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The effect of fibres in feedstuffs on nutritional value and how to determine it

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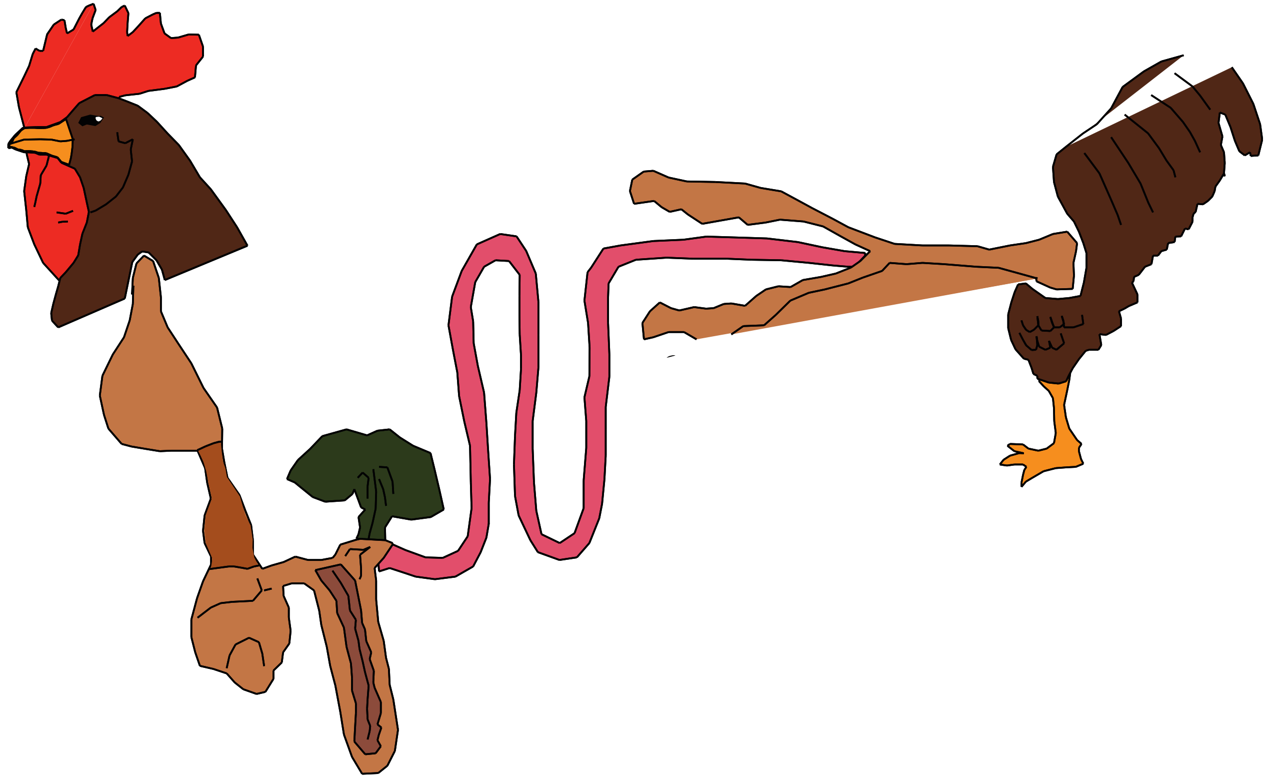
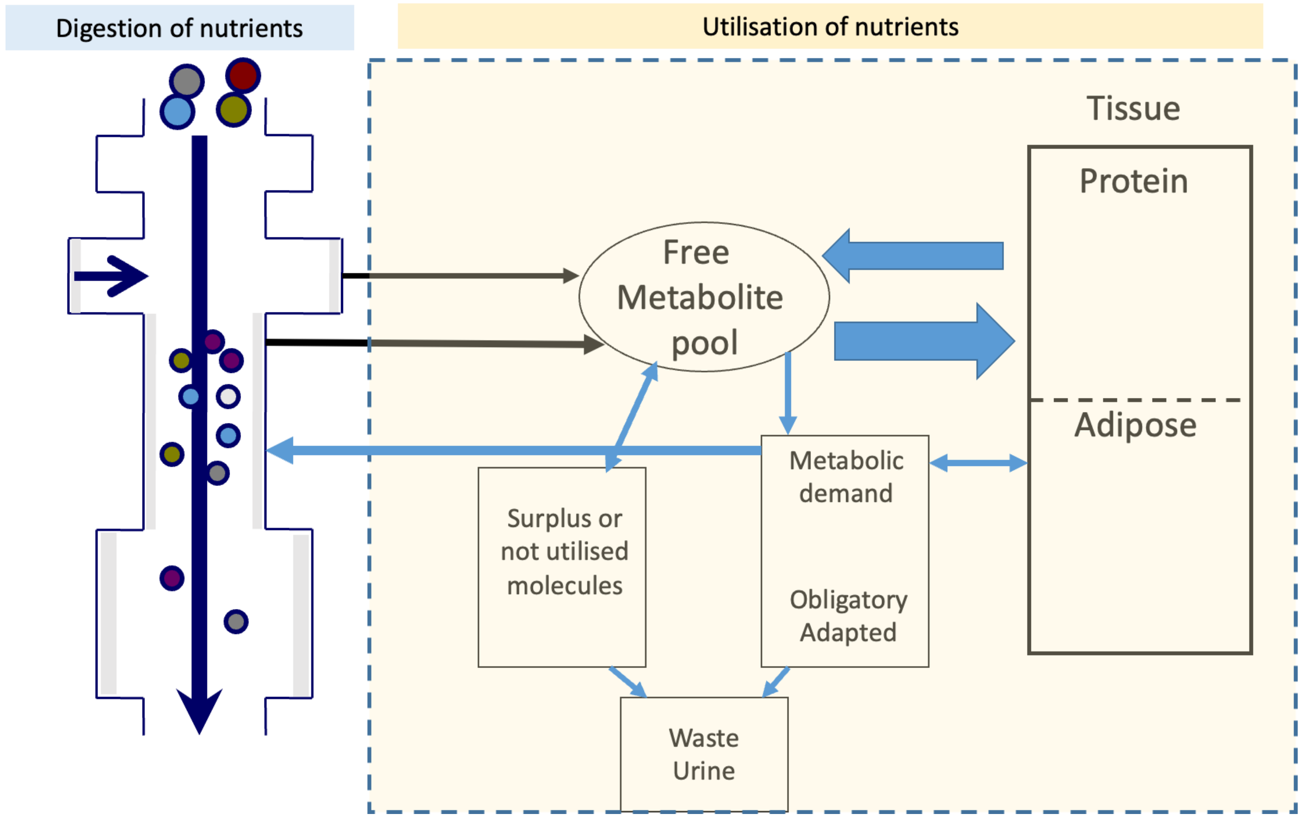
Points to be addressed

- Introduction
- Fibres
    - Cell walls
    - How to determine them
- Fibres in feedstuffs
    - Cereals and cereal co-products
    - Protein rich feedstuffs
- The nutritional effects of fibre
- Conclusions

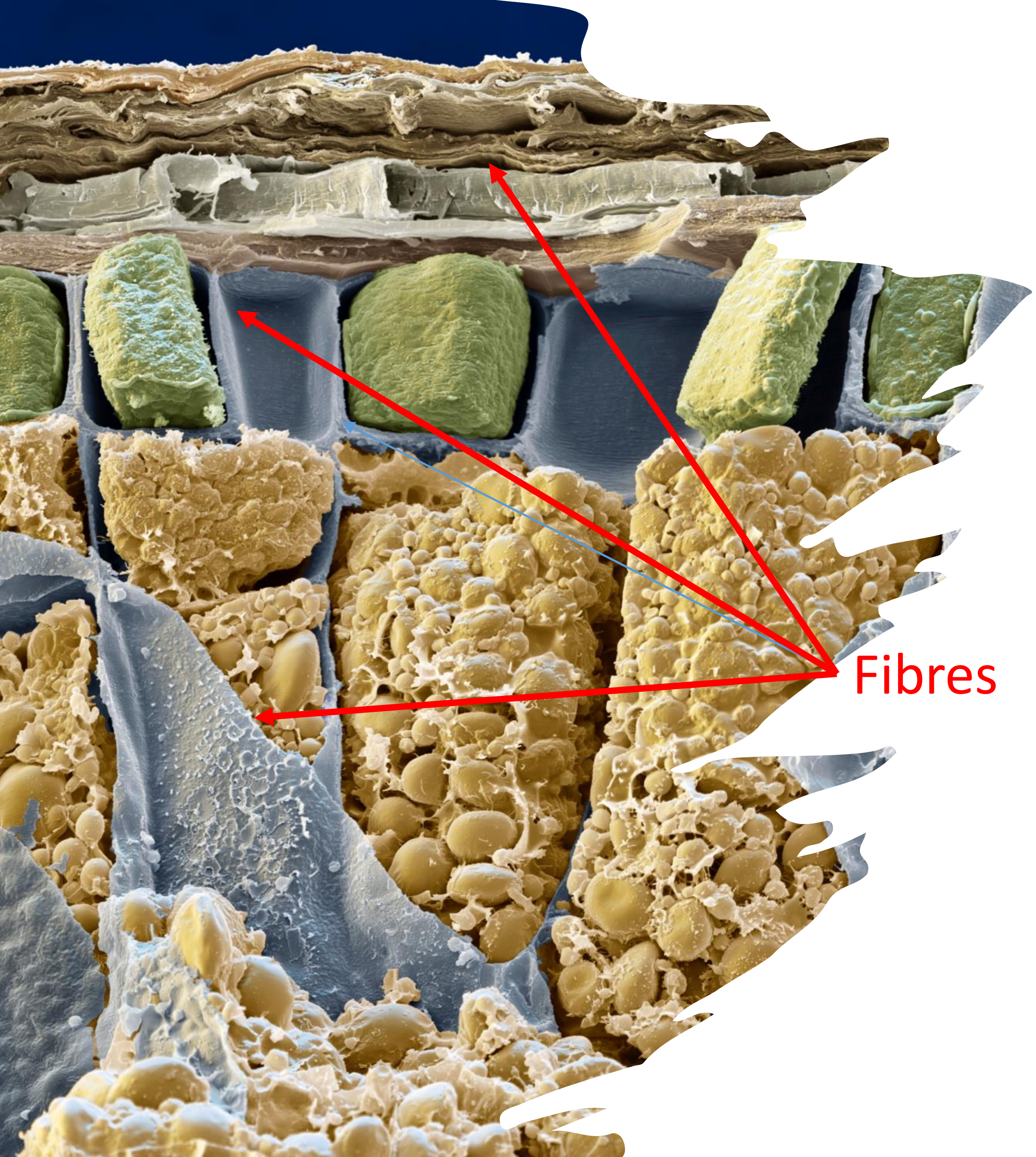


Introduction

- The nutritive value of a feed refers to "the amount of nutrients contained in a feed that can be utilized by the animal".
- Its estimation consequently involves
    - How well the nutrients are **digested**
    - How well the nutrients are **utilized** by the animals



