Looking to the Future of Sustainable Feed Production for Pigs
Success Factors in a Concept "Feed 3.0"

Dr. Heinrich Kleine Klausing
Managing Director, Deutsche Tiernahrung Cremer, Germany

Importance of sustainable feed production in pig nutrition

Sustainable feed production in Pig Nutrition is crucial for …

- reducing **environmental impact**
- ensuring **animal health** and **welfare**
- meeting the growing **global demand for pork**

in an **ethical** and **resource-efficient** manner.

The holistic solution from the customer perspective

Yesterday

The holistic solution from the customer perspective

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Today & Tomorrow

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Agenda

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- **Advances in feed processing**
  - Insight on hydrothermal processing
  - Insight on solid state fermentation
- **Newest considerations in feed formulation**
  - Insight on meaning of DCAB in sow feed
  - Insight on constipation around farrowing, endotoxins and meaning of fermentable fiber
- **Newest generation feed additives**
  - Insight on meaning and evaluation of organic acids
- **Take-home message**

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Key drivers of technical innovation in a Concept “Feed 3.0”

- **Integration of future technology in whole chain of pig nutrition**
  Robotics, IoT, real-time monitoring using sensor technology → AI

- **Application of precision nutrition**
  Customized diets based on individual needs and digitized data acquisition and processing on farm including real-time cross-linking with feed formulation using AI

- **Utilization of sustainable novel ingredients**
  protein-rich byproducts, fiber-rich byproducts, feedstuffs with specific functionalities

- **Utilization of novel valorization technologies**
  - valorization of e.g. starch-/fiber-rich feed ingredients by hydrothermal processes
  - valorization of e.g. protein-rich feed ingredients by Solid-State Fermentation
  - protection of temperature-sensitive additives / feed specialities by post-pelleting application technology / vacuum-coating

Automation and digitalization

- ✓ **Automation:** Integration of **automated systems** in feed mills has revolutionized feed processing. Automated batching, mixing, and pelleting systems ensure precision and consistency.
- ✓ **Benefits:** Increased production rates, reduced labor costs, enhanced product quality.
- ✓ **Digitalization:** Use of **IoT** and **data analytics** to monitor and optimize feed production processes.
- ✓ **Example: Real-time monitoring** of feed quality (e.g. NIRS) and machinery performance to prevent downtime and ensure consistent output as well as feed quality.

Quality control and safety

- ✓ Implementation of stringent quality control measures to ensure feed safety and consistency.
- ✓ **Nutrients**: **Constant monitoring** using **network technology** such as NIRS
- ✓ **ANF**: feedstuff-specific **definition & monitoring**; mycotoxins & other undesirables
- ✓ **Hygiene**: **monitor** microbial contamination in the **production & product environment** and avoid it as much as possible.

Advances in feed processing in a Concept "Feed 3.0"

