Digestion and energetic utilization of dietary fibres in pigs

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Fiber an important dietary ingredient

➢Contributes to nutritive value of diet

Direct and indirect, positive and negative

1

Chemical composition of the diet

Physical properties of the diet

e.g. WBC
Viscosity
Bulk

Nutritive value
Energy supply (fermentation products)
Energy digestion

Digestive processes
Digesta matrix
Physical barrier
Endogenous secretions/losses
Digesta flow and retention time
Microbial population/fermentation products
GIT development

Reduced/increased digestion of other nutrients
Reduced/increased energy losses

Feed intake, activity…..

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[1] From: www.dreamstime.com

Contents

- Defenitions and analyses
- Fibre fermentation and passage
- Recalcitrant fibres from DDGS and rapeseed meal

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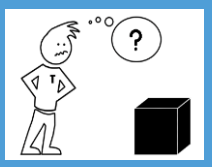
Defenitions and analyses



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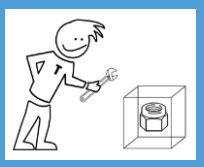

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[1] From: www.qainsight.net

Fiber ≠ Fiber

- Resistant starch
- Lignin
- NSP > chemically diverse
  - Cellulose
  - Hemicellulose
    - β – glucans, (hetero)xylans, xyloglucans, glucomannans
  - Pectic polysaccharides
    - Homogalacturonans, rhamnogalacturonans, arabinans, arabinogalactans
- Chemical composition doesn't tell it all

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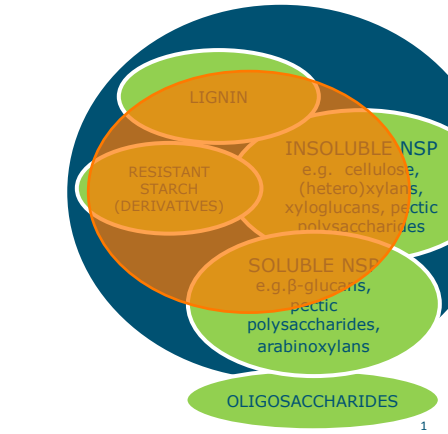
Fibre analysis: method determines outcome...



[1] Figure modified from Zielinski et al. 2013.

Commonly used gravimetric fiber analyses
Crude fiber (CF)
Neutral detergent fiber (NDF)
Acid detergent fiber (ADF)
Acid detergent lignin (ADL)

Note influence of physical properties e.g. particle size

Total dietary fiber / Total NSP + lignin
Enzymatic - chemical methods (e.g. Englyst or Uppsala)
Enzymatic - gravimetric methods (e.g. AOAC 2009)
DM-CP-Ash-Cfat-Starch-Sugars (CVB)

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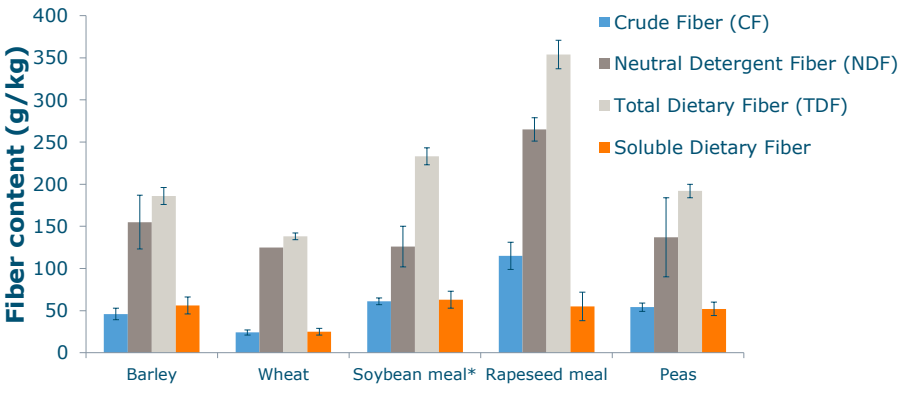
de Vries, S. Proc Eur Symp Poult Nutr. 20: 40 – 47. **2015.**

Method determines ranking of ingredients



Fiber content of feed ingredients[1,2]

[1] Crude fiber and neutral detergent fiber (NDF) reported by CVB, 2011. If no SD is reported sample size was < 5.
[2] Total dietary fiber (TDF) and soluble dietary fiber (SDF) as reported by Bach Knudsen, 1997.
* Trading class CF 45-70, CP < 450 g/kg.