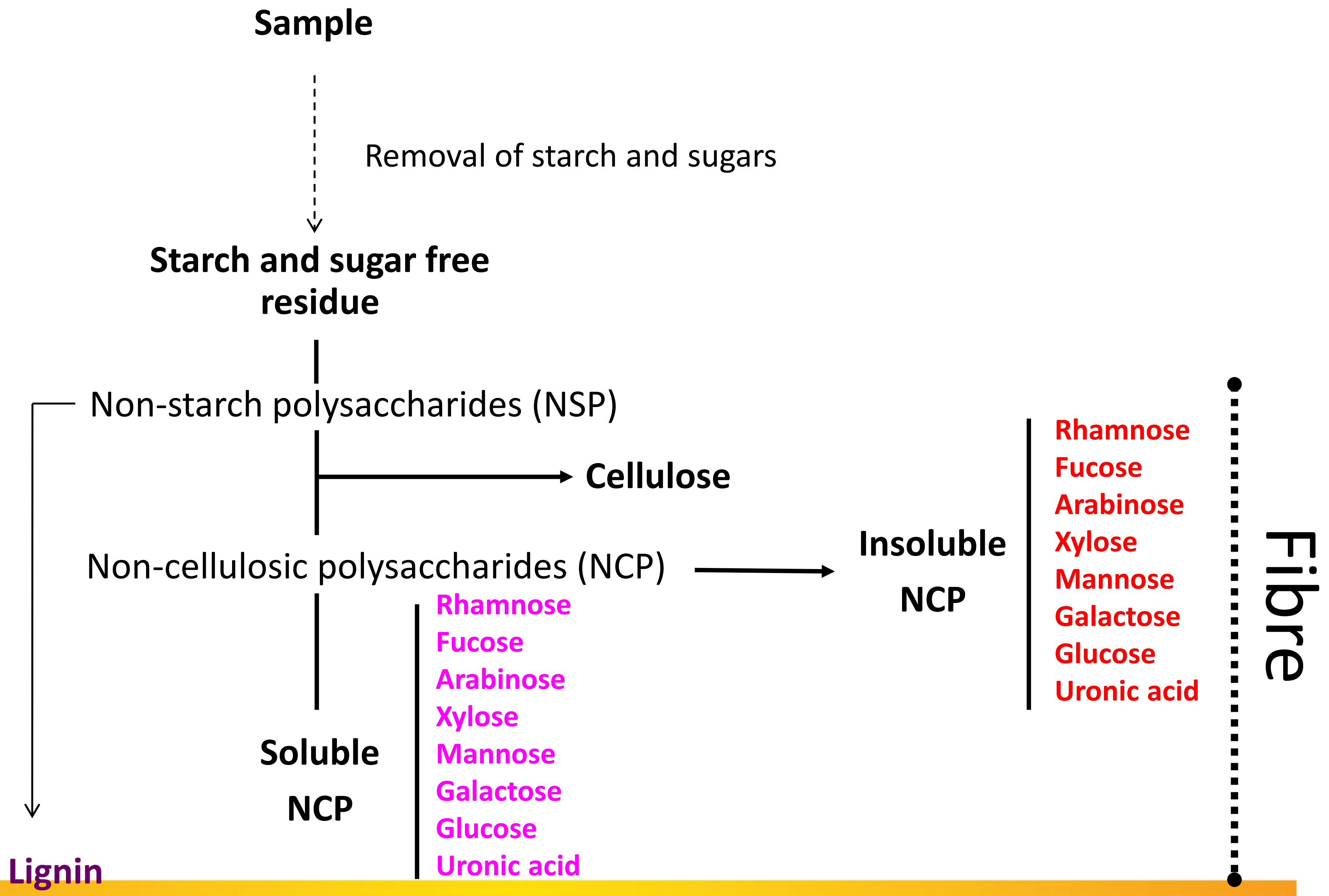
Fibers represent typically 120-137 g/kg of broiler diets of which 55-65 % comes from cereals and the remaining from protein rich feedstuffs



Fibre and the digestion of nutrients

- Fibre is the singlemost important factor for the digestion of nutrients
- In plants the majority of fibres are located in the cell walls
- Fibres have different composition and structure in the cell walls from different plants and within different cell tissues of a plant