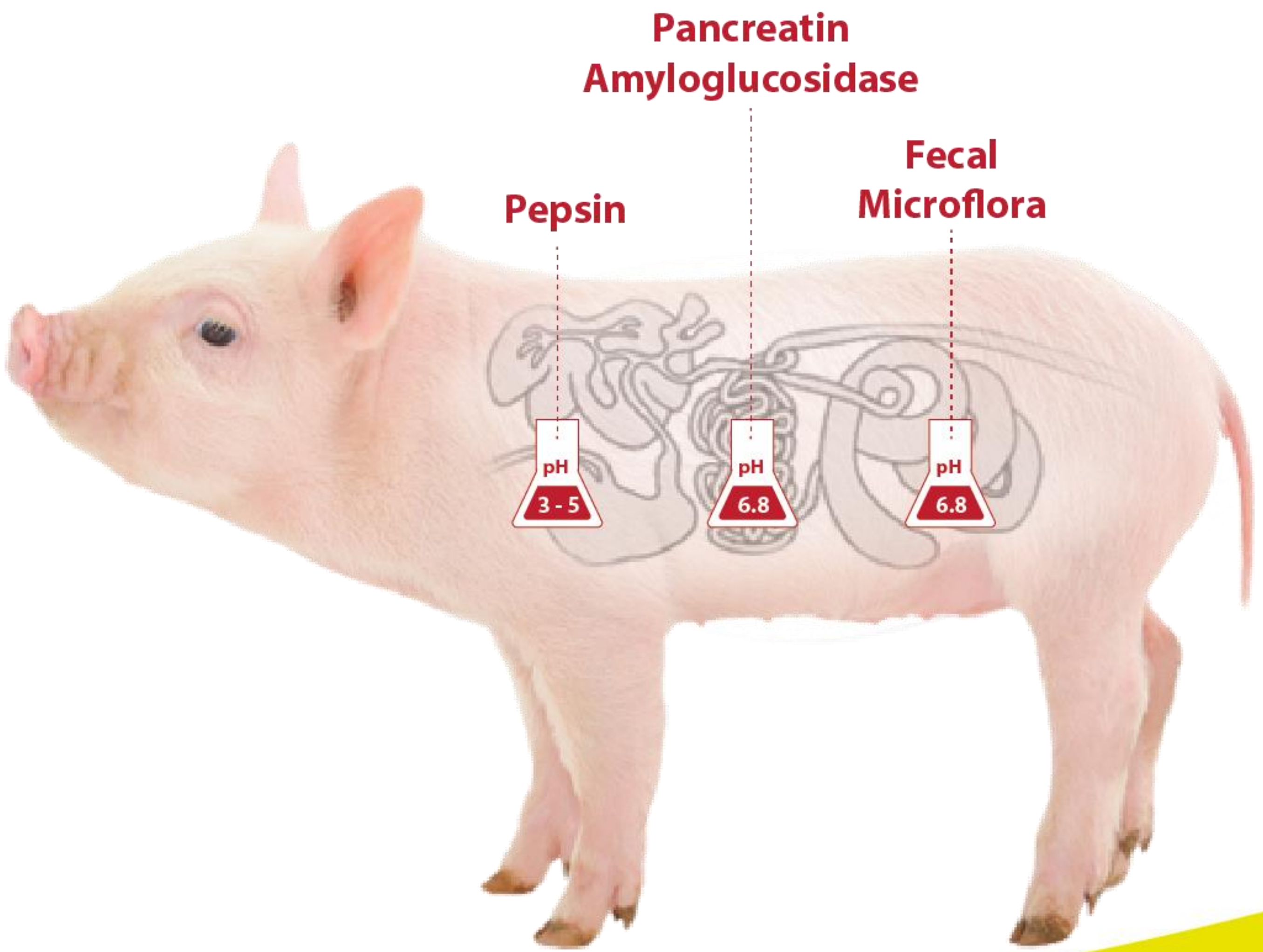
Pelleting

- ✓ Compressing feed ingredients into dense, uniform pellets.
- ✓ **Advantages:** Improved feed intake, reduced feed wastage, and enhanced nutrient density.
- ✓ **Recent developments:** Use of state-of-the-art pellet mills considering the best possible **preservation** of **particle structure** in the pellet.
- ✓ **Note**: avoid microbial contamination/recontamination! Draw **supply air** for **coolers** from **hygienically unsuspicious areas** or **clean** (e.g., Hepa filter).

Hydrothermal processing

- ✓ Use of steam (increased moisture), temperature, pressure and shear forces to **process feed ingredients**, **improving** their **nutritional value** and **safety**.
- ✓ **Benefits:** Reduction of **anti-nutritional factors**, improved ***starch gelatinization***, enhanced **protein digestibility**, **sanitization**.

pH in the GIT - Key function for intestinal health



Retention time + pH

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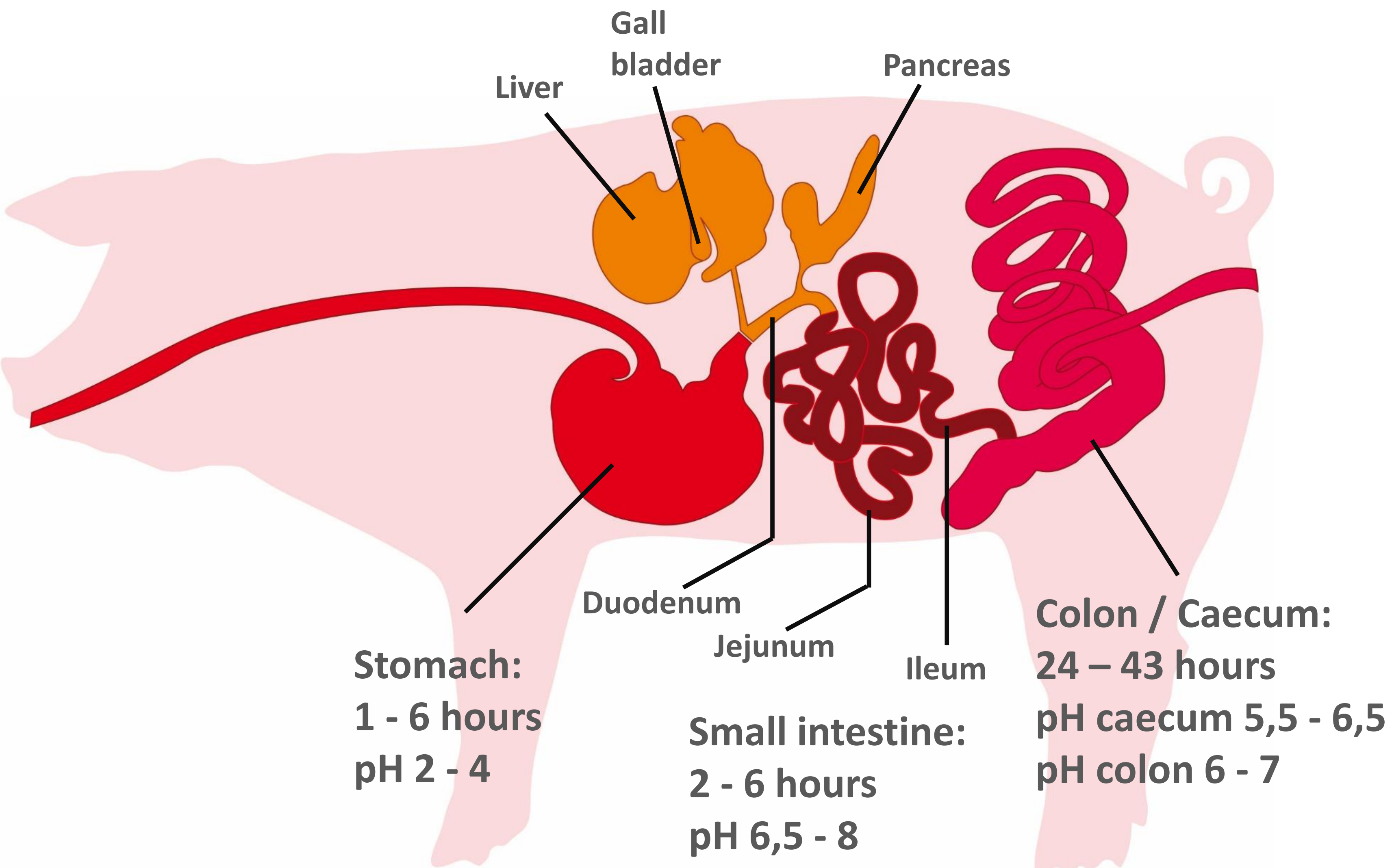