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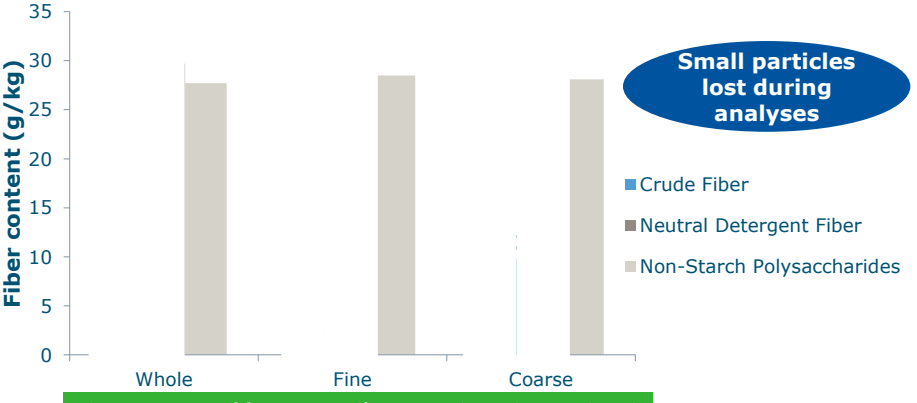
Particle size interferes with CF and NDF



Fiber contents of fractionated[1] rapeseed meal as analyzed by different methods

[1] Rapeseed meal was fractionated using air classification.
[2] Geometric Mean Diameter (µm)

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de Vries et al. unpublished.

Resistant Starch, an "NSP" ??

- 'Resistant' by definition but various chemical structures:
  - RS1: physically inaccessible starch (entrapped in cell wall matrix): beans, coarsely ground cereal grains
  - RS2: resistant starch granules/molecular structure (crystalline): potato, banana, high-amylose starches
  - RS3: retrograded starch
  - RS4: chemically modified starch (branching, cross-linking)
  - RS5: amylose-lipid complex

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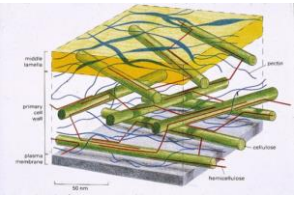
Fiber ≠ fiber

Summary

- Look beyond generic fiber fractions
  - Assembly of structures
  - Chemical composition doesn't tell it all
  - Keep in mind analytical constraints
    - Make sure analytical method matches purpose
      - TDF for routine analysis
      - NSP for scientific purpose
    - Know your methods (i.e. know what fibers recovered)



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Fermentation and energy value

- Fermentation as related to fiber composition
- Competition between degradation and passage
- Energy value of fiber

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90% of variation in energy value of fibers is related to variation in fermentability

Apparent Total Tract Digestibility

Subjected to digestive processes: Grinding/mastication, moisture, pH changes, digestive enzymes, microbial fermentation, …

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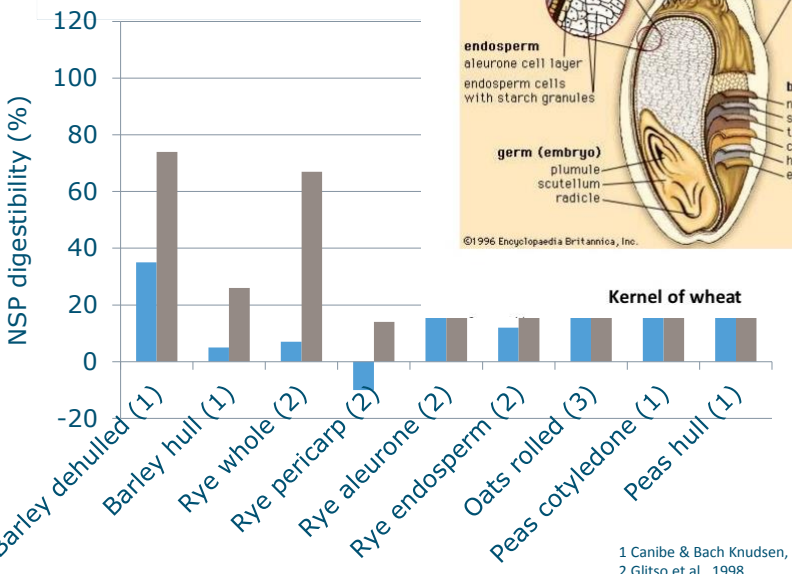
Variation in botanic