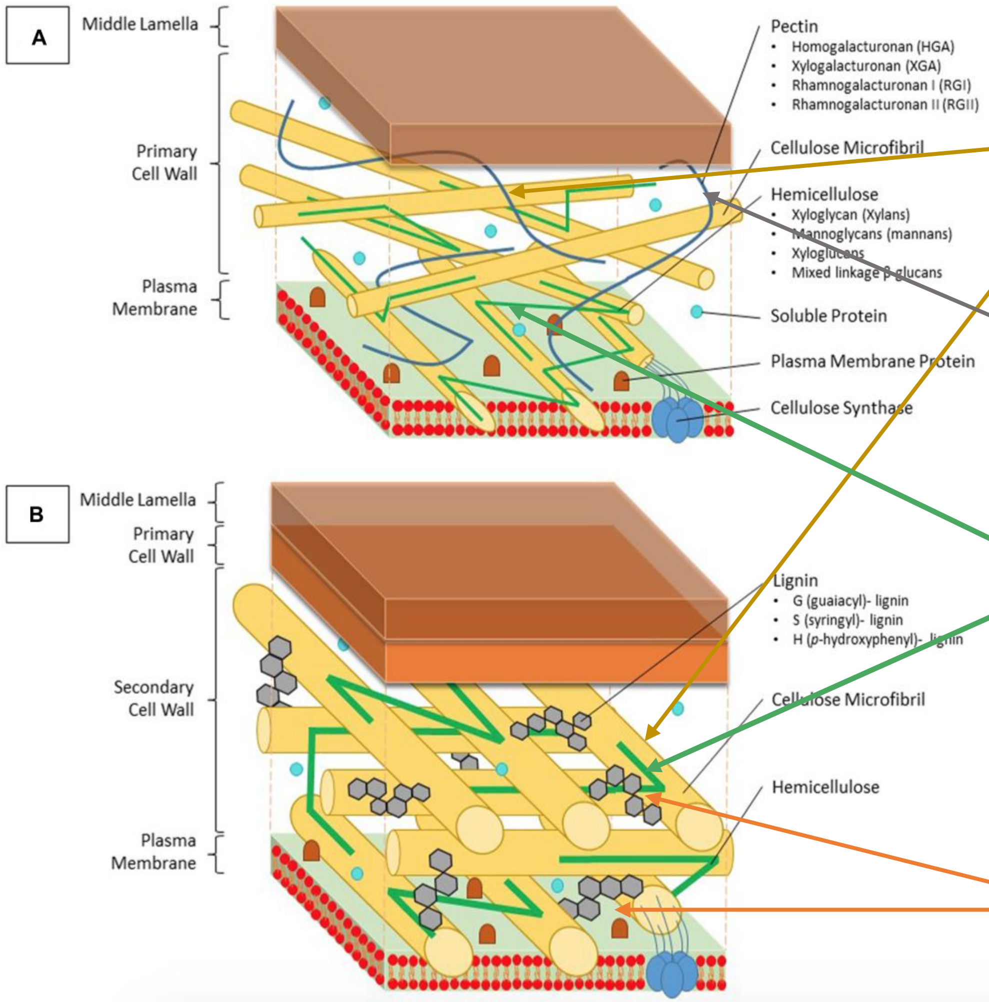
How NSP and lignin can be determined



What is measured in the enzymatic-chemical-gravimetric dietary fibre method

Non-lignified

Lignified



Cellulose

Non-cellulosic monomeric constituents

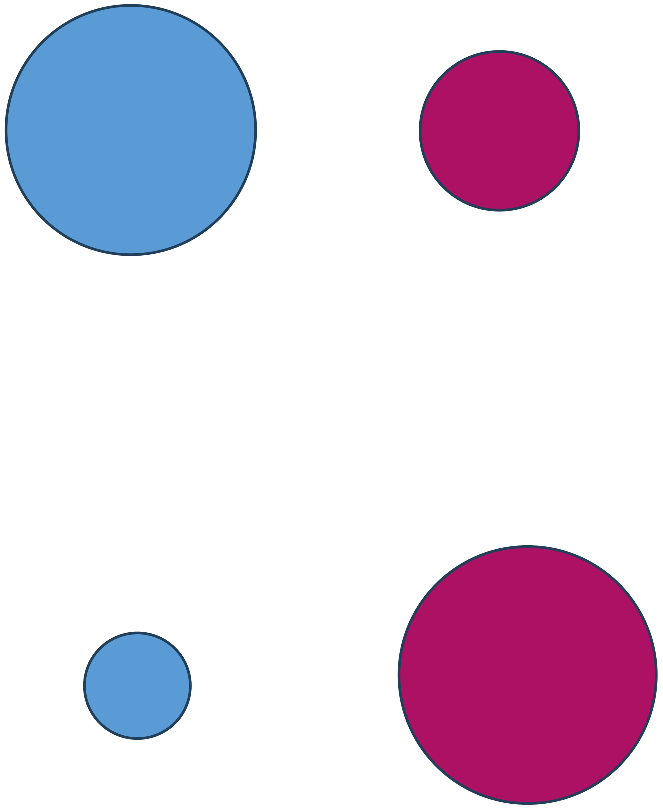
Uronic acids

Rhamnose
Fucose
Xylose
Mannose
Galactose
Glucose

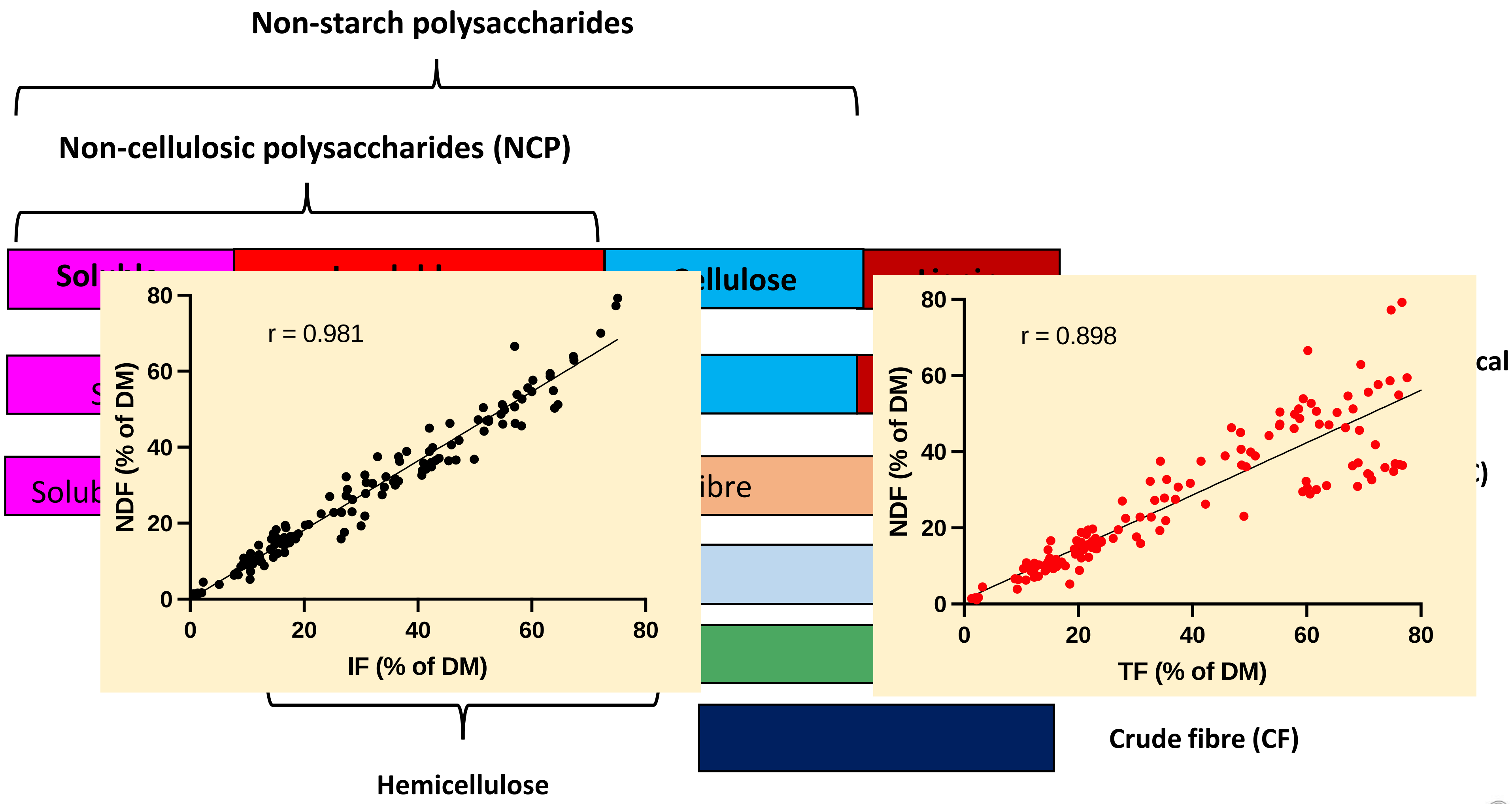
Klason lignin

Proportion

Soluble | Insoluble

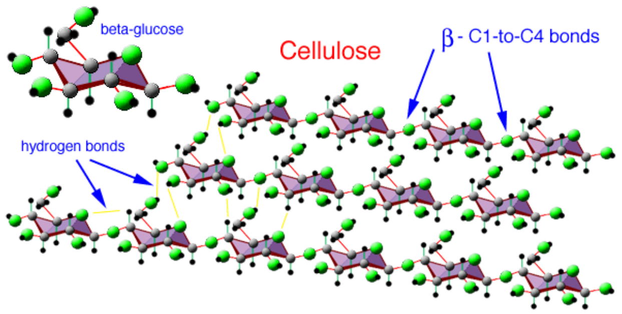


The different fiber methods are not measuring the same!

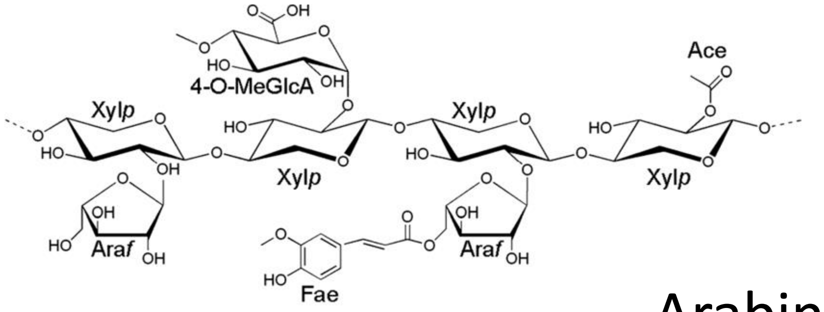


Fibers in feedstuffs – Cereals and its co-products (energy and protein)

The main cell wall components of cereals and its co-products

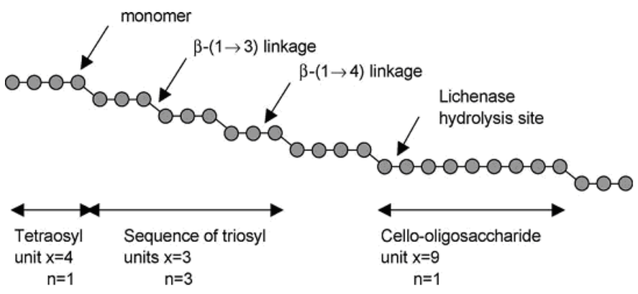


Cellulose

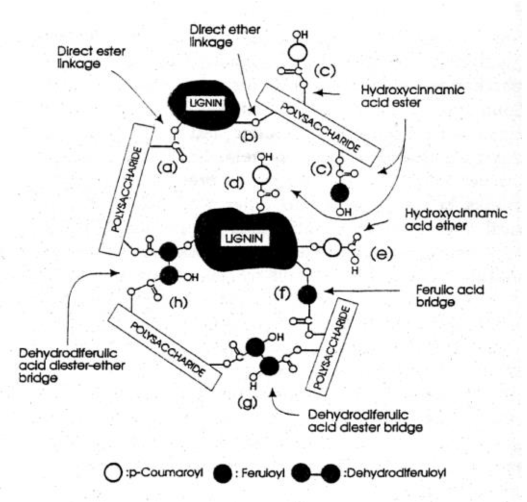


Arabinoxylan

Ace = acetate
Araf = α-L-arabinofuranose
Xylp = β-D-xylopyranosse
Fae = ferulate
4-O-MeGlcA = 4-O-α-D-methyl glucuronic acid