Source: Lærke, HN & Hedemann, MS 2012, 'The digestive system of the pig'. in KE Bach Knudsen, NJ Kjeldsen, HD Poulsen & BB Jensen (eds), *Nutritional physiology of pigs - Online Publication.* Videncenter for Svineproduktion, Foulum.

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Hydrothermal processing of grain provides homogeneity

Comparing hydrothermally processed and untreated grain

Barley, wheat, corn

Hydrothermally processed

Hydrothermal processing of grain provides homogeneity

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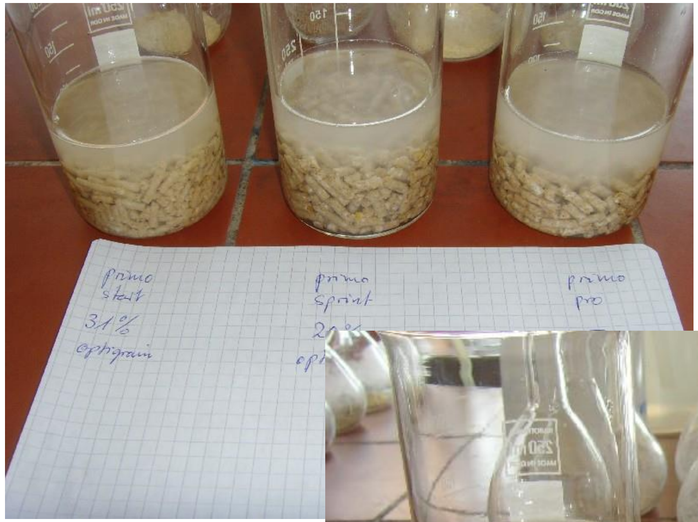
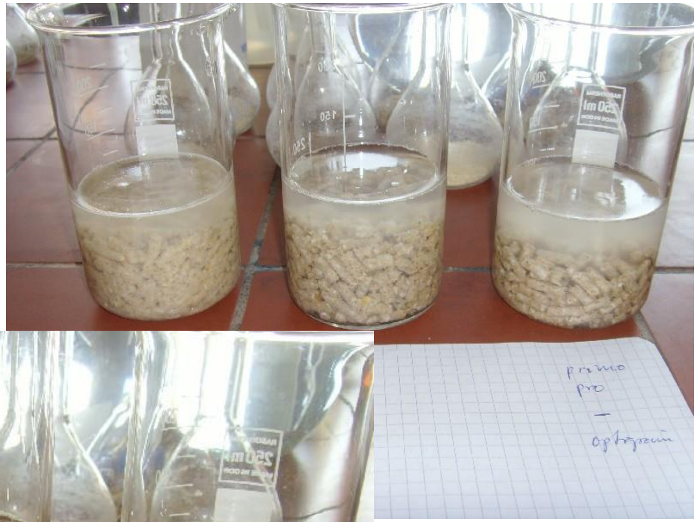
Impact on the dissolution of pellets in water



0 minutes



5 minutes

Content of hydrothermally processed grain

30%	20%	0%

10 minutes

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Hydrothermal processing of grain – Influence on viscosity