1 Canibe & Bach Knudsen, 2002
2 Glitso et al., 1998
3 Bach Knudsen & Hansen, 1991

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Effects of soluble and insoluble fibers

	Soluble NSP	Insoluble NSP
Stomach		
Viscosity	+++	+
Water binding	++	+++
Retention time	++	
Small intestine		
Viscosity	++	
Water binding	++	+++
Glucose absorption	_	
Large intestine		
Fermentation	+++	++
Bulking	+	+++
Retention time		--

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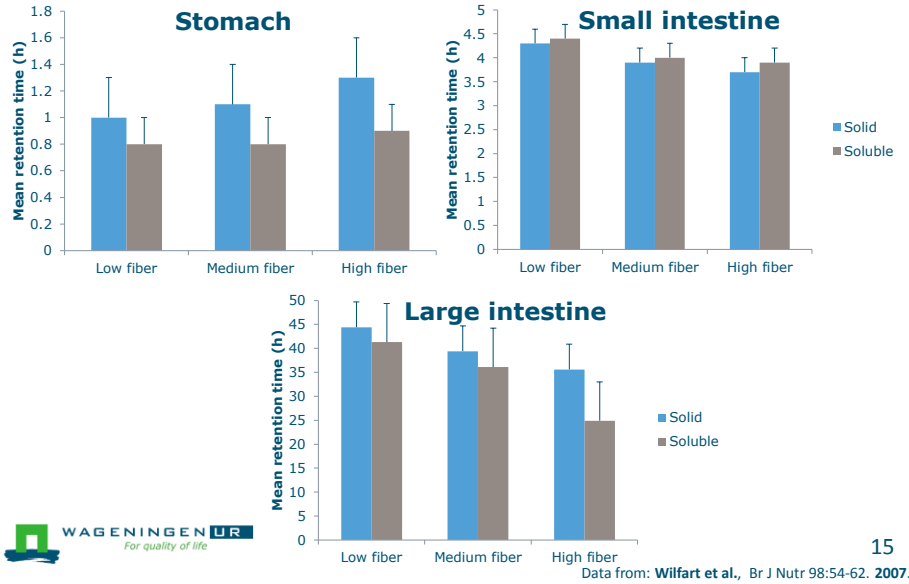
Modified from: **Bach Knudsen, KE.** Anim Feed Sci Technol. 90: 3 – 20. **2000.**

Effect of wheat bran on transit behaviour



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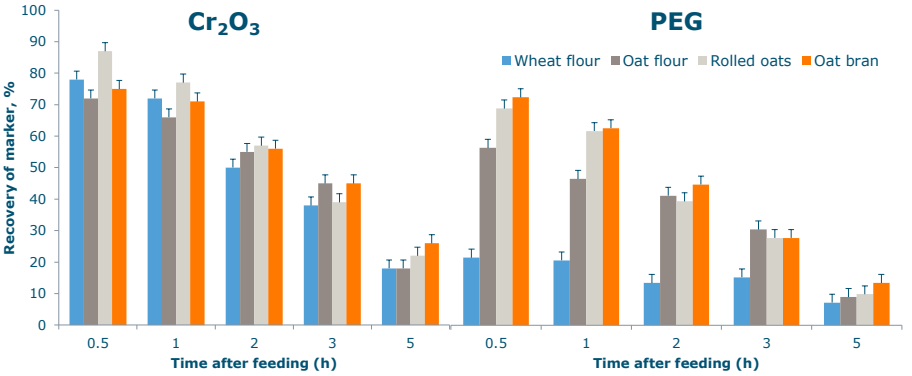
Data from: **Wilfart et al.**, Br J Nutr 98:54-62. **2007**.

