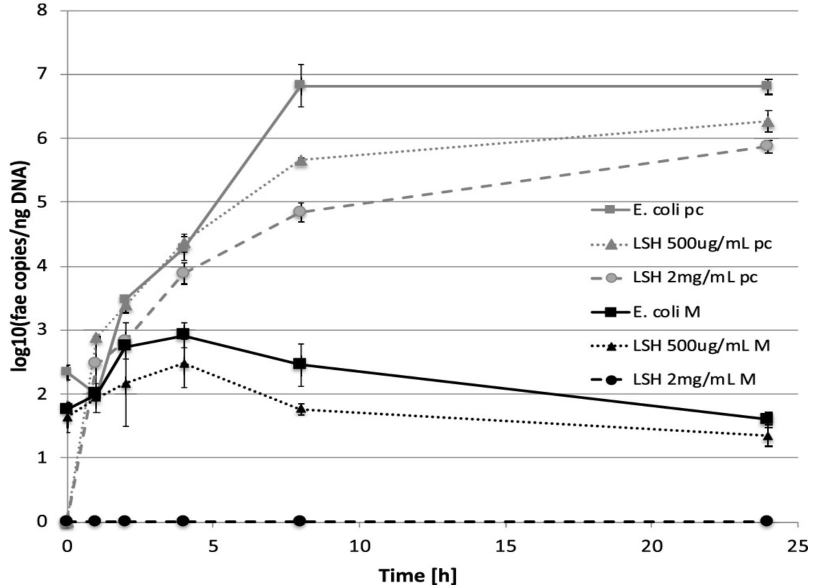

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1. The Big Picture: Rethinking Animal Health and Welfare

2. The Gut as a Central Hub
(Linking digestion, microbiome, and immunity)

3. Intervention Points: Feed Additives as Tools

4. Future Directions: From Efficiency to Resilience

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- Microbiome-targeted strategies
- Functional metabolites
- Advanced delivery systems
- Integrated health concepts

Gut health is central to animal health

Feed additives offer targeted solutions

Future: integrated systems