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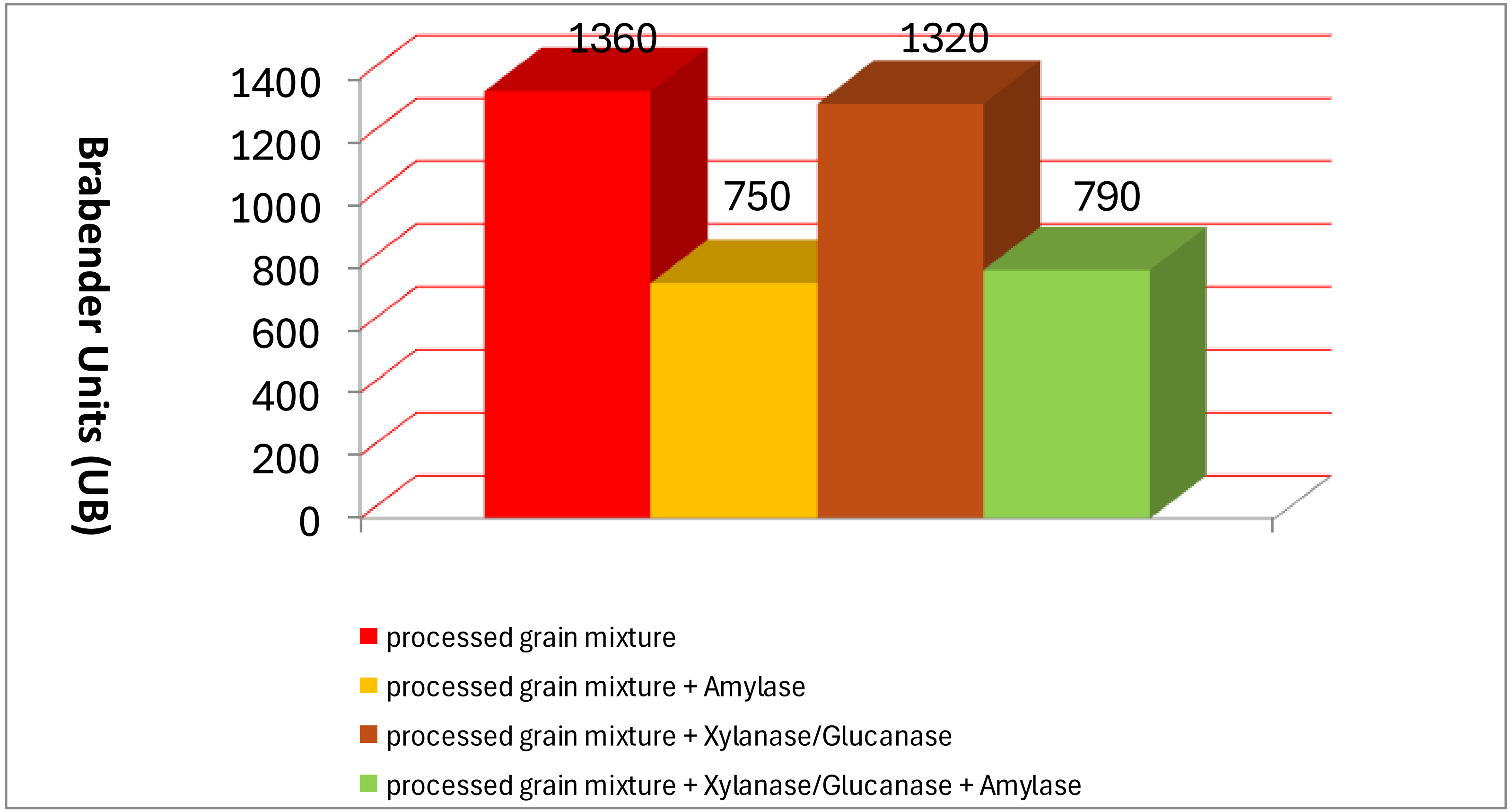
Viscosity of hydrothermally processed grain mixture is caused by starch hydrolysis



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Hydrothermal processing of grain – Influence on viscosity

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Viscosity of hydrothermally processed grain mixture is caused by starch hydrolysis

Left: 50 g refined grain mixture and 250 g water
Right: 50 g refined grain mixture and 250 g water plus 3 mg Alpha-Amylase (60 g per MT)

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Diet viscosity and its influence on the digestion in the stomach

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Impact of feed viscosity on physiological parameters and protein digestion in young monogastric animals

Treatment	Control	Trial	Significance
Viscosity (mPa s)	3.6	21.8	
Retention time of the solid phase in the stomach - Recovery of marker (%)	21.4	25.7	0.18
Protein hydrolysis in stomach (%)	26	34	0.13
Aminopeptidase activity (U/g protein)	359	516	<0.01
ileal N digestibility (%)	75.2	79.8	0.22
faecal N digestibility (%)	80.3	84.2	0.04

Source: Fledderus et al.: Increasing diet viscosity using carboxymethylcellulose in weaned piglets stimulates protein digestibility; Livestock Science 109 (2007) 89-92

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Hydrothermal processing of grain and protein value

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Effect of hydrothermal processing on in vitro protein degradability in barley

	Unprocessed		Hydrothermally processed	
Batch	3-hour dig% unprocessed	24-hour dig% unprocessed	3-hour dig% processed	24-hour dig% processed
1	73,7	90,5	85,8	91,5
2	79,5	89,1	84,9	91,1
3	76,7	90,1	81,8	90,4
4	77,5	90,8	84,3	90,4
5	77,2	87,4	81,8	90,3
6	76,0	91,3	81,0	90,0
Average	**76,8**	**89,9**	**83,3**	**90,6**

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Source: Internal lab reports