Soluble DF mainly affects gastric retention of liquid digesta



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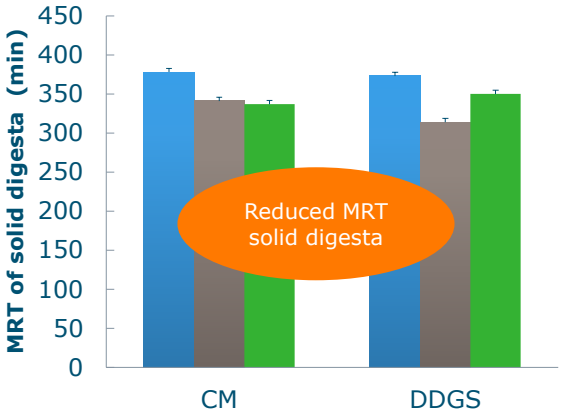
Data from: **Johansen et al.**, Br J Nutr 75:339-351. **1996**.

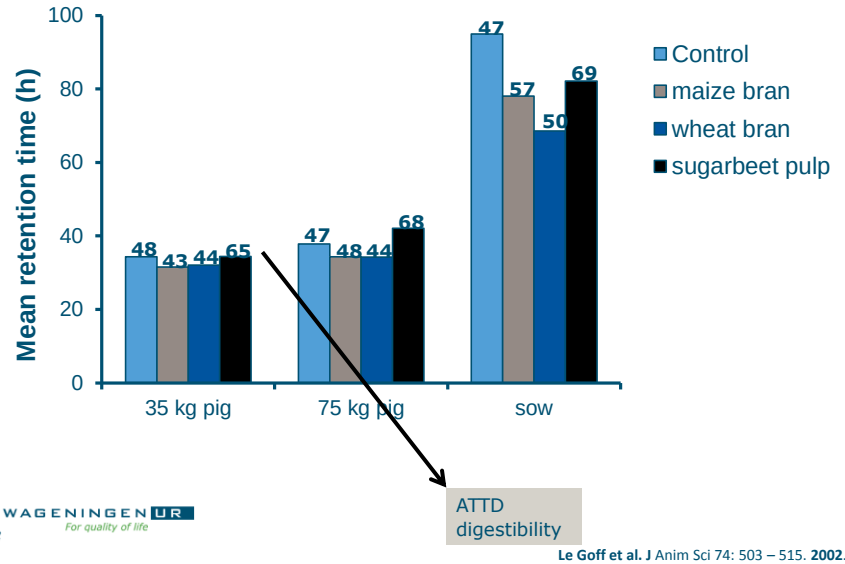
But also solid digesta can be affected



Effect of fiber source	
	P -value
Raw material	0.36
β-glucan	< 0.01
RS	0.04
Interaction	0.20

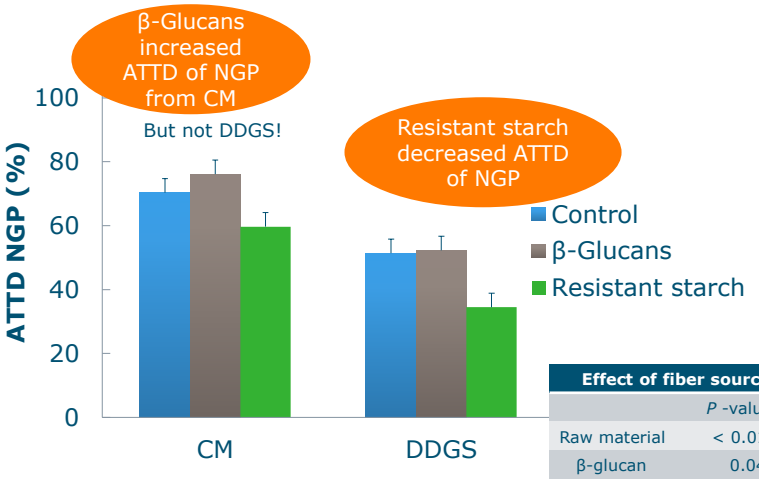
de Vries, S. 2014. PhD Thesis, chapter 9

