



We create chemistry

Natugrain[®] TS

Maximizing nutrient utilization in complex poultry and pig diets



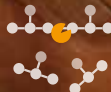
Natugrain[®] TS is a combination of β -xylanase and β -glucanase that supports modern, high-performance, sustainable animal production by:

- Increasing the release of nutrients and energy from the diet
- Decreasing digesta viscosity
- Aiding effective fermentation in the hindgut
- Improved feed utilization

The science of sustainable feed that succeeds

BASF Enzymes

The science of making more from less



animal-nutrition.basf.com

More than

★ **30** ★
YEARS

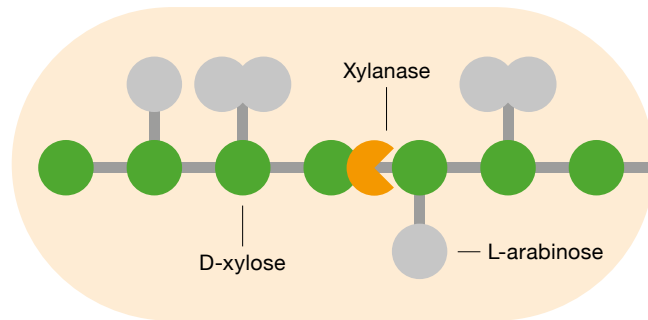
Pioneering Expertise
BASF Enzymes

Well-balanced enzyme activities to counteract anti-nutritional effects from arabinoxylans and β -glucans

Non-starch polysaccharides (NSPs) are the least digestible compounds in feedstuffs used for pig and poultry. Their anti-nutritional properties reduce the utilization of dietary nutrients by increasing digesta viscosity and by trapping valuable nutrients.

Natugrain[®] TS contains BASF's highly purified NSP-degrading enzymes endo-1,4- β -xylanase and endo-1,4- β -glucanase. Natugrain[®] TS improves the digestibility of nutrients and energy utilization from feedstuffs such as wheat, corn, rye, barley, sorghum, etc.

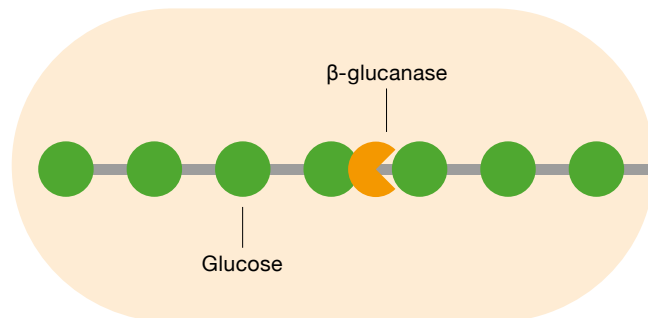
Endo- β -xylanase hydrolyzes arabinoxylans into xylo-oligosaccharides (XOS) and arabinoxylo-oligosaccharides (AXOS)



Arabinoxylan

- **Endo-xylanase** is the enzyme responsible for the partial hydrolysis of arabinoxylans
- Xylanase hydrolyzes the **β -1,4 bonds between xylose units** in the arabinoxylan backbone

Endo- β -glucanase breaks down β -glucans into smaller molecules



β -glucan

- **Endo- β -glucanase** is the enzyme that breaks down β -glucans into smaller molecules
- Cereal β -glucans contain a **mixture of β -1,4 and β -1,3 glycosidic bonds**

Natugrain[®] TS, a mix of xylanase and β -glucanase that supports feed utilization based on three interactive mechanisms of action

Mechanism of action 1

Reduction of digesta viscosity

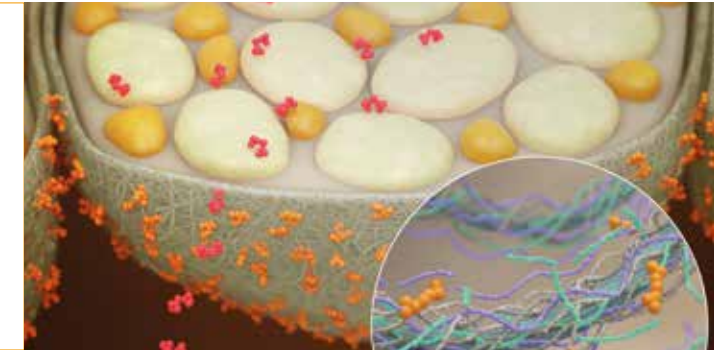
Breakdown of viscous arabinoxylans and β -glucans which reduces intestinal viscosity and increases nutrient utilization.



Mechanism of action 2

Cell wall disruption

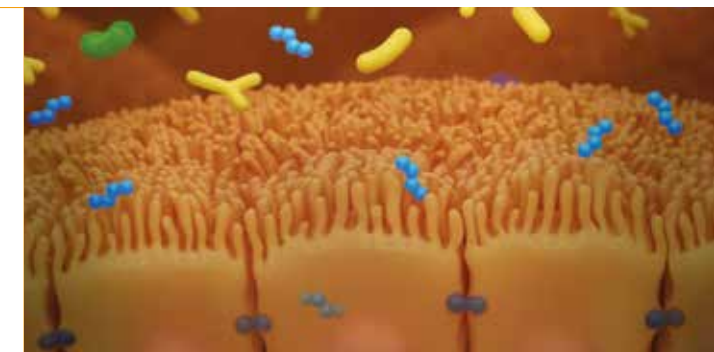
Degradation of plant cell walls releases trapped nutrients, which can be digested by the animal.



Mechanism of action 3

Release of oligosaccharides

Depolymerization of arabinoxylans into XOS/AXOS which provide positive prebiotic effects.



Mechanism of action 1

Reduction of digesta viscosity

Natugrain® TS effectively reduces the digesta viscosity

β -glucans and soluble viscous arabinoxylans can increase intestinal viscosity, hindering the digestion of nutrients¹.

