Let’s make it work!
Efficient biotechnology for efficient animal nutrition

Dr. Ralf Kelle
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Amino acids are “essential”!
Stable trends drive demand

**Population growth**
A growing population means a growing demand for meat, eggs, milk, and fish

**Resource-efficient animal feeding**
Limited natural resources must be used as efficiently as possible

**Sustainable nutrition**
Healthy nutrition, with adequate animal protein, that is affordable and available over the long term
Biotech investment projects in the Health & Nutrition Business Unit

- Expansion of biotech R&D 2011-2014
- Lysine JV in Volgodonsk Start-up 2015
- Expansion of Midwest Lysine Start-up 2012
- Fermas Technology & Launch Platform 2013-2015
- Agroferm expansion Start-up 2013
- Lysine production in Castro Start-up 2014
From production organism to production process

**Input**
- T, pH, shear stress, P/V
- pO₂ airflow
- Concentration of S, P, Mg, Na, K, Fe, Zn, Co, etc.
- Feed of C-source, N-source and base/acid
- Quality of water and other raw materials
- Solubility and oxidation of salts and vitamins
- Product concentration
- Byproduct concentration
- Osmotic pressure

**Output**
- Product formation
- Byproduct formation
- Growth of organism
- Product form
- Foaming
- Crystallization
- Process efficiency
- Viscosity
Biolys® production compared with conventional production

Bacteria + C-source + Ammonia + Sulphuric Acid + Nutrients for Bacteria + Water!

- Fermentation
- Evaporation
- Spray granulation
- Biolys®
- Wastewater

Dry biomass

- Drying

Liquid L-Lysine base

- Ion exchange
- Crystallization
- Drying
- Dry L-lysine-HCl

Mother liquor
- residual lysine-HCl
- decomposition products
- impurities from raw material source

Wastewater

Ammonium sulphate
The art of targeted optimization of metabolism

- Amplify biosynthetic pathways
- Slow down side-reactions
- Avoid feed back inhibition
- Balance precursor supply and side reactions
- Enhance net export into the medium

E. coli & C. glutamicum

- Glucose
- Fructose
- Glucose-6-P
- Fructose-6-P
- Fructose-1,6-BisP
- Fructose-1-P
- Dihydroxyaceton-P
- Glycerinaldehyd-3-P
- Glycerat-1,3-BisP
- Glycerat-2-P
- Glycerat-P
- Enolpyruvat
- P
- Acetyl-CoA
- Citrat
- Oxalacetat
- Aspartat
- Aspartatsemialdehyd
- meso-Diaminopimelat
- Lysin
- Isoleucin
- Valin
- Panthotenate
- Methionin
- Homoserin
- Threonin
- Pyruvat
- P-Enolpyruvat
- 2-P-Glycerat
- 3-P-Glycerat
- Glycerat-1,1-BisP
- Glutamic Acid
- Nicotinat-Biosynthese
How can speed and efficiency be optimized?

**Diagram**

- **Sugar** → **Enzyme A**
- **Enzyme B** → **Enzyme C** → **Enzyme D** → **Metabolic intermediates**
- **Enzyme F** → **L-Lysine**
- **CO₂**

- Metabolic intermediates as building blocks for bacterial growth
Good bacterial growth negatively impacts efficiency
Minimized growth is at the expense of process speed
Expanded biotech expertise drives progress in productivity

- Progress, Midwest Lysine 2009-2013
- Biolys® production, Fermas 1992-2001
- Establishment of biotech R&D
- Biolys® production, MWL 2000-2008

Technological development of industrial fermentation
= f (yield, product concentration, productivity)
Expanded biotech expertise drives progress in productivity

- Continuous improvement in production costs and process efficiency
- Continuous improvement of lysine content at the same level of value using the other components of Biolys®
- Continuous improvement of product properties for use in feed production
Increase in efficiency of the Biolys® production process, 2002-2020

Climate warming potential [kg CO₂e/kg]

- Process emissions
- Raw materials
- Electricity
- Thermal energy
- Transport
- Wastewater treatment
- Carbon source
- Packaging
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www.evonik.com/feed-additives
feed-additives@evonik.com

Evonik. Power to create.
Evonik is working on solutions that go beyond amino acids.

- Diagnostics for preventing disease and reducing intervention (such as use of antibiotics) in animal nutrition
- Secondary metabolites
  - L-Isoleucine
  - L-Valine
  - L-Threonine
  - L-Lysine
  - L-Tryptophan
- Essential fatty acids for aquaculture
- Probiotics with scientifically proven effect and measurable benefit for use in animal nutrition

Portfolio development

Complexity of the technology