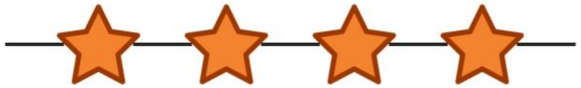


β-glucan



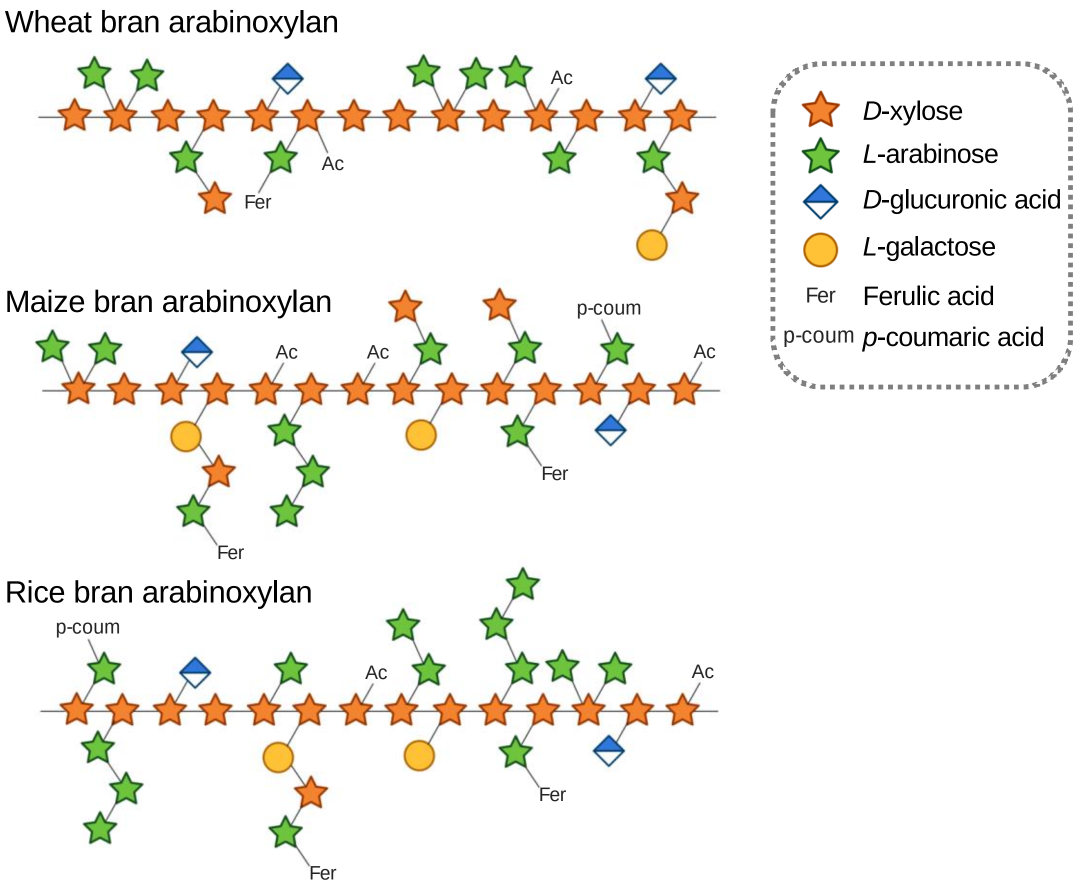
Lignin

Structural differences in arabinoxylan



Xylan backbone

Arabinose substitutions

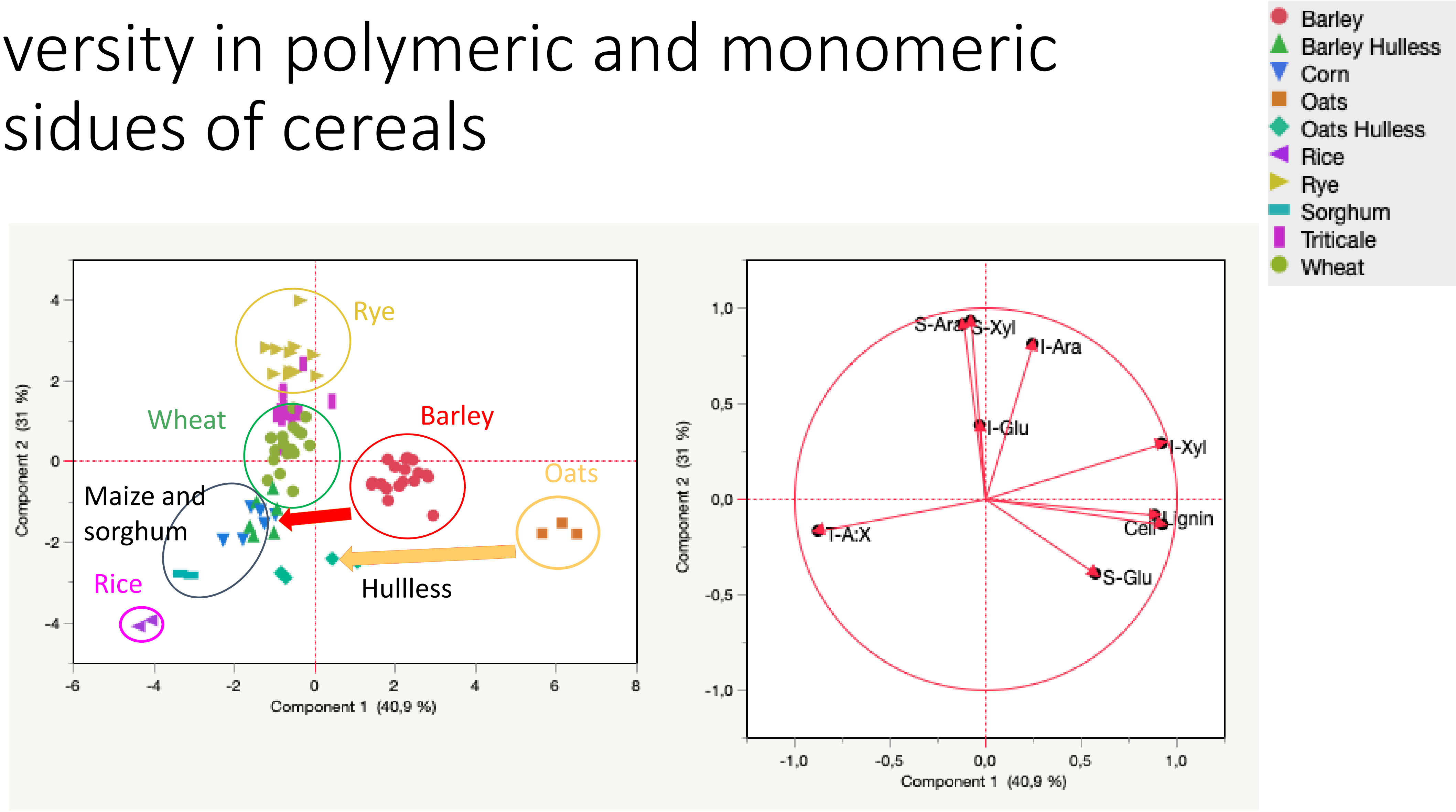


Polymers and monomeric residues (g/kg DM) in cereals

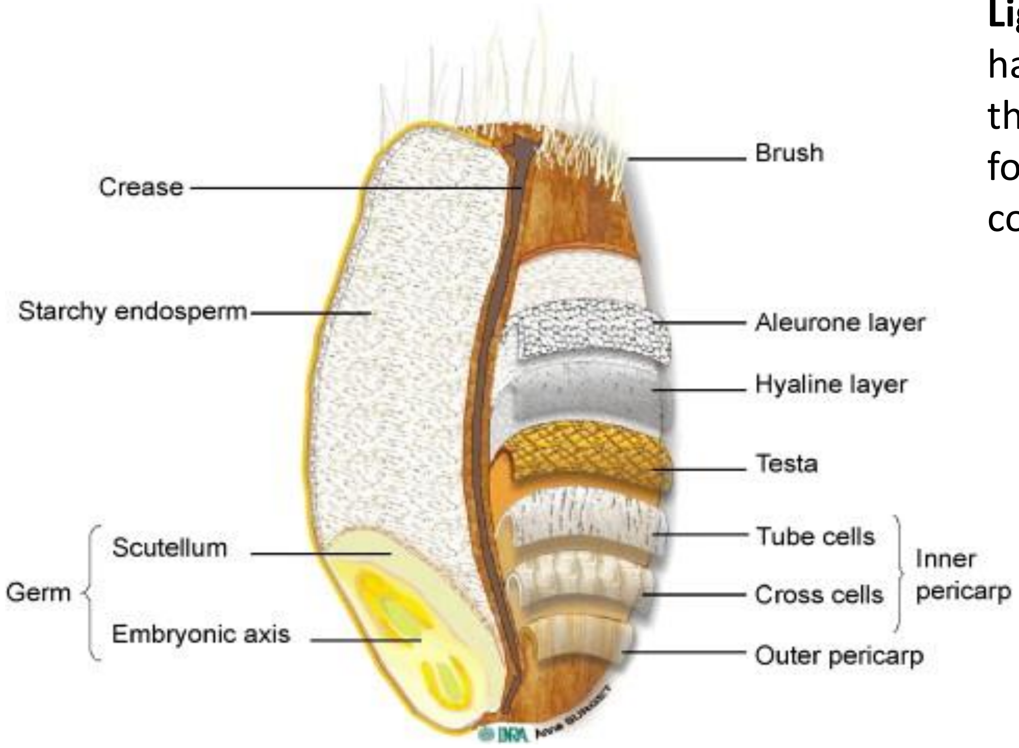
		Non-cellulosic polysaccharides									
	Cell	Ara	Xyl	Man	Gal	Glc	UA	NCP	NSP	KL	Fibre
Brown rice	1	5	4	1	1	8	2	21 (2)	22 (2)	13	35
Sorghum	15	17	13	1	3	10	4	51 (4)	66 (4)	16	83
Maize	22	22	30	3	5	10	7	75 (9)	97 (9)	11	108
Wheat	20	29	47	3	4	11	5	99 (25)	119 (25)	10	138
Rye	16	36	61	5	5	26	4	136 (42)	152 (42)	21	174
Barley	43	28	56	4	3	47	6	143 (56)	186 (56)	35	221
Oats	82	18	80	3	7	33	10	150 (40)	232 (40)	66	298

Cell, cellulose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose; AU, uronic acids; NCP, non-cellulosic polysaccharides; NSP, non-starch polysaccharides; KL, Klason lignin; Values in parenthese are soluble NCP.

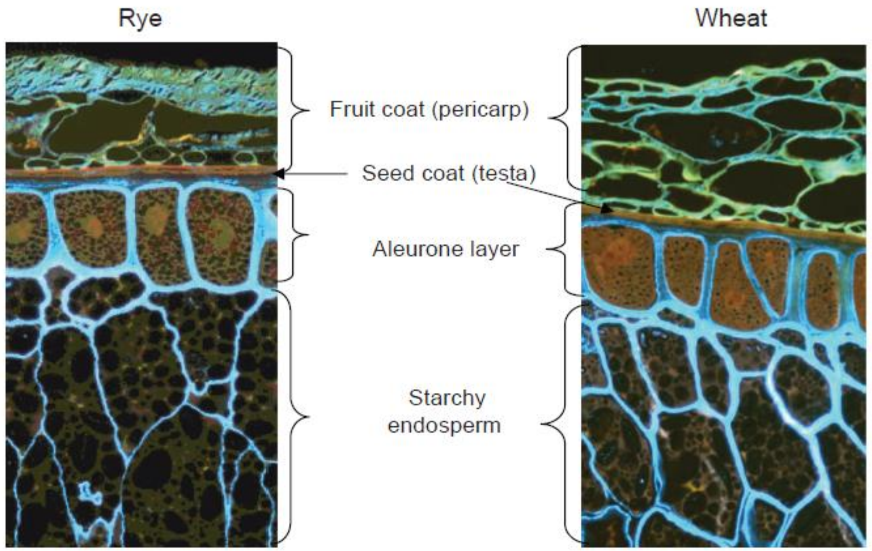
Diversity in polymeric and monomeric residues of cereals