Piglets – Hydrothermal processing of grain supports gut health

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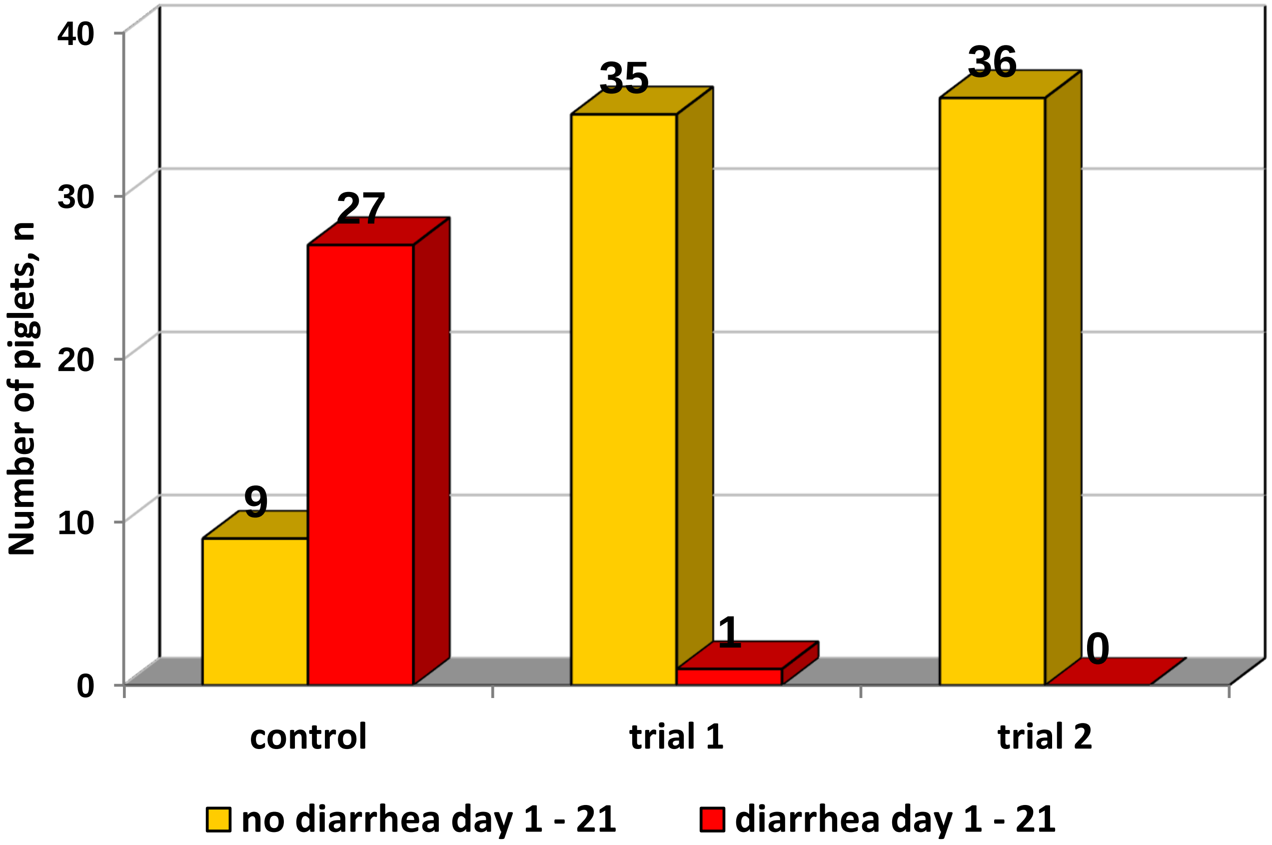

Trial under controlled practical conditions; average weaning age 26 days; 36 piglets per group

Control: no hydrothermally refined grain

Treatment 1 and 2: 25 % hydrothermally refined grain

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Source: Internal project report KK

Fermentation

- ✓ Biological process that uses microorganisms (***anaerobic***: bacteria or ***aerobic***: fungi, yeast) to convert feed ingredients into **better digestible**, nutritious forms and to produce beneficial **postbiotics** like organic acids or specific peptides.
- ✓ **Benefits:** Enhanced nutrient availability, **improved gut health**, reduced need for antibiotic application to control dysbiosis symptoms.
- ✓ **Recent Trends:** Use of **Solid-State Fermentation** on an industrial scale to refine protein-rich byproducts like soybean meal, rapeseed meal, sunflower meal, ….

Case study: Soybean meal solid-state fermentation

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	Non-fermented soybean meal	Fermented with LAB	Hydrolysed with ENZYMES & fermented with LAB
pH	6,50	5,30	4,60 ↘
Lactic acid, % in DM	0,05	2,08	5,04 ↗
Protein, % in DM	50,62	54,60	53,54 ↗
Stachyose, % in DM	5,18	4,53	1,47 ↘
Raffinose, % in DM	1,72	0,89	0,18 ↘

Solid state fermentation with Lactobacilli strains (LAB) can:

1. Significantly **decrease pH value** and **increase lactic acid concentration**
   ➔ improved palatability & positive impact on gut microbiome in monogastrics
2. **Reduce antinutritive carbohydrates** like stachyose and raffinose in soybean meal
   ➔ positive impact on gut microbiome in monogastric animals ➔ improved gut health

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Source: Dr. Ferm KfT (2024) & own data

Benefits of fermented feed(-stuff) in sows around farrowing

On-farm control of sow feces in different production phases with and w/o fermented feed