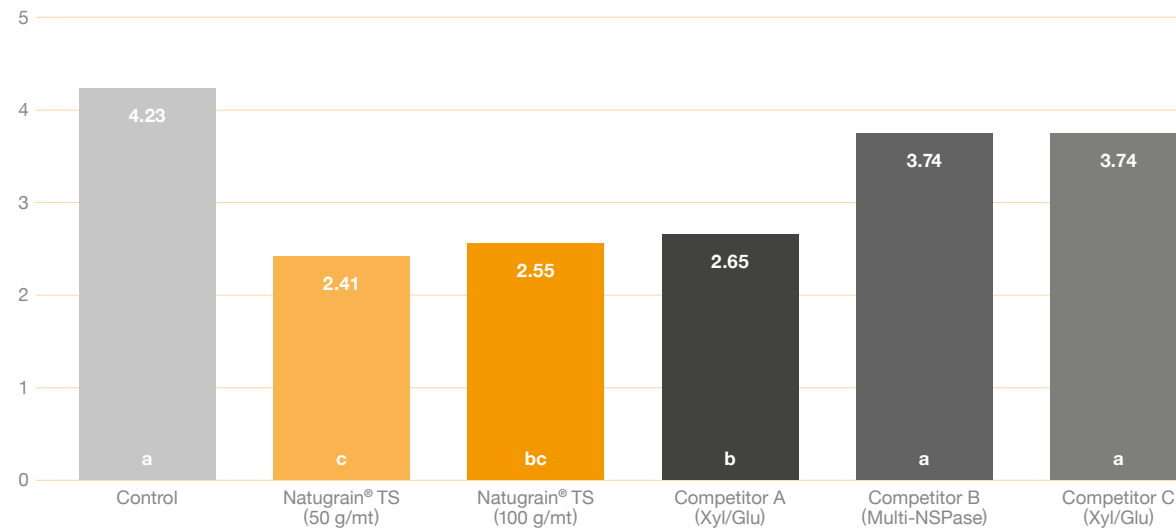
By breaking down soluble viscous xylans and β -glucans, Natugrain® TS reduces intestinal viscosity, resulting in more fluid digesta and greater digestion efficiency.



Wheat-barley-soy-based diet: viscosity comparison in broiler chickens

Ileal viscosity (day 21), mPa.s

P<0.05
LiHo-36-10



Mechanism of action 2

Cell wall disruption

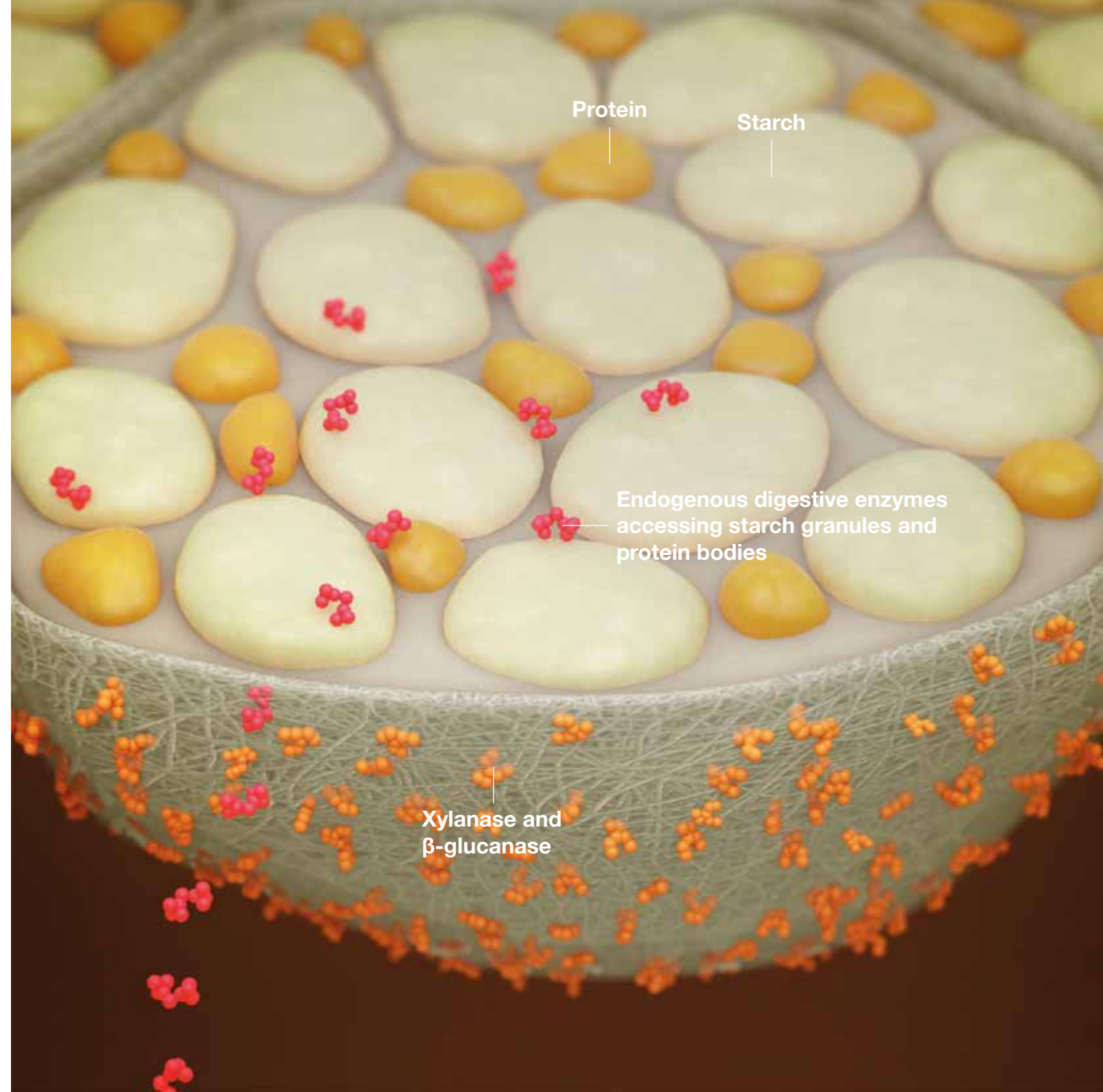
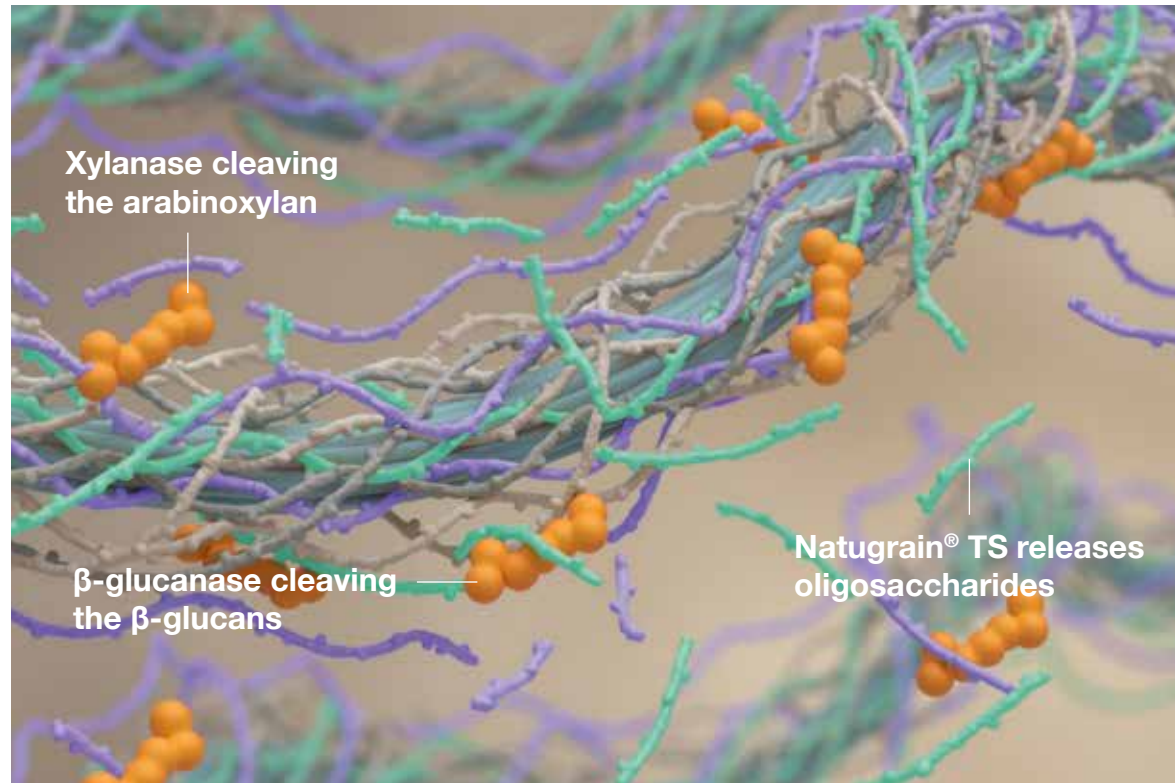
Natugrain® TS increases the permeability of cell walls