Non-lignified and lignified cell walls, i.e. wheat and rye

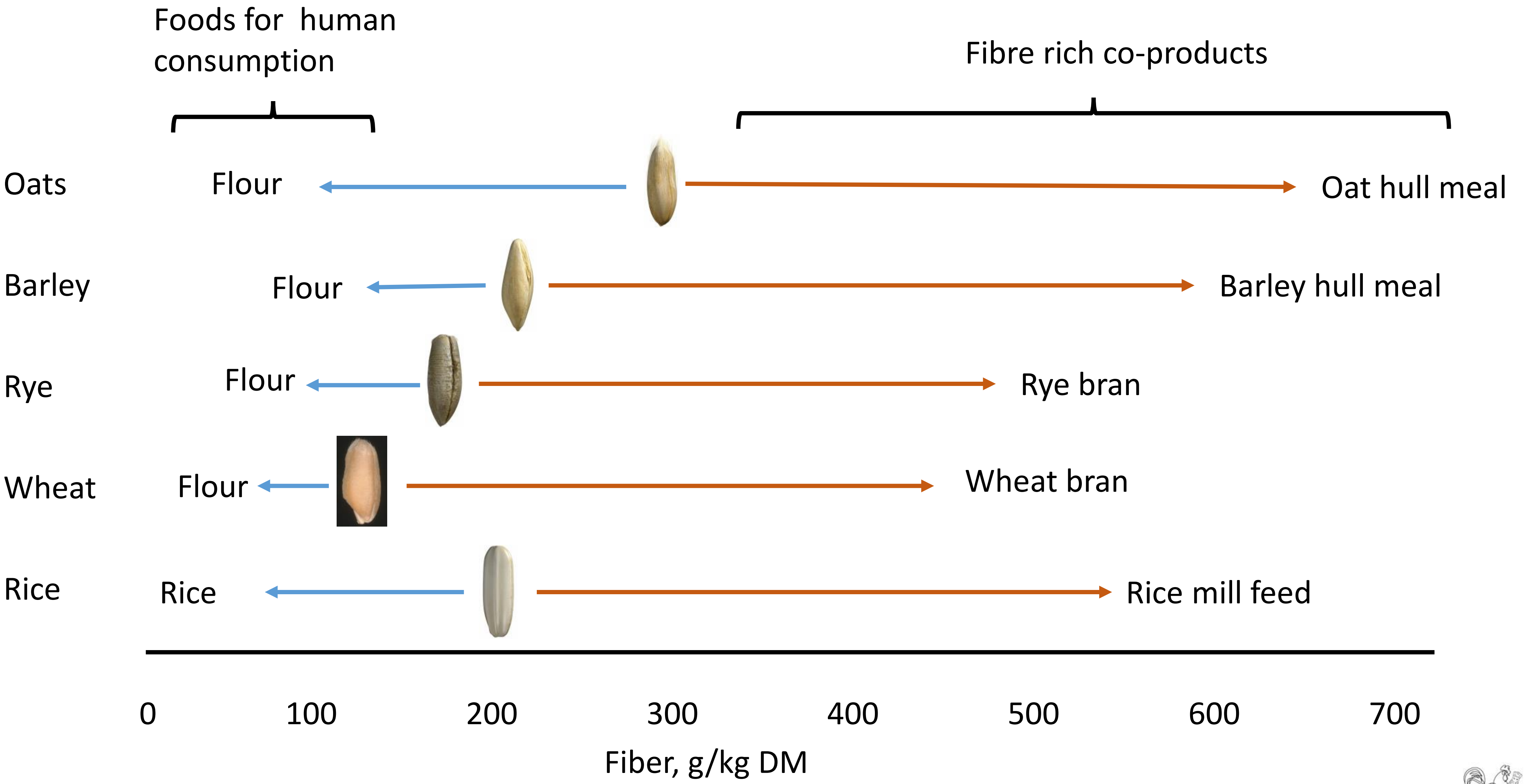


Lignified: The tissues of the outer part of the kernel have primarily a role of protection. Cell walls in these tissues are thick, hydrophobic and essentially formed of cellulose and complex xylans but also contains significant amounts of lignin.



Non-lignified: In endosperm tissues, cell walls represent 2-7% of the tissue, they are thin and hydrophilic and essentially formed of two polymers: arabinoxylan and mixed linkage (1-3)(1-4)-β-glucan.

Fibre in whole grain cereals, corresponding human foods and fibre rich co-products

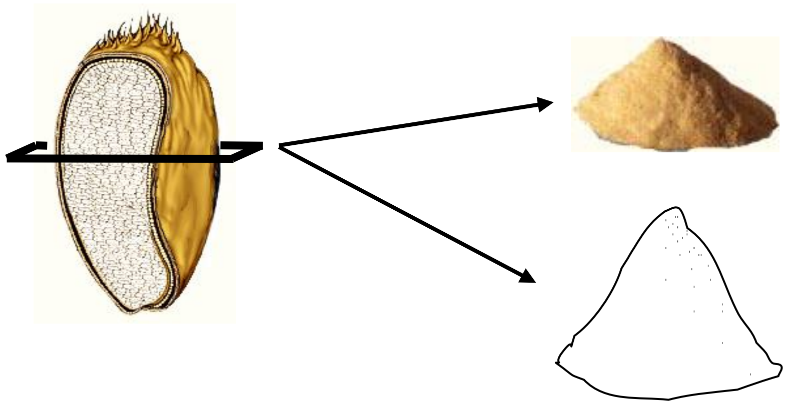


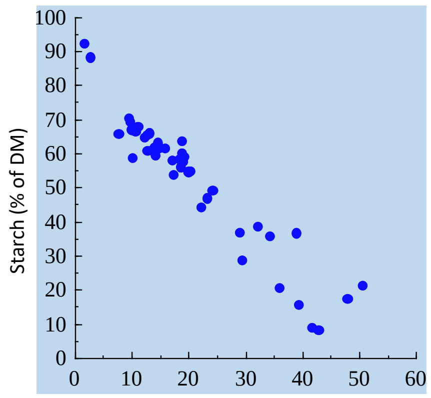
Cereal co-products (I)

Cereal co-products are generally more variable that their parent grains

For instance, the fiber variation in wheat bran compared with whole grain wheat is:

- Whole grain wheat: 112-147 g/kg DM; Δ = 35 g/kg
- Wheat bran: 389-589 g/kg DM; Δ = 200 g/kg



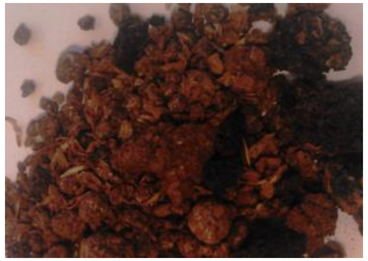


Cereal coproducts (II) Maize and wheat DDGS

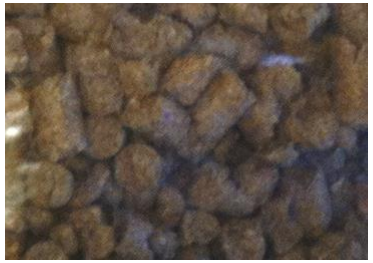
138 DDGS samples

Maize
72 samples
21 ethanol plants

Wheat
56 samples
2 ethanol plants



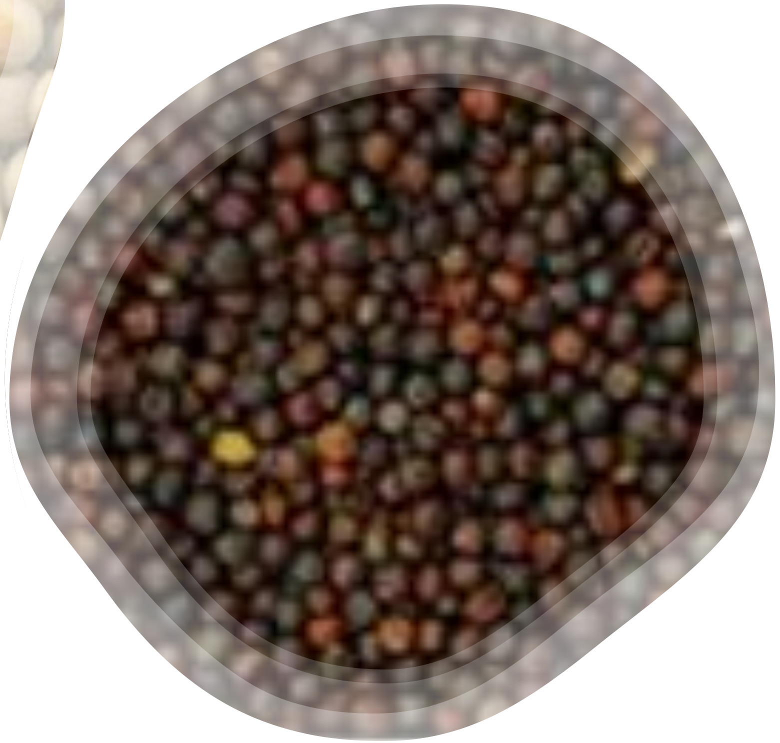
Mixed cereal
10 samples
1 ethanol plant



11 Maize samples

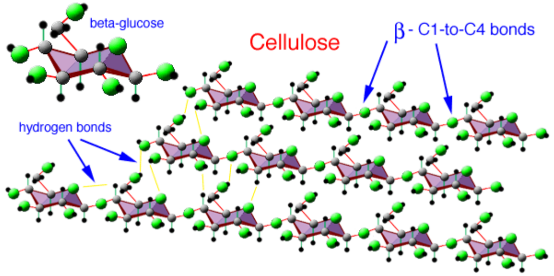
- Large differences in chemical composition between maize and wheat DDGS sources
- The NSP fraction in maize DDGS is more complex than in wheat DDGS
- The most readily degradable arabinoxylan is modified during processing
- Arabinoxylan in DDGS is more complex than in the grain
- Ester-linked ferulic acids are not modified during processing

Pedersen et al. (2014 & 2015).