	Operation 1 Ferment		Operation 2 Ferment		Operation 3 Ferment		Operation 4 Ferment		Feed without Ferment	
	pH feces	Clostr. (cfu/g)	pH feces	Clostr. (cfu/g)	pH feces	Clostr. (cfu/g)	pH feces	Clostr. (cfu/g)	pH feces	Clostridium (cfu/g)
10 weeks gestation	6,5	0	6,9	1.000	-	-	7,0	1.400	6,8-8,3	16.000–48 million
End gestation	6,4	1	6,7	10	6,5	10	7,4	10	6,8-8,2	4.000-64 million
End farrowing	6,8	1	6,6	10	7,2	1300	7,4	520	6,8-8,2	4.000-64 million

Source:
Dr. Ferm KfT (2024)

Nutritional Additives

- ✓ **Amino Acids**: Essential for protein synthesis and overall growth
- ✓ **Recent Trends**: Increased use of synthetic amino acids to **balance diets** and reduce **reliance** on protein-rich **feed ingredients**.
  - ✓ *Future influence of EC anti-dumping measures against Chinese companies?*
  - ✓ *Formulation based on precaecal digestible Amino Acids is a MUST!*
- ✓ **Vitamins, Trace Elements, Minerals**: Critical for **metabolic processes** and immune function

Low milk production: Spotting the signals!

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The metabolism of minerals in sows

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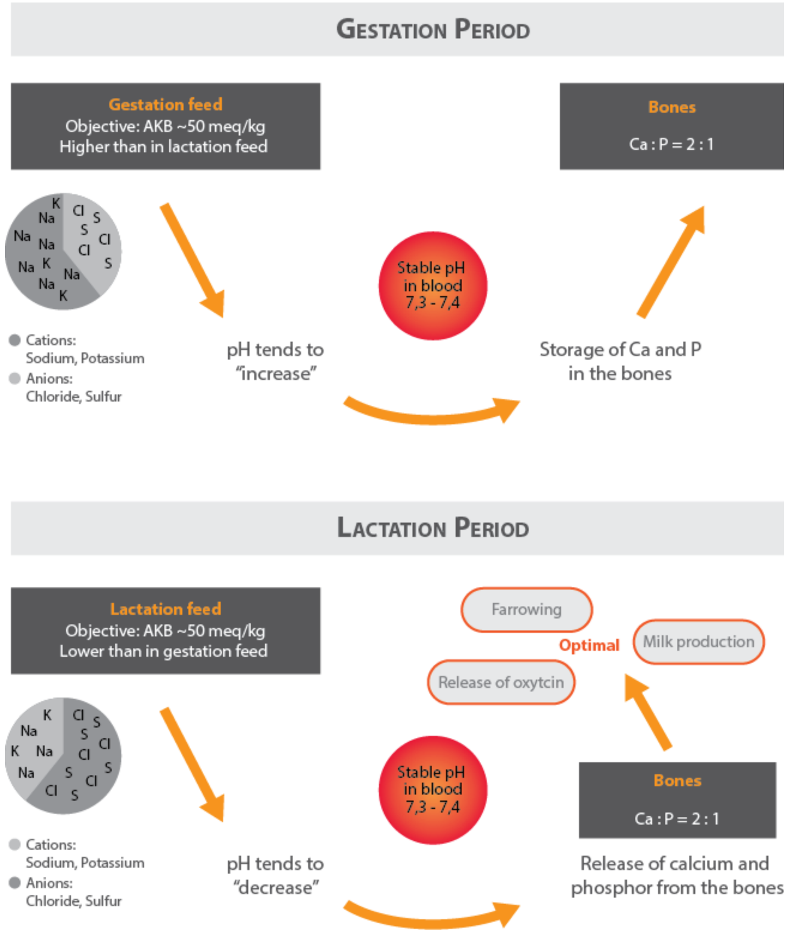
That's how the Ca-metabolism works…

Ca and P metabolism of sows in gestation and lactation periods



Source: Modified according to Stalljohann (2014)

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The metabolism of minerals in sows

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dEB = 43,498 x Na + 25,574 x K – 28,206 x Cl

DCAB = 43,5 x Na + 25,6 x K – 28,2 x Cl – 62,4 x S

(KAB = -13 x M+C + 49,9 x Ca – 59 x P + 43,5 x Na + 25,6 x K – 28,2 x Cl + 82,3 x Mg)

gestation diet						
DCAB (mEq/kg DM)		RECOMMENDATION				
		content 87%	content 100 %			
Ion	factor	g/kg	g/kg		DCAB 100%DM	
Na	43,5	2,7	3,1		135,0	
K	25,6	6,9	7,9		203,0	
Cl	-28,2	2,6	3,0		-84,3	
S	-62,4	1,9	2,2		-136,3	
					117,5	mEq/kg DM

lactation diet						
DCAB (mEq/kg DM)		RECOMMENDATION				
		content 87%	content 100 %			
Ion	factor	g/kg	g/kg		DCAB 100%DM	
Na	43,5	2,5	2,9		125,0	
K	25,6	7,3	8,4		214,8	
Cl	-28,2	3,8	4,4		-123,2	
S	-62,4	2,2	2,5		-157,8	
					58,8	mEq/kg DM

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Health and performance enhancers – components & additives

- ✓ **Gut health:** Focus on **ingredients** that promote a **healthy gut microbiome**.
  where appropriate ➔ **ingredient valorization** by hydrothermal processes and / or fermentation.
- ✓ **Additives:** Probiotics, prebiotics, postbiotics ➔gut health and nutrient absorption.
- ✓ **Immune modulation:** Incorporating feed additives that boost the immune system.
- ✓ **Examples:** Phytogenics, immunoglobulins, beta-glucans, nucleotides, …. with immunomodulatory properties.