NSPs are the primary constituents of a plant cell wall, entrapping valuable nutrients such as starch and proteins. This complex fiber matrix makes it difficult for these nutrients to be digested.

The degradation of the plant's cell wall by xylanase and β -glucanase leads to an increased release of entrapped nutrients such as starch and proteins².

Arabinoxylan and β -glucan of the endosperm cell walls of cereals are the NSPs with the highest susceptibility to exogenous enzymes³.

Degradation of plant cell walls releases trapped nutrients



Mechanism of action 3

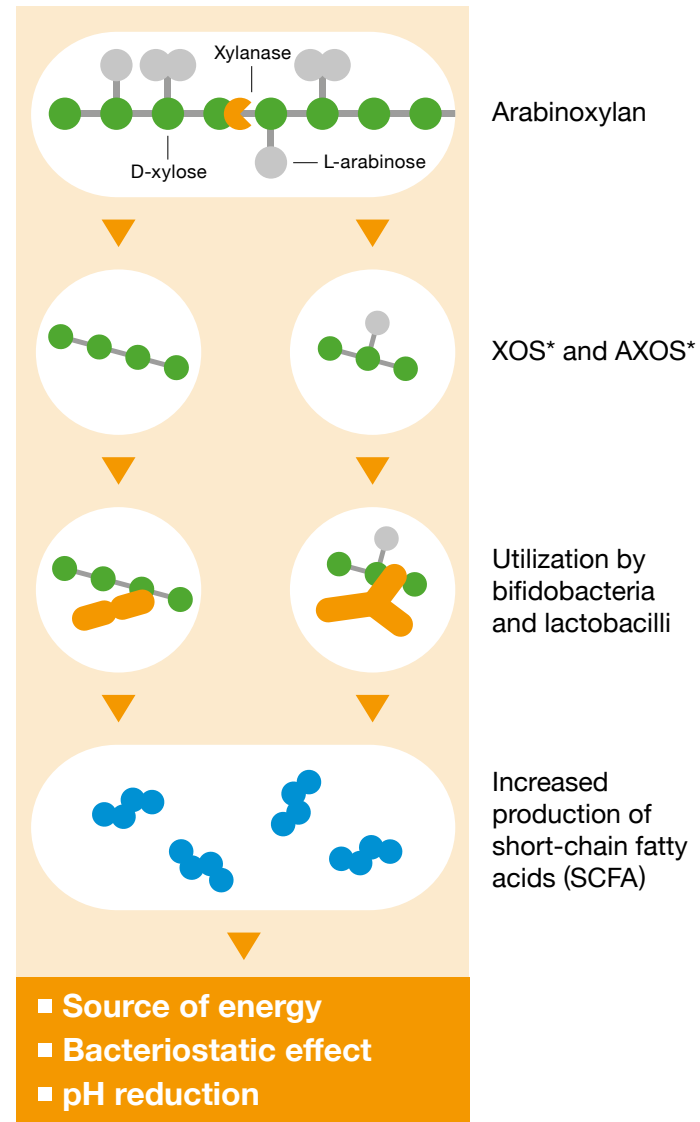
Release of oligosaccharides

Natugrain® TS releases oligosaccharides with the ability to increase the production of short-chain fatty acids (SCFA), which in turn can improve gut function