Digesta transit in growing pigs and sows



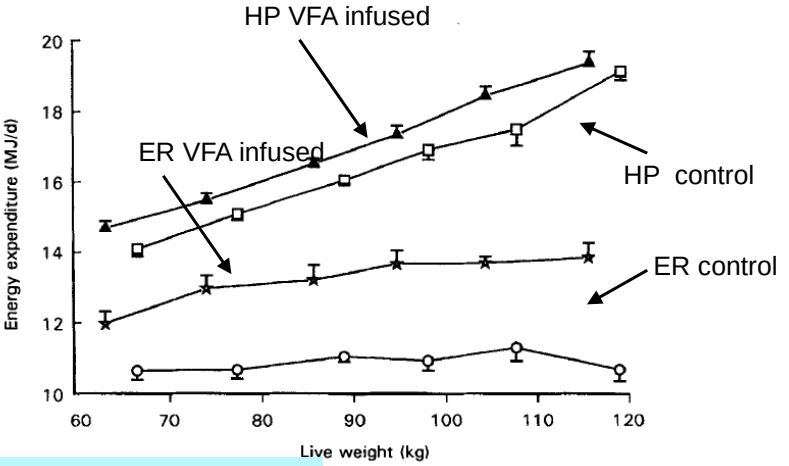
Le Goff et al. J Anim Sci 74: 503 – 515. 2002.

Fiber – Fiber interactions



Effect of fiber source	
	P -value
Raw material	< 0.01
β-glucan	0.04
RG	< 0.01
Interaction	0.13

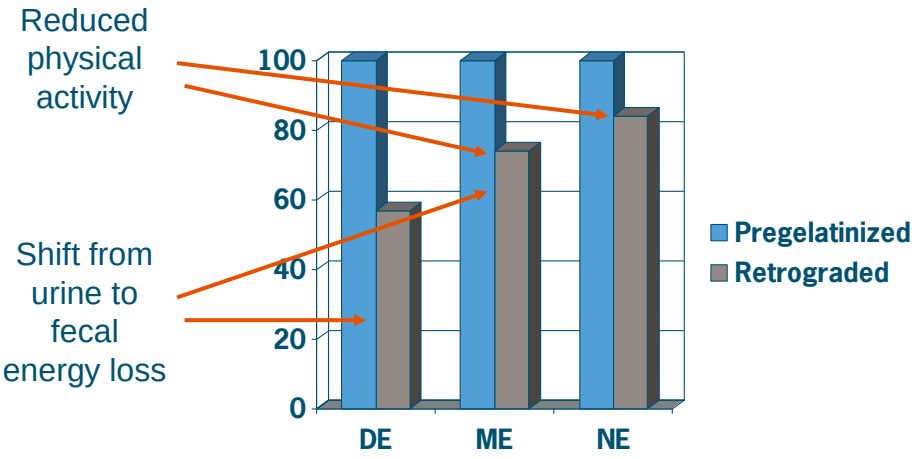
Net energy value of fermentation end-products



$$\frac{\Delta ER\ (kJ)}{VFA\ infused\ (kJ)} = 80\%$$

Jørgensen et al. Br J Nutr 77: 745 – 756. **1997**.

Energy value of RS, relative to pregelatinized



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Gerrits et al. J Nutr 142: 238 – 244. 2012.

Fermentation and energy value of fibers

Summary

- Fermentation depends on:
  - Chemical composition
    - e.g chain length, linkages b/w sugar molecules
  - Structural arrangements in cell wall
    - Crosslinks b/w polysaccharides, protein and lignin
- Clear interactions between ingredients
- Fibers affect retention time, digestion and absorption of other diet components
- Energy value follows fermentabili

Need to reconsider addititvity approach in feed evaluation?