Practical example: The challenges of sows around birth

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What are the challenges?

Delayed birth, lack of milk

→ Obvious and subclinical constipation
→ "release of harmful substances" from gram-negative bacteria in the intestine
(Endotoxins) – MMA!?

Low feed intake

Not enough energy around farrowing

→ Use of body fat reserves at early stages
→ Release of harmful substances (toxins) accumulated in body fat
→ Energy deficiency
→ Low milk production

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Sows: Challenges around birth - Endotoxins

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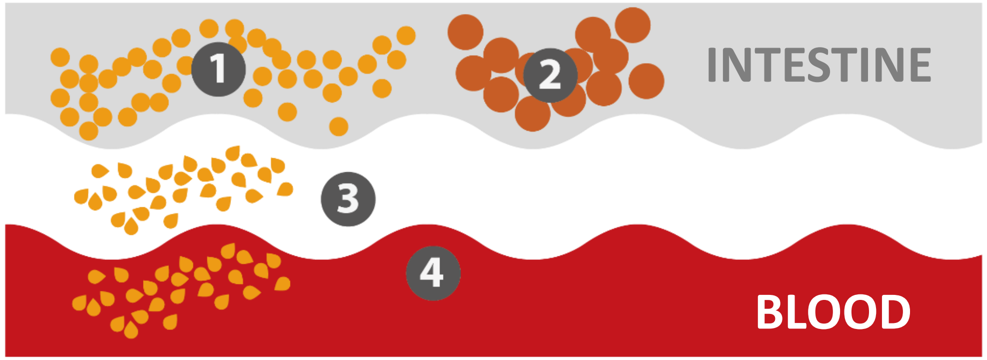

2 Constipation

1 Proliferation of *E. coli*

3 Decomposition of *E. coli* and release of endotoxins

4 Endotoxins pass into the bloodstream

Fever
Inflammation of the udder (mastitis)
Inhibition of prolactin

Low milk production (hypogalactia/agalactia)

Constipation leads to the release of endotoxins that pass into the blood. Sows show fever and painful inflammations of the udder.

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Source: Nutztierpraxis Schwein (2013)

“Fiber” – “NSP” – “structure carbohydrates”

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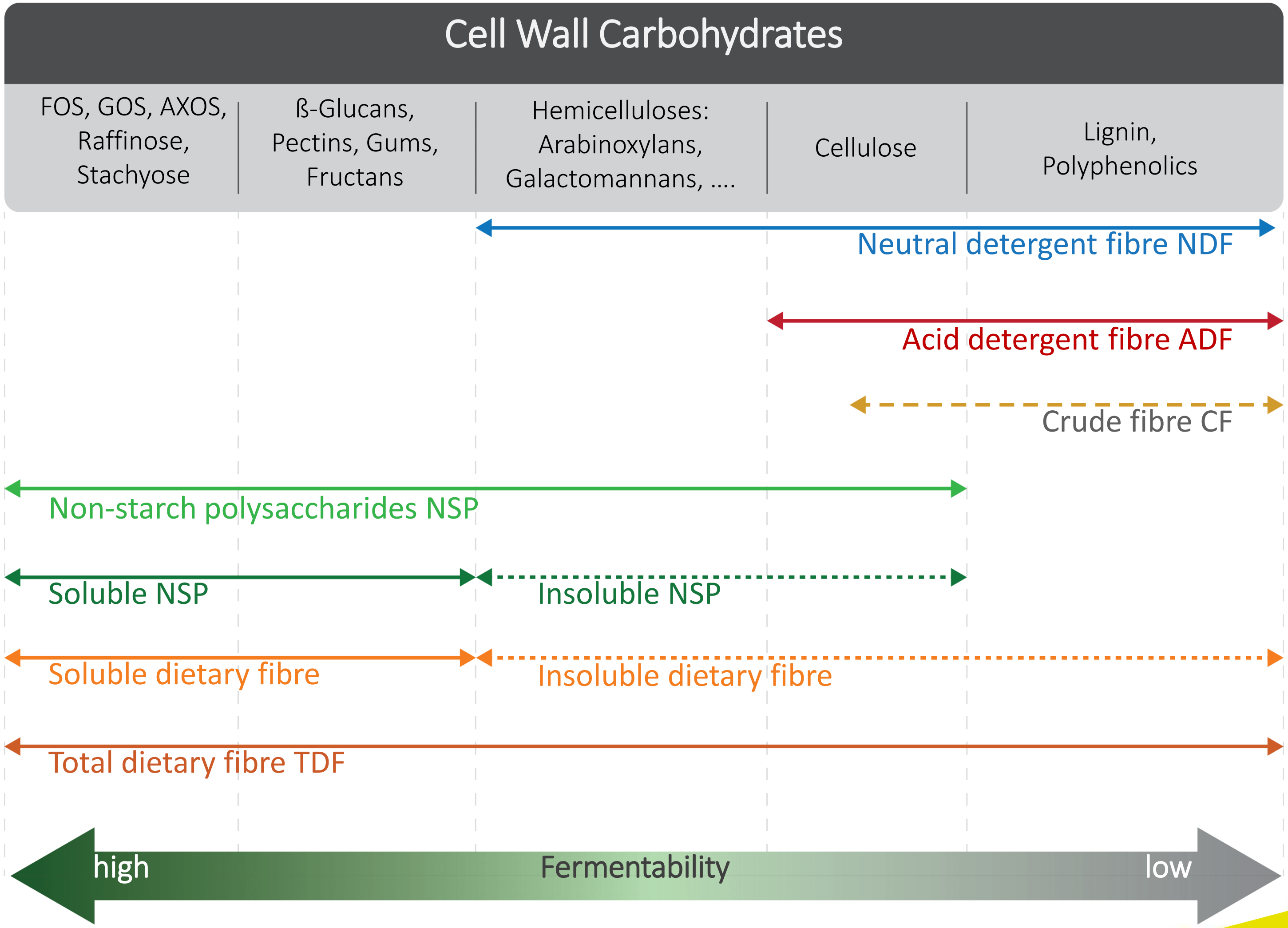
Classification of plant carbohydrates (modified according to NRC, 2012)