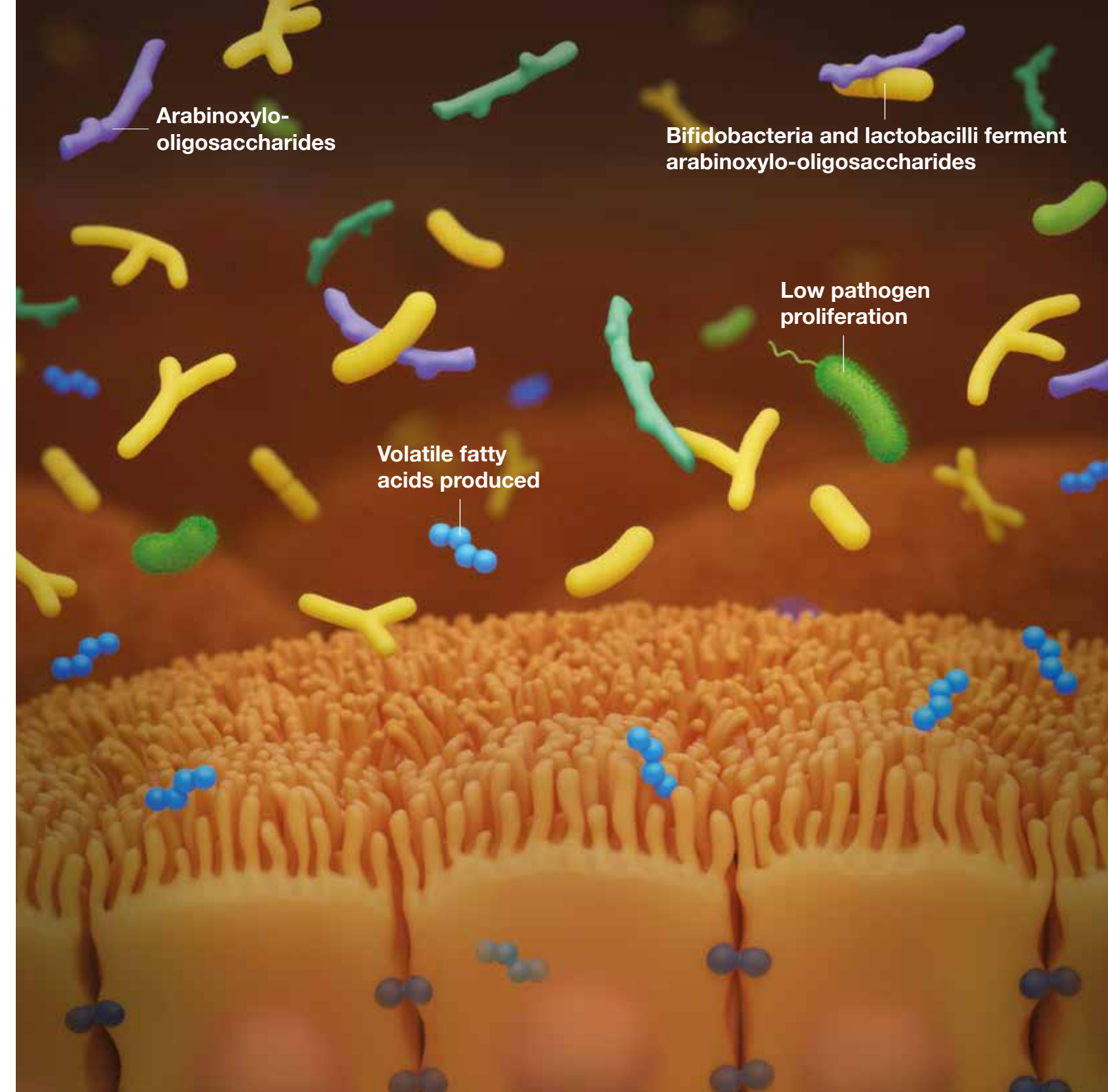
The degradation of arabinoxylans releases xylo- and arabinoxylo-oligosaccharides (XOS and AXOS).

These compounds act as prebiotics and can be used by some bacteria resulting in the production of SCFAs. The higher production of SCFAs can result in a better gut function and animal wellbeing^{4, 5}.

Arabinoxylan structure and its breakdown by xylanase



*Examples of XOS and AXOS



Mechanism of action 3

Release of oligosaccharides and glycoside hydrolase (GH) families

GH10 or GH11 xylanases

All xylanases can cleave the β -1,4-linkages. The majority of feed xylanases belong to **GH10 or to GH11 families** which are structurally different.

GH10 (Natugrain TS®)

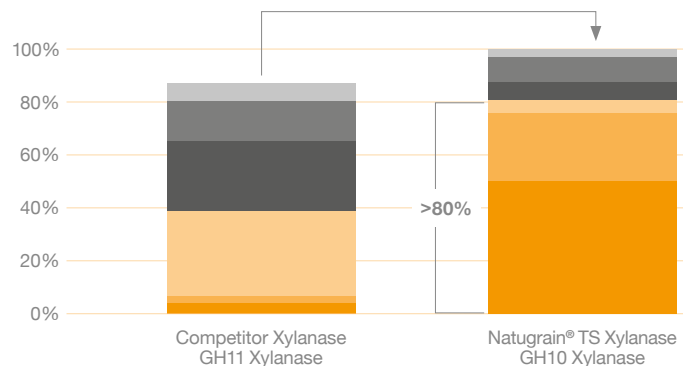
- Are more versatile and cleave highly substituted arabinoxylans⁶
- Are less selective, hydrolyzing highly substituted xylans more efficiently resulting in greater AXOS production⁷

GH11 families

- Only cleave unsubstituted regions⁶

Natugrain® TS GH10 xylanase is more efficient at depolymerizing xylans, therefore it produces more AXOS

Arabinoxyl-oligosaccharides (AXOS) production relative to Natugrain® TS xylanase total AXOS production*



Xylose units in AXOS
 ■ X2 ■ X3 ■ X4 ■ X5 ■ X6 ■ X7

What happens after the incubation of wheat arabinoxylan with Natugrain® TS xylanase?

- AXOS production is higher
- Provision of small oligomers (Σ X2-X3-X4) is greater
- Xylose (X1) can have a negative effect in poultry and was not produced by the xylanases

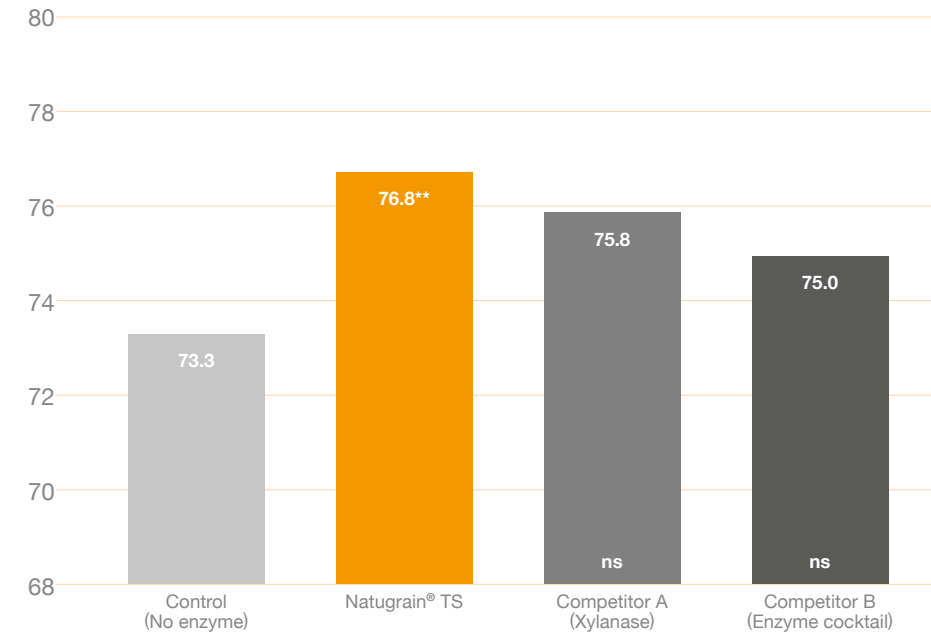
AXOS with lower molecular weight are more fermentable and generate more SCFAs⁸.