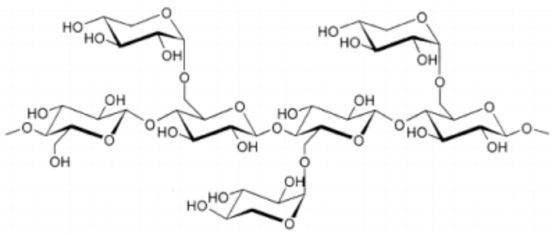


Fibers in feedstuffs – Protein rich feedstuffs (protein and energy)

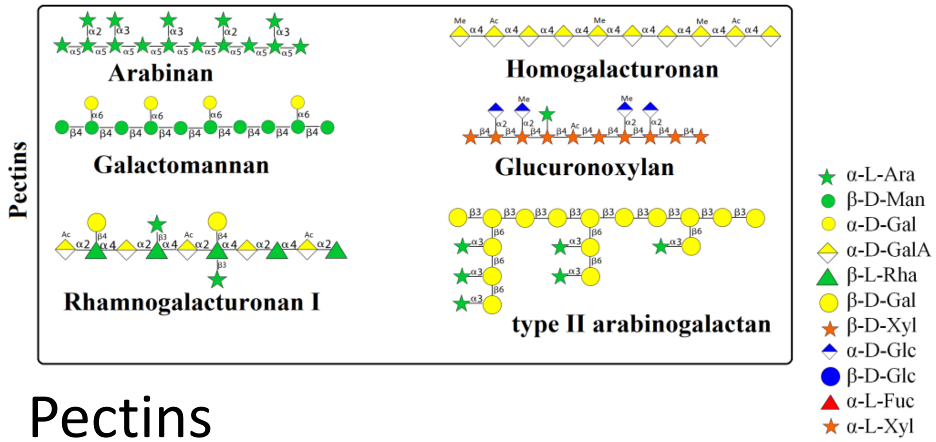
The main cell wall components in protein rich crops and feedstuffs



Cellulose



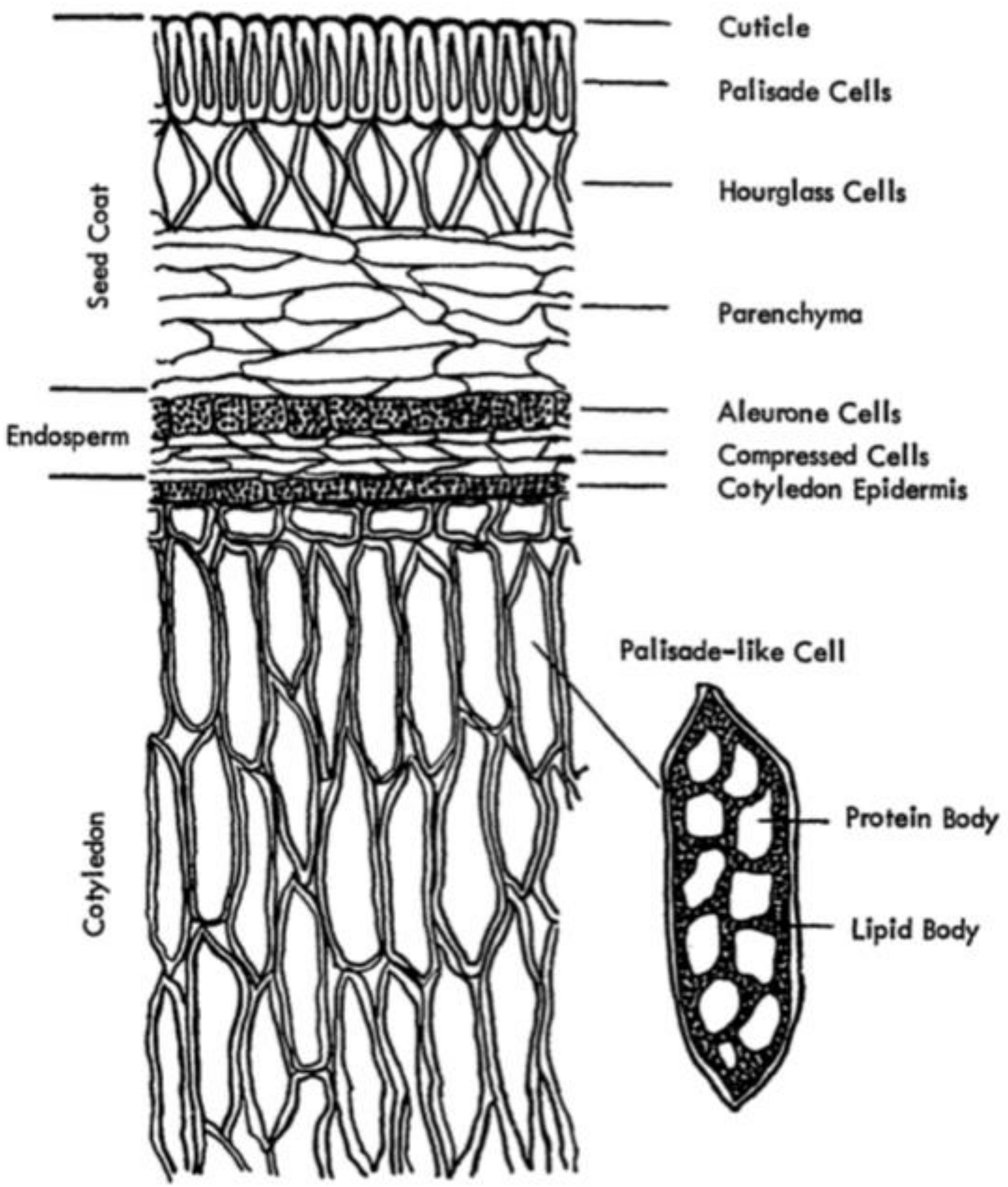
Xyloglucan



Pectins

Pectin represents a heterogeneous group of polysaccharides composed of as many as 17 different monosaccharides. The main structural elements: homogalacturonan, rhamnogalacturonan types I and II, glucuronoxylan, and arabinogalactans types I and II

Cell tissue layers of protein rich feedstuffs exemplified by soybeans



Hull

The primary role of the hull layer is protection The cell walls are thick, hydrophobic and with high levels of cellulose, xyloglucans and acidic pectic.

Cotyledon

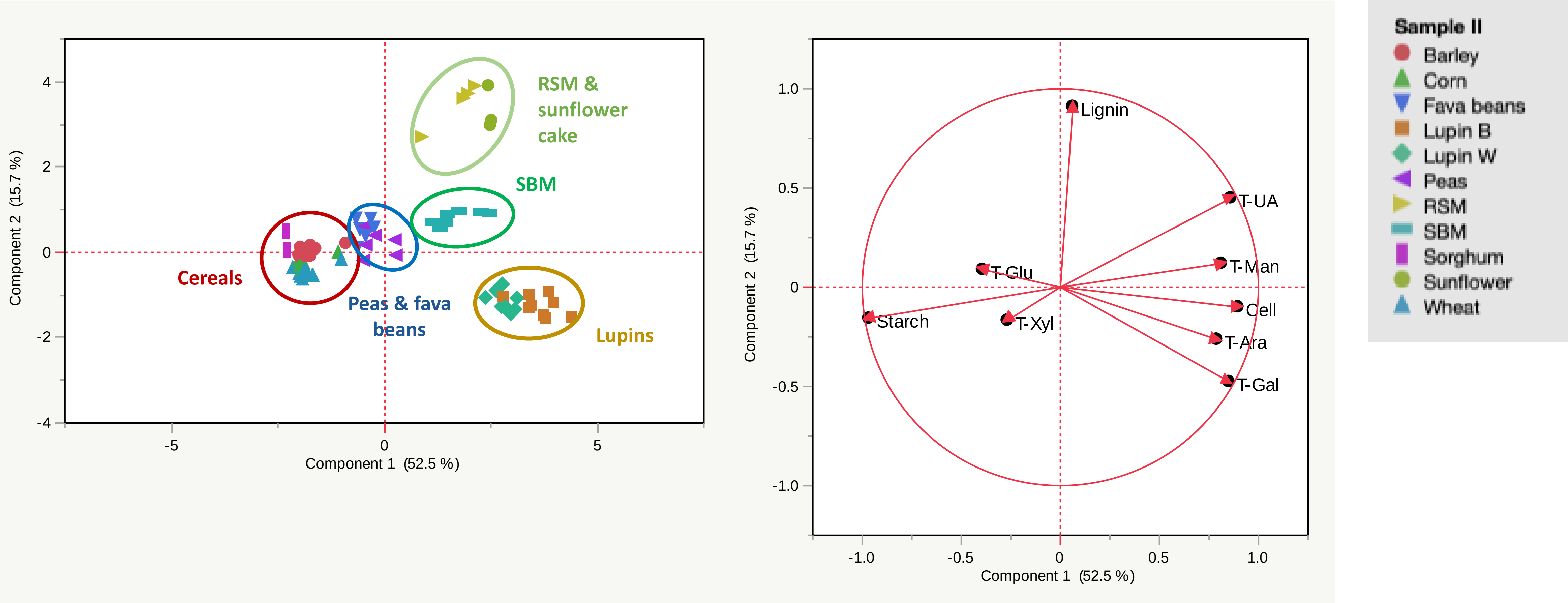
The cotyledon have thin cell walls which are hydrophilic and composed primarily of pectic polysaccharides, xyloglucans, and cellulose

Polymers and monomeric residues (g/kg DM) in protein rich feedstuffs

		Non-cellulosic polysaccharides									
	Cell	Ara	Xyl	Man	Gal	Glc	UA	NCP	NSP	KL	Fibre
Soybean meal	62	26	19	13	41	7	48	155 (63)	217 (63)	16	233
Rape seed meal	52	43	17	6	19	21	61	168 (55)	220 (55)	134	354
Palm cake	73	12	1	309	15	7	19	393 (32)	466 (32)	136	602
Sunflower cake	123	31	59	12	13	17	67	192 (57)	315 (57)	133	448
Peas	53	26	13	2	7	36	32	127 (52)	180 (52)	12	192
Fava beans	81	24	12	2	6	32	33	109 (50)	190 (50)	20	210
Lupin	131	43	36	9	141	2	39	274 (134)	405 (134)	12	416