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Source: Potthast (2018); Jaworski et al. (2019) in AAF 2019-10-30

Sows: Prevention of constipation

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- **Do not reduce the amount of feed before parturition significantly (consistency of stool is the limiting factor)** → avoid the mobilization of body fat reserves at an early stage
- **Lactation feed with adequate fiber level and type (≥ 5 % crude fiber and ≥18% insoluble dietary fiber (fermentable carbohydrates))**
- Around farrowing: Use **benefits of fermented feed (-stuff)** on **gut health** and **shedding** of potentially **harmful bacteria**
- **Guarantee adequate quantities of water** (particularly important in liquid feeding systems or when flooding the trough in gestation units)

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Newest considerations in feed formulation in a Concept "Feed 3.0"

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Sustainable Ingredients

- ✓ **Alternative Proteins:** Incorporation of **highly digestible protein** sources as partly replacement for third country soybean meal.
- ✓ **Benefits:** Reduced **environmental impact**, lower land and water use, and **sustainable production**.
- ✓ **Example: Single Cell Proteins** from **fermentation** processes using sustainable carbon sources.
- ✓ **By-products:** by-products from oil-milling (rapeseed, sunflower seed) using **newest processing technology**.
  ➔ *Partly solution for requirements arising from EUDR regulation?*

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Environmental considerations

- ✓ **Carbon footprint reduction:** Formulating feeds to **minimize greenhouse gas emissions** and environmental impact.
- ✓ **Strategies:** Using **low-emission ingredients**; optimization of **energy consumption** and **energy sources** in feed production; **optimizing feed efficiency**.
  - ➢ **QS-SojaPlus** in Germany: branch-wide certification using only soy from sustainable cultivation based on FEFAC Soy Sourcing Guidelines.
  - ➢ **Climate Platform Meat** in Germany: Branch initiative "from farm to fork"!
- ✓ **Water use efficiency:** Specific selection of processing technic.

Newest generation feed additives in a Concept “Feed 3.0”

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- **Enzymes** → Phytase, carbohydrases, proteases
- **Prebiotics** → insoluble, highly fermentable fiber source → “symbiosis” with carbohydrases → production of **SCFA** in distal gut, especially **butyric acid**
- Probiotics → live micro-organisms conferring health support to the host by intestinal flora balance
- **Postbiotics** → Metabolic products of probiotics with, e.g., influence on the balance of the intestinal flora
- **Organic acids** → formic acid, lactic acid, …., MCFA: the right ones in the right dosage
- **Phytogenics** → composition with adapted release along the digestive tract
- Immunoglobulins → natural sources in critical periods (birth and weaning)
- ✓ Toxin solution & **detoxification** → endotoxins; mycotoxins

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“How to select Organic Acids”

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How to evaluate organic acids?

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		g/mol	pK_A
Propionic acid	($C_3H_6O_2$)	74,1	4,90
Butyric acid	($C_4H_8O_2$)	88,1	4,80
Sorbic acid	($C_6H_8O_2$)	112,1	4,80
Acetic acid	($C_2H_4O_2$)	60,0	4,76
Benzoic acid	($C_7H_6O_2$)	122,1	4,20
Lactic acid	($C_3H_6O_3$)	90,1	3,87
Formic acid	(CH_2O_2)	46,0	3,75
Citric acid	($C_6H_8O_7$)	192,4	3,14

Strong acids: **pK_A -1,74 – 4,5**
Medium acids: **pK_A 4,5 – 9**
Weak acids: **pK_A 9,0 – 15,74**

pK_A is an acid dissociation constant used to describe the acidity of a particular molecule.
pK_A values describe the point where the acid is 50% dissociated (i.e. deprotonated).

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Take-home message: Key success factors in a Concept „Feed 3.0“

- Integration of advanced technologies
- Automation and digitalization
- Sustainable and alternative ingredients
- Precision nutrition
- Health and welfare enhancements
- Environmental sustainability
- **Collaboration and knowledge exchange**

THANK YOU!

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Questions & Answers

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