Higher AXOS release leads to greater production of short-chain fatty acids (SCFAs)

- Natugrain® TS increases cecal fermentation, which indicates a shift in microbial populations.
- The SCFA can lower the gut pH, creating an unsuitable environment for pathogenic bacteria and increasing the solubility of minerals.
- SCFA can also penetrate the lipid membrane of pathogens.



SCFA concentration (mM) after 10-hour ex vivo fermentation*



**Different from Control group (P<0.01)

ns: not significantly different from Control group (P>0.05)

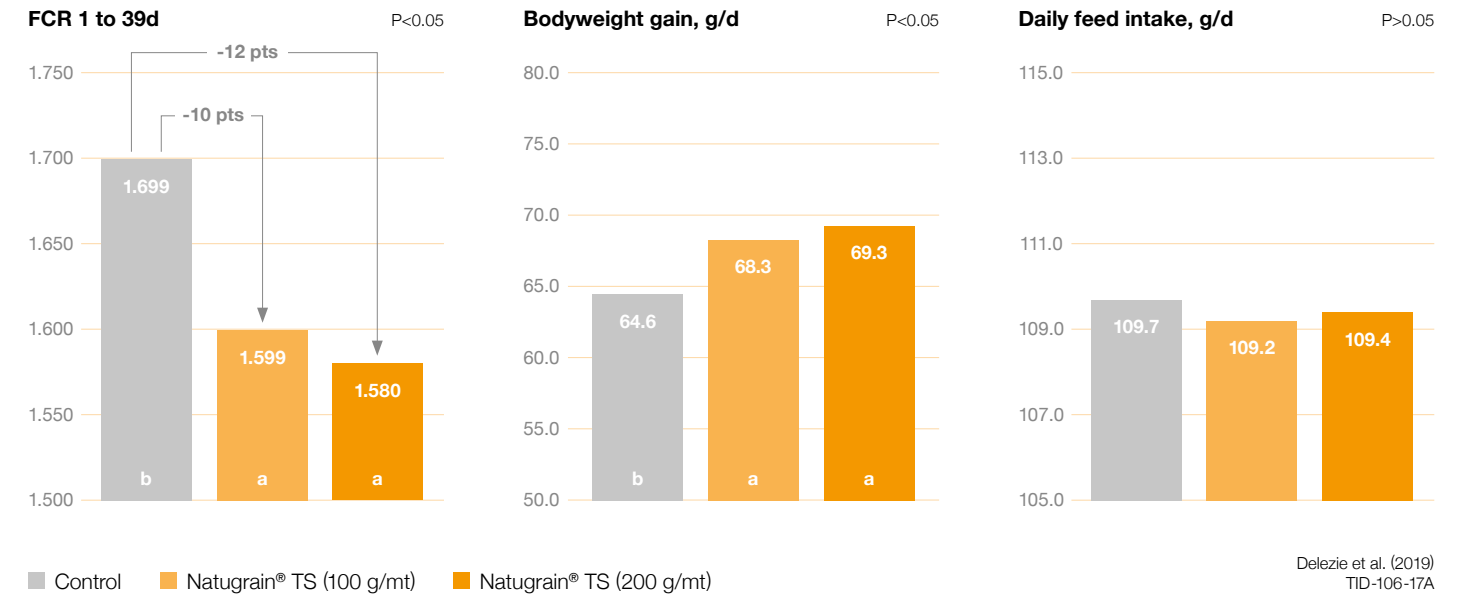
Control = untreated arabinoxylan; Other groups represent enzyme-treated arabinoxylan



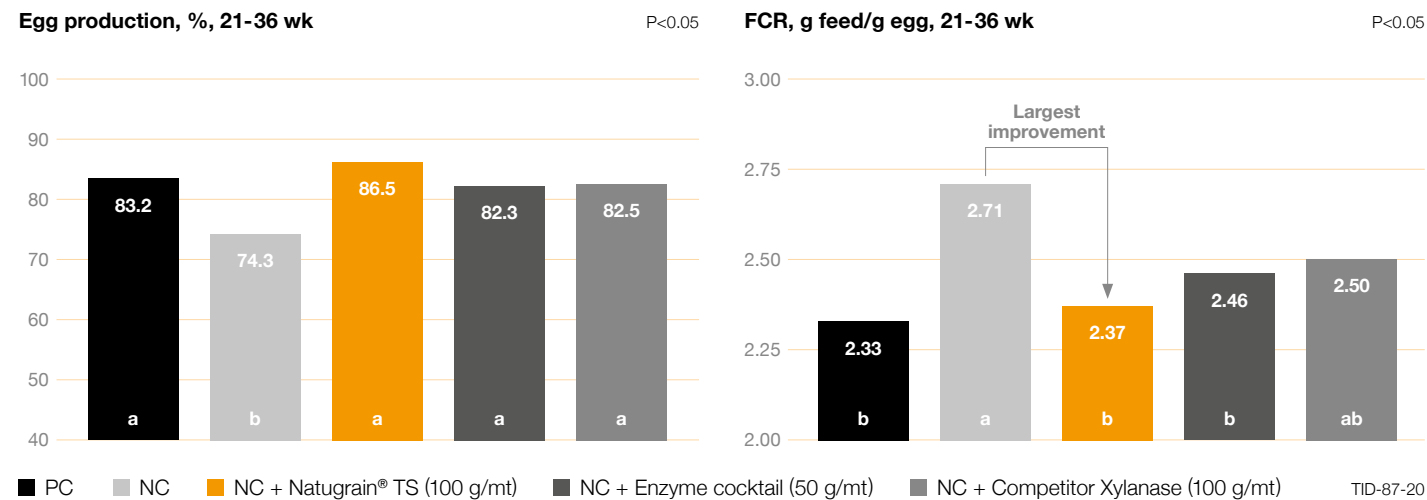
Natugrain® TS optimizes performance and nutrient utilization in poultry



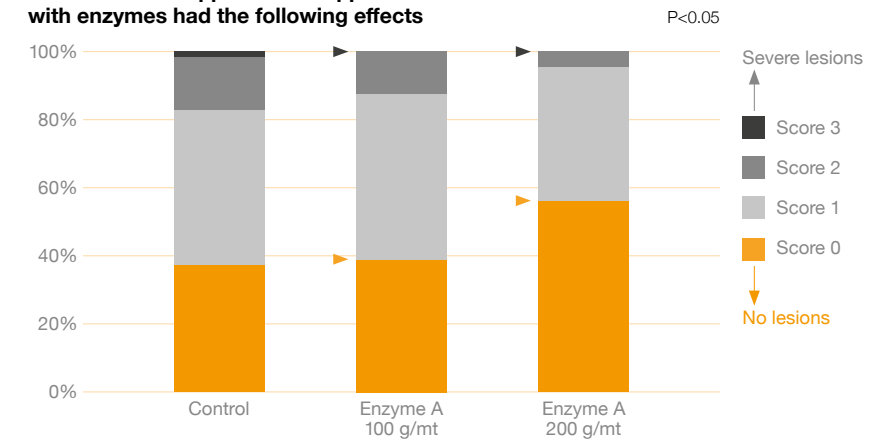
Improved feed utilization and reduced severity of footpad lesions in broiler chickens