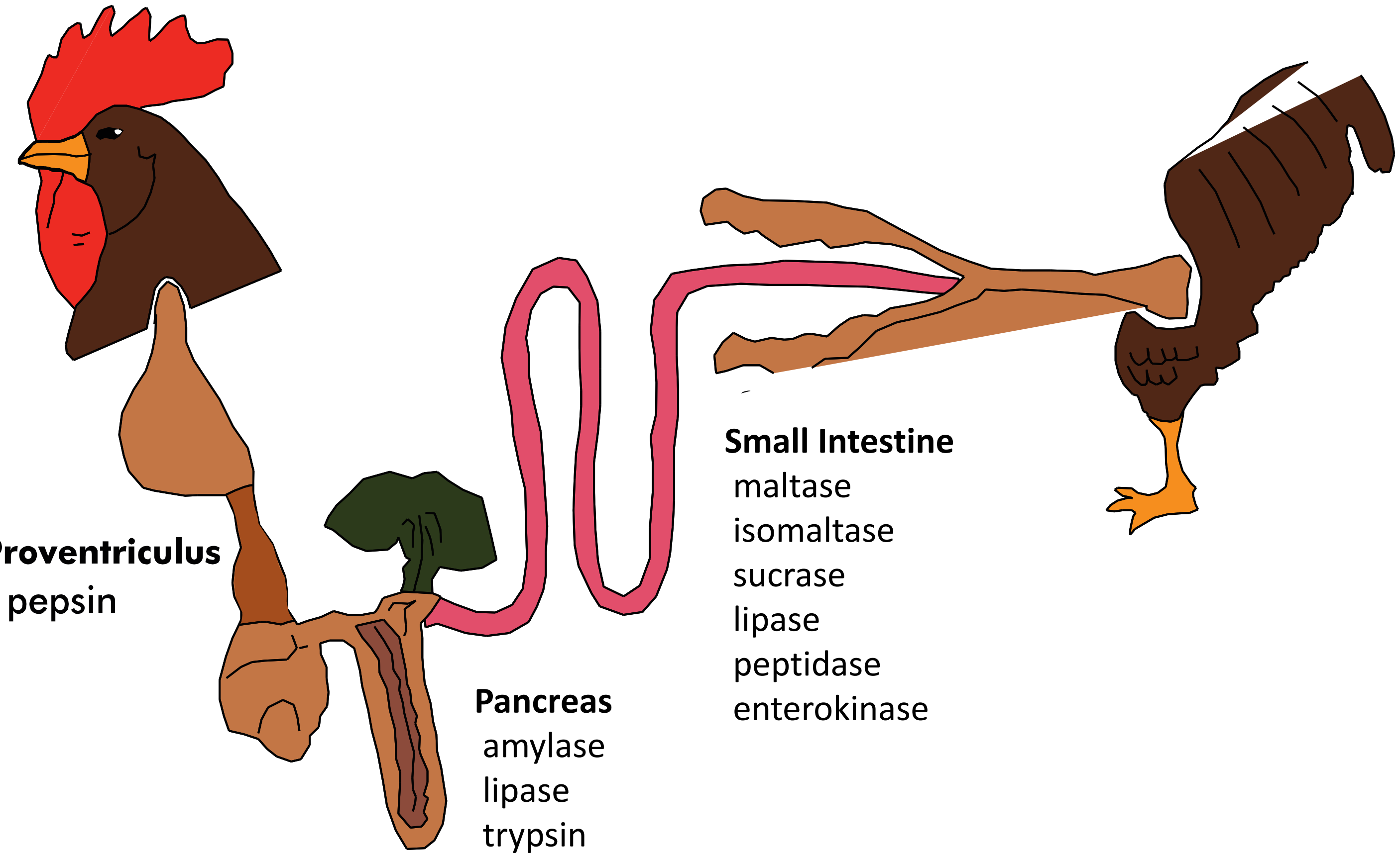
Cell, cellulose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose; AU, uronic acids; NCP, non-cellulosic polysaccharides; NSP, non-starch polysaccharides; KL, Klason lignin; Values in parenthese are soluble NCP.

Diversity in carbohydrates and lignin among feedstuffs



Nutritional effects of fibre

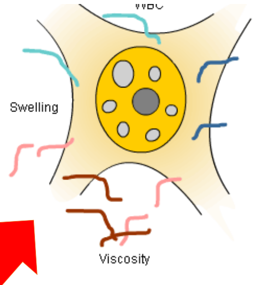
Enzymes produced by chickens



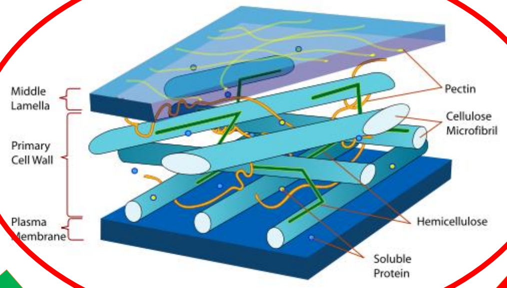
No endogenous fibre degrading enzymes!