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Recalcitrant fibers from DDGS and rapeseed meal

Corn Dried distillers grain with solubles (DDGS)

Rapeseed meal (RSM)

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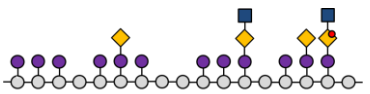
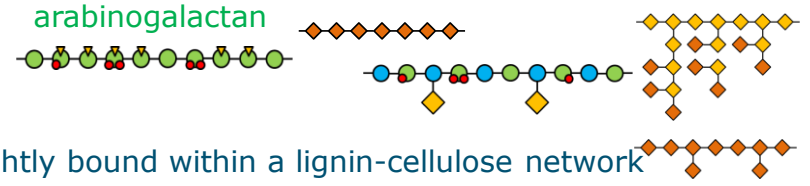
Fiber structures in rapeseed meal

- Originating from rapeseed
- Cellulose



- Hemicellulose
  - Xyloglucan, glucuronoxylan, galactomannan
- Pectic polysaccharides
  - Homogalacturonan, rhamnogalacturonan, arabinan, arabinogalactan



- Tightly bound within a lignin-cellulose network
  > Rigid cell wall matrix

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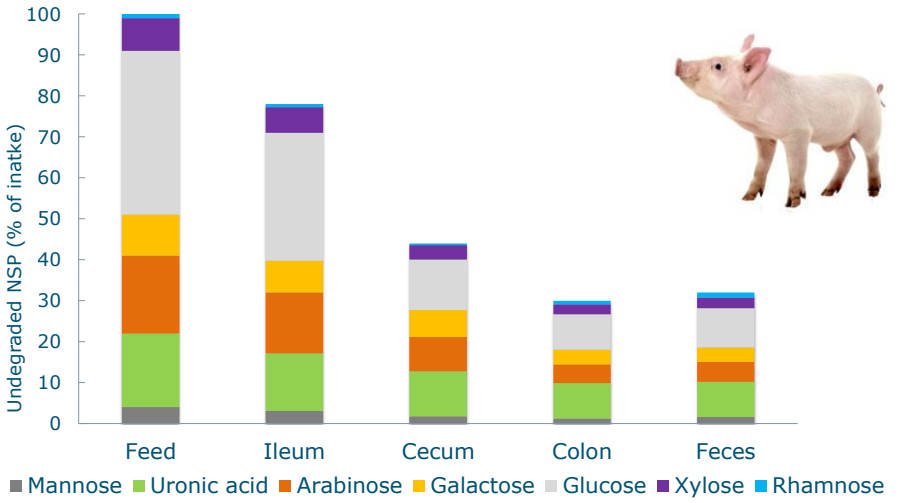
Pustjens et al. Carbohydr Polym. 98: 1650 – 1656. **2013.**

Fermentation of NSP from RSM in swine



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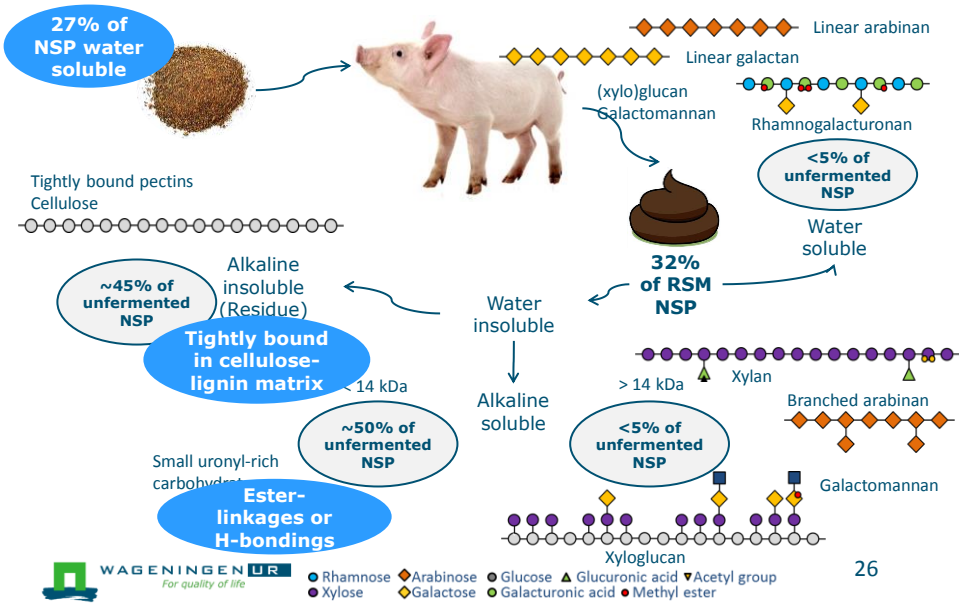
Pustjens et al. Indust Crop Prod 58: 271 – 279. **2014**.