Improved feed utilization in laying hens



Scientific data supports that supplementation with enzymes had the following effects



- ▶ Reduction of more severe lesions (scores 2 and 3) when Enzyme A was added
- ▶ Higher incidence of "no lesions" when Enzyme A was added

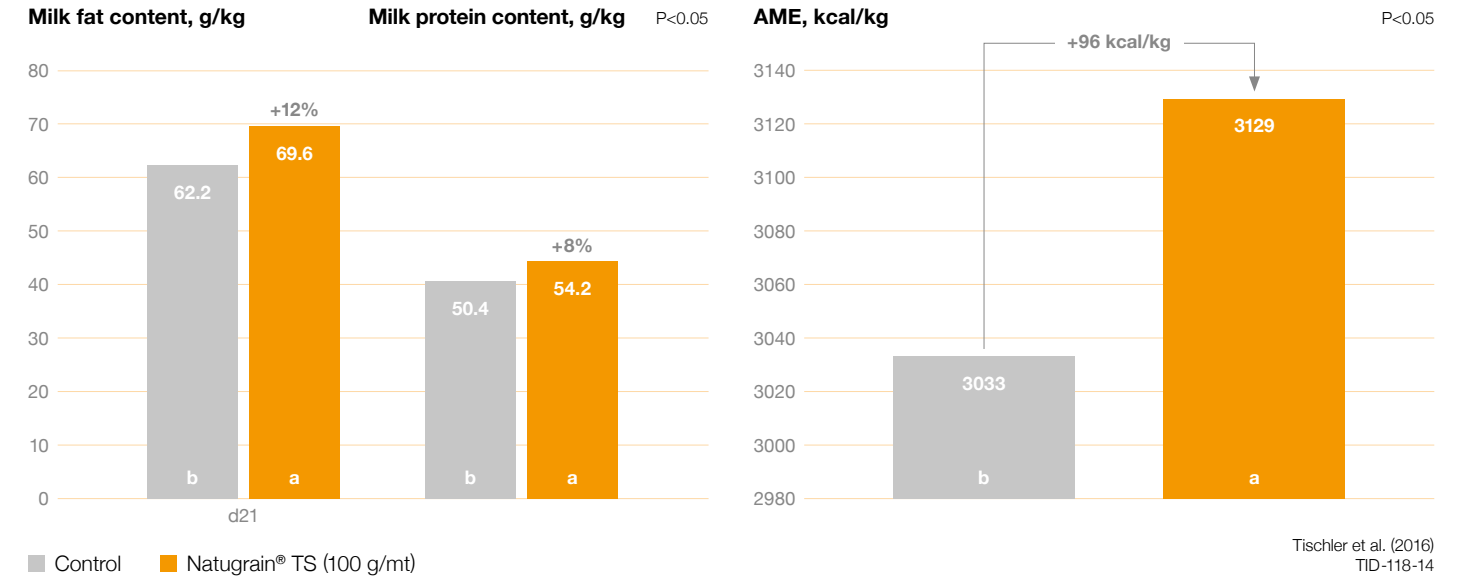
Deficiencies in these enzymes can lead to footpad dermatitis. Reduction of footpad lesions can result in better animal wellbeing