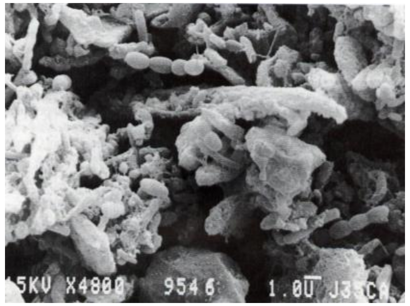
Possible effects of fiber in nutrition

CW indigestible by itself

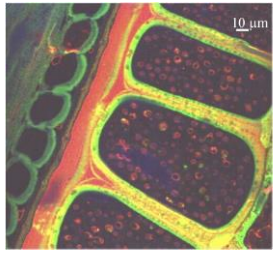


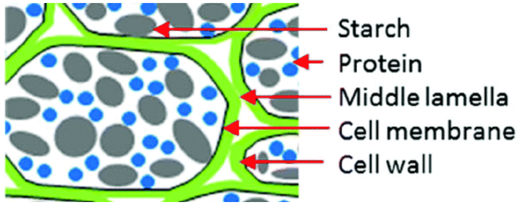
Viscosity effects





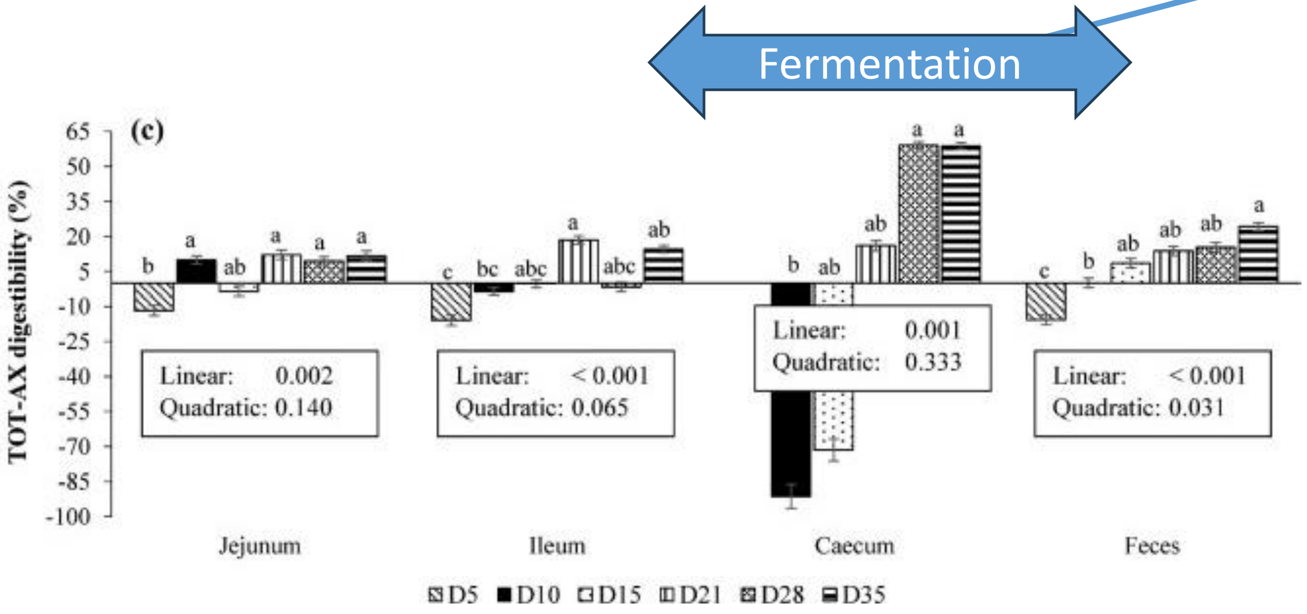
Prebiotic effects

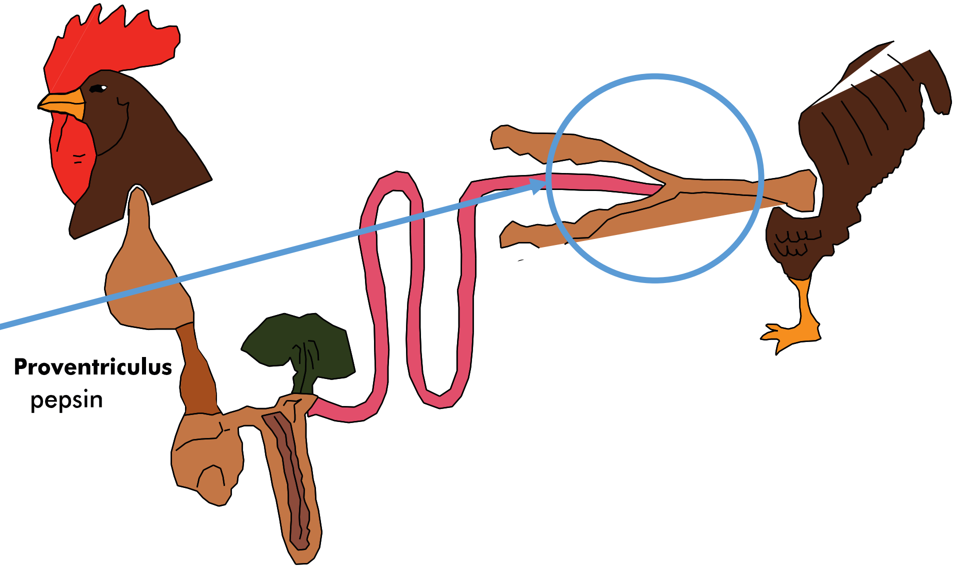




Cage effects

Age related digestibility of AX in broilers



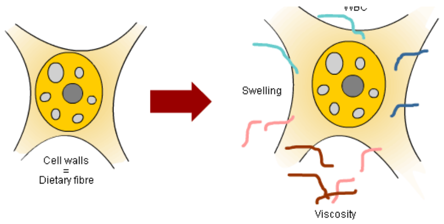


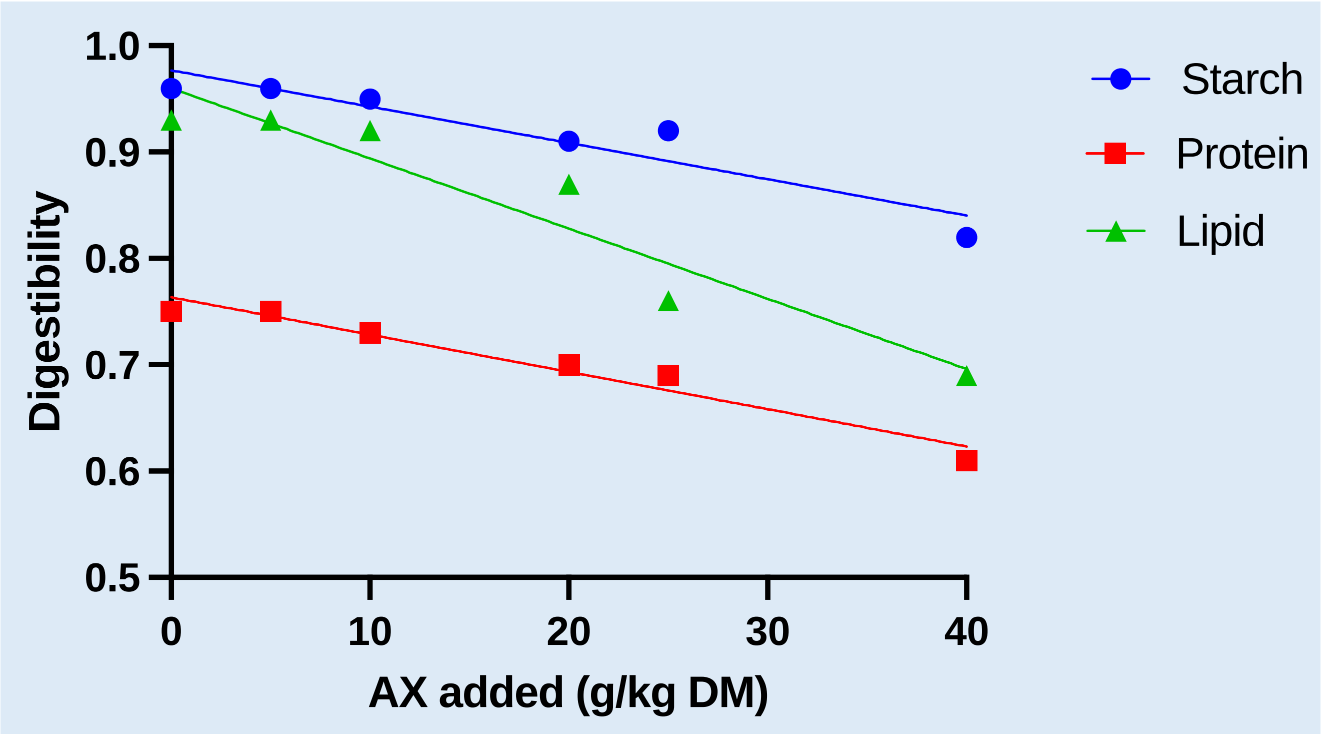
NSP fermentation can contribute up to 3-4% of ME

Jørgensen et al. (1996), Br. J. Nutr. 75: 379-395.

Bautil et al. (2019), Poultry Sci. 98: 4606-4621.

Viscosity effects exemplified by adding concentrated AX





Studies with cereal grains have in general confirmed that soluble fibre resulted in higher extract viscosity being negative for the nutrient digestibility and AME.

In contrast, soluble fibre in protein-rich feedstuffs are only influencing viscosity to a limited extent because of cross-linkages of polysaccharides in the fibre matrix.

Choct and Annison (1992), Br J Nutr 67: 123-132.

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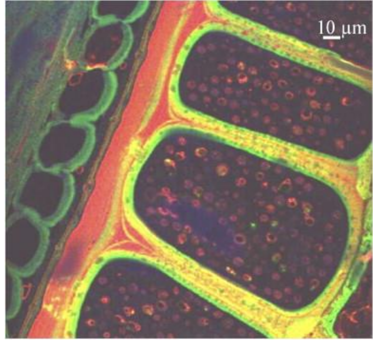
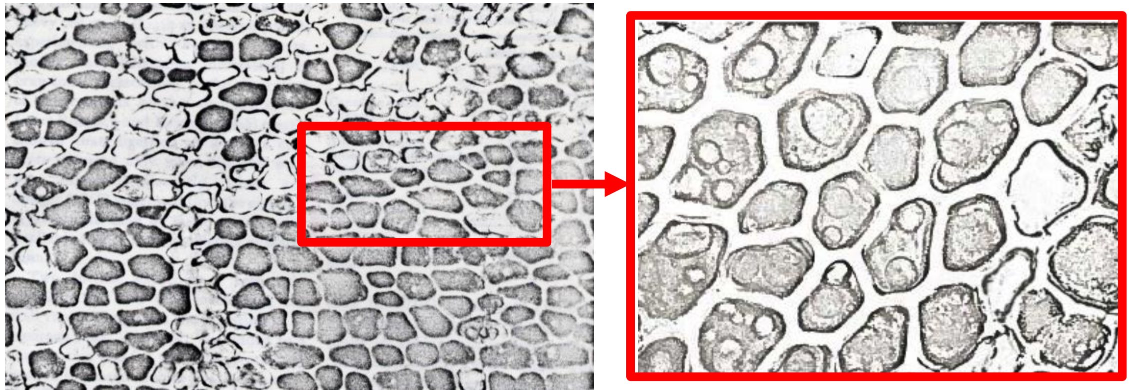
Cage effects: Number of empty aleurone cells and residual protein after digestion by chickens

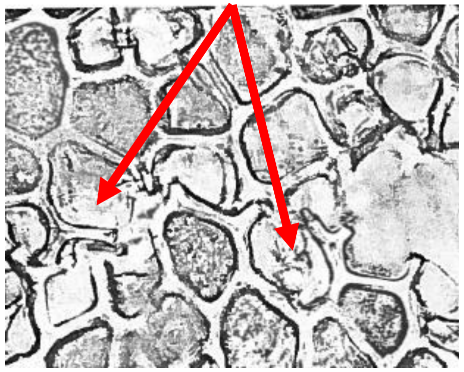


Feed	Empty aleurone cells, %		Protein content, %	
	Intestine	Feces	Intestine	Feces
Canadian mash	28.8	32.8	7.47	7.12
Canadian pellets	43.2	50.2	6.61	6.27
American mash	15.0	21.4	8.41	8.38
American pellets	35.6	40.0	6.73	6.38

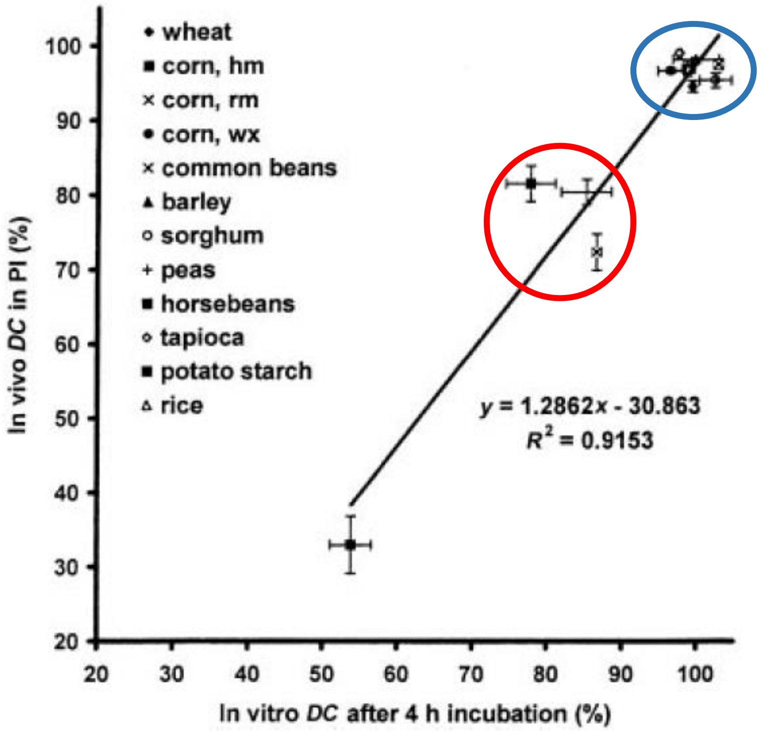
The cell walls of the aleurone cells can be modified to a variable extent depending on cereals by exogenous enzymes (Vangsøe et al 2021 & 2022 and Njeru 2023).

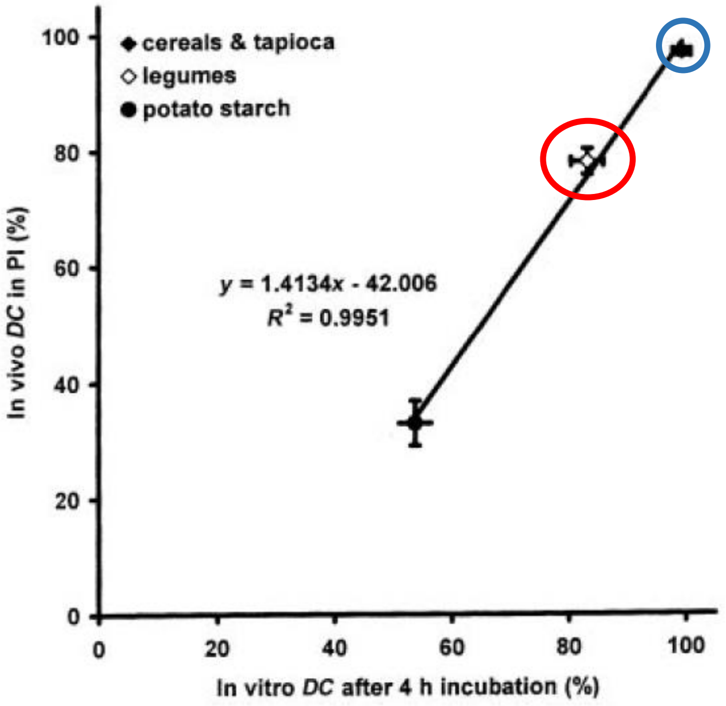
Saunders et al. (1969).