Detailed characterziation of recalcitrant fiber



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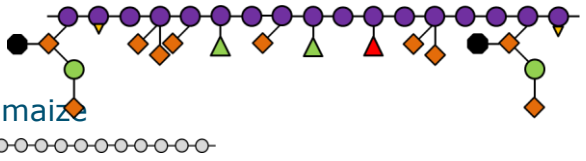
Pustjens et al. Indust Crop Prod 58: 271 – 279. **2014**.

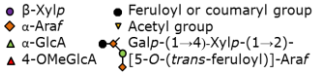
Fibre structures in maize DDGS



- Originating from maize
- Cellulose

- Hemicellulose
  - Highly substituted glucuronoarabinoxylans (GAX)
    - Single unit side chains (ara, UA)
    - Oligomeric side chains of (ara, xyl, gal)
    - Ferulic acid, coumaric acid
      - Ester-linked to ara

> Cross-links between xylan structures



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Appeldoorn et al. J Agric Food Chem 58: 11294-11301.**2010**
Huisman et al. Carbohydr Polym 43: 269 – 279. **2000**.

Fermentation of NSP from DDGS

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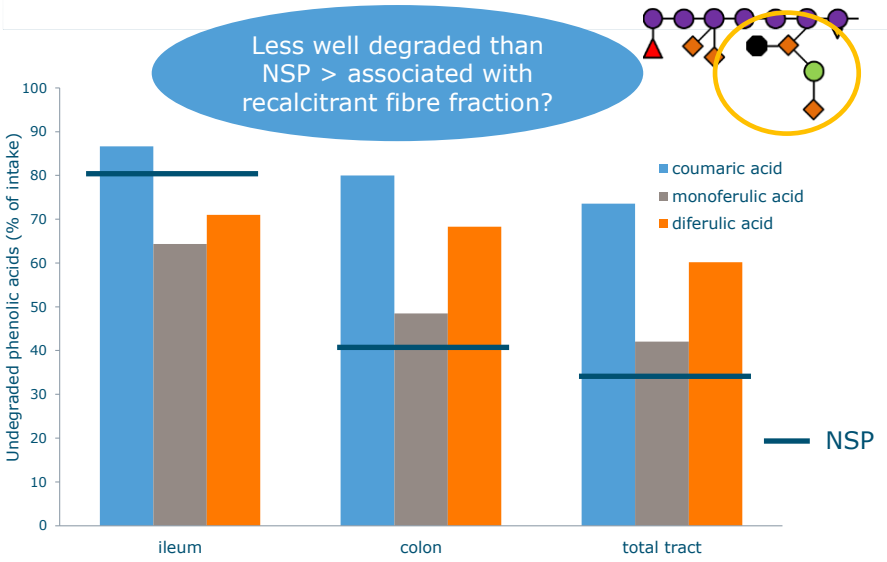
de Vries et al. J Anim Sci 92:5496-5506. **2014.**

Degradation of phenolic acids



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de Vries et al. J Anim Sci 92:5496-5506. **2014.**

Recalcitrant fibres

Take home message

- RSM: large fraction of low MW uronyl-rich CHO
- DDGS: phenolic acids concentrate in unfermented fraction; cross-links between xylan structures limit fermentation
- Detailed analysis of recalcitrant (i.e. non-fermented) fibres needed for progress in understanding of fermentation (and thus of energy value)

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Thank you for your attention

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