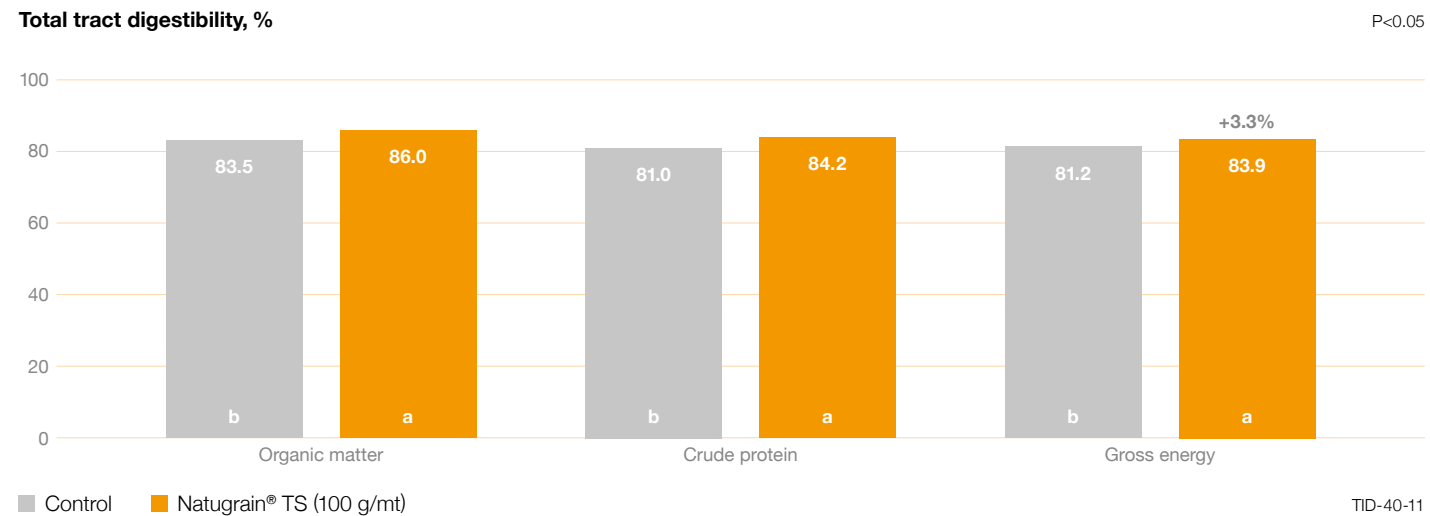
Natugrain® TS improves feed utilization



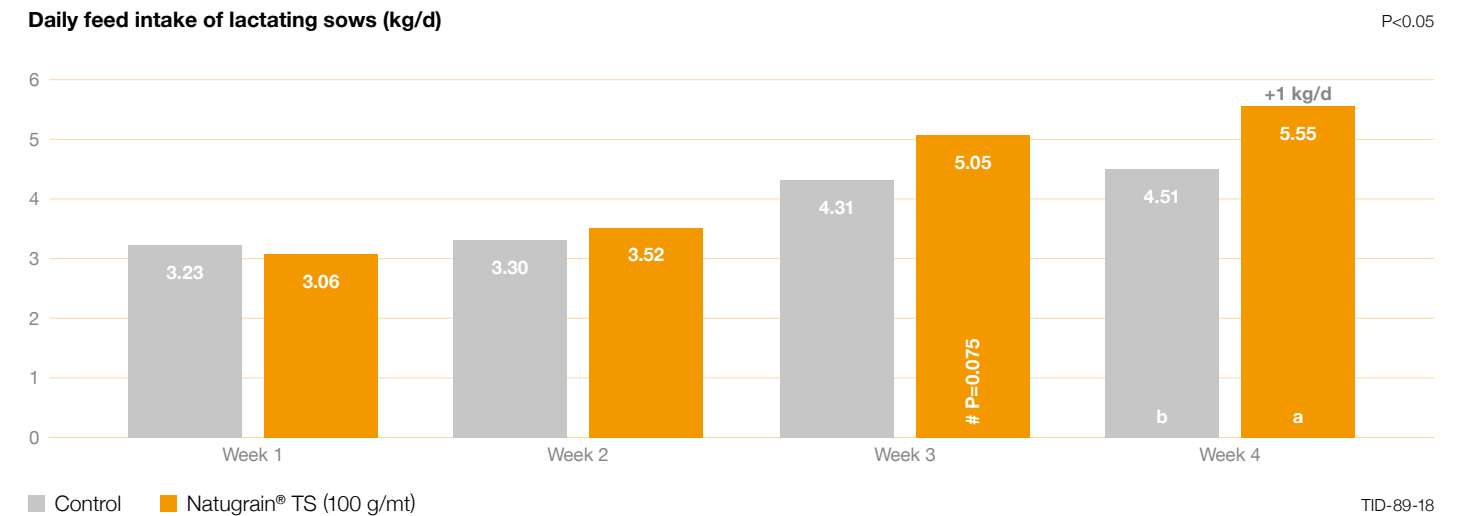
Increased nutrient supply in milk and improved energy utilization in lactating sows



Improved nutrient digestibility in fattening pigs



Attenuated bodyweight losses and increased feed intake in sows during lactation

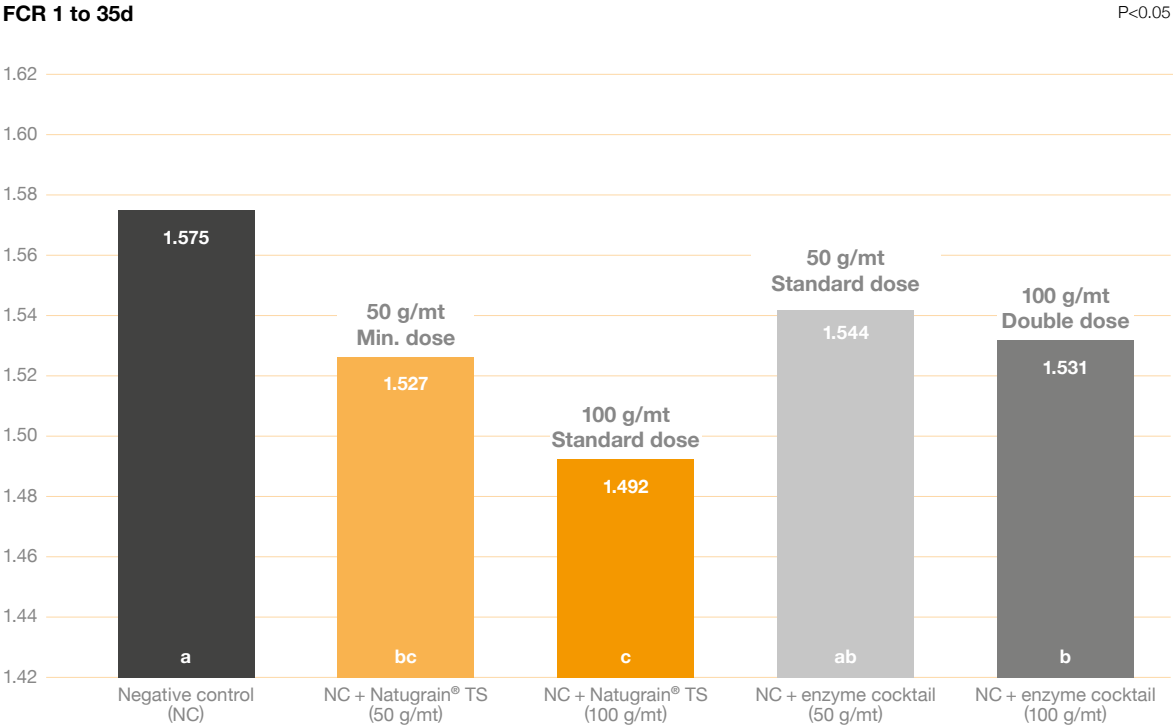


Natugrain® TS: benefits and characteristics

In vivo trials have shown that Natugrain® TS, a mix of purified xylanase and β-glucanase, can outperform ‘enzyme cocktails’

- Cereal-based diets contain many NSPs with different complexities
- In theory, it is plausible that a wide variety of NSP-enzymes are necessary to degrade the complex cell wall structures in cereal grains
- However, in vivo trials have shown that the standard dose of Natugrain® TS can outperform enzyme cocktails with multi-NSP-enzymes activities

Natugrain® TS (Xyl/Glu) vs. enzyme cocktail* in a wheat-soy-canola-based diet*



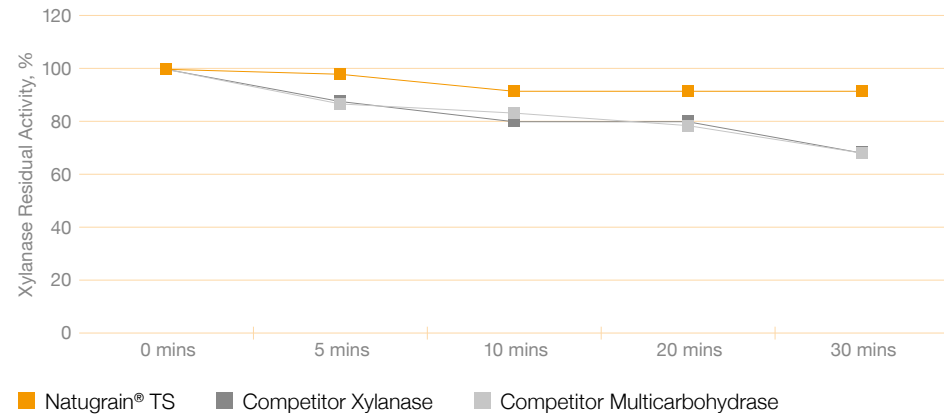
*Enzyme cocktail with 19 enzyme activities: Xylanase, β-xylosidase β-glucanase, debranching enzymes, cellulase, pectinases and others. TID-58-16



Natugrain® TS: benefits and characteristics

Natugrain® TS is highly stable at acidic conditions

Gastric stability in simulated gastric fluid (pH 2.8 and pepsin)



Stomach
pH 2.5 – 4.5



Crop
pH 4.5 – 6.0



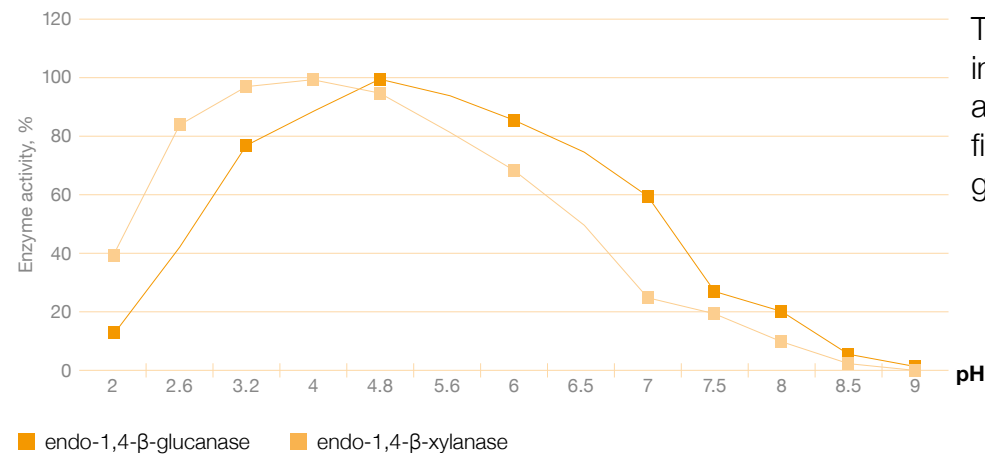
Proventriculus
pH 2.0 – 5.0

Gizzard
pH 2.0 – 5.0

In the acidic conditions of simulated gastric fluid (pH 2.8; pepsin); xylanase showed a residual activity of over 90% over a 30-minute period.

Natugrain® TS: active in a wide pH range

Xylanase is highly active (>70%) in a pH of 2.6 to 6.0
Glucanase is highly active (>70%) in a pH range of 3.2 to 6.5



The xylanase and β-glucanase inside Natugrain® TS are highly active over a wide pH range that fits to the conditions of the gastrointestinal tract.

Natugrain® TS has excellent stability and miscibility

- Excellent shelf-life stability even at high temperatures
- Excellent stability in pre-mixes
- High stability during pelleting
- Quickly dissolved, ensuring optimal activity in a short period of time



Choose the Natugrain® TS formulations that are right for you

Product name	Form	Concentration	Dosage	Application	Shelf life	Article no
Natugrain® TS	Powder	Endo-1,4-β-xylanase, min. 5600 TXU/g* Endo-1,4-β-glucanase, min. 2500 TGU/g**	560 TXU/kg and 250 TGU/kg feed (= 100 g/mt feed)	Recommended for pelleting up to 85°C (185°F)	18 mo. (≤ 20°C)	53688722 20 kg bag in box 53688775 350 kg big plastic bag
Natugrain® TS 5XG	Powder	Endo-1,4-β-xylanase, min. 28000 TXU/g* Endo-1,4-β-glucanase, min. 12500 TGU/g**	560 TXU/kg and 250 TGU/kg feed (= 20 g/mt feed)	Recommended for pelleting up to 85°C (185°F)	18 mo. (≤ 20°C)	50476892 20 kg bag in box
Natugrain® TS L	Liquid	Endo-1,4-β-xylanase, min. 5600 TXU/g* Endo-1,4-β-glucanase, min. 2500 TGU/g**	560 TXU/kg and 250 TGU/kg feed (= 100 g/mt feed)	Recommended for post-pelleting liquid applications	24 mo. (≤ 20°C)	50126560 125 kg plastic drum 53686496 1000 kg bulk container
Natugrain® TS DL	Liquid	Endo-1,4-β-xylanase, min. 11200 TXU/g* Endo-1,4-β-glucanase, min. 5000 TGU/g**	560 TXU/kg and 250 TGU/kg feed (= 50 g/mt feed)	Recommended for post-pelleting liquid applications	24 mo. (≤ 20°C)	50345001 1000 kg bulk container
Natugrain® Wheat TS	Powder	Endo-1,4-β-xylanase, min. 5600 TXU/g*	560 TXU/kg (= 100 g/mt feed)	Recommended for pelleting up to 85°C (185°F)	12 mo. (≤ 20°C)	52569309 20 kg bag in box

*One TXU is defined as the amount of enzyme that liberates 5 μmol of reducing sugars (xylose equivalents) per minute from a buffer solution containing 1 g of arabinoxylan per 100 ml at pH = 3.5 and 40°C.

**One TGU is defined as the amount of enzyme that liberates 1 μmol of reducing sugars (glucose equivalents) per minute from a buffer solution containing 0.714 g of beta-glucan per 100 ml at pH = 3.5 and 40°C.

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¹Bach Knudsen, K. E. (2014). Fiber and nonstarch polysaccharide content and variation in common crops used in broiler diets. Poultry Science, 93, 2380-2393.

²Khadem, A. et al. (2016). Does release of encapsulated nutrients have an important role in the efficacy of xylanase in broilers? Poultry Science, 95, 1066-1076.

³Bach Knudsen, K. E., & Vangsoe, C. (2019). Chapter 4: Fibre –how and which structures can be modified by enzymes. The value of fibre: Engaging the second brain for animal nutrition. Wageningen Academic Publishers.

⁴Saville, B. A., & Saville, S. (2018). Xylooligosaccharides and arabinoxylanoligosaccharides and their application as prebiotics. Applied Food Biotechnology, 5, 121-130.

⁵Courtin, C. M. et al. (2008). Dietary inclusion of wheat bran arabinoxylanoligosaccharides induces beneficial nutritional effects in chickens. Cereal Chemistry, 85, 607-613.

⁶Cited by Heinze, S. et al. (2017). Identification of endoxylanase XynE from Clostridium thermocellum as the first xylanase of glycoside hydrolase family GH141. Scientific reports, 7, 1-10.

⁷Morgan, N. K. et al. (2017). Efficiency of xylanases from families 10 and 11 in production of xylo-oligosaccharides from wheat arabinoxylans. Carbohydrate polymers, 167, 290-296.

⁸Chen, Z. et al. (2019). Arabinoxylan structural characteristics, interaction with gut microbiota and potential health functions. Journal of Functional Foods, 54, 536-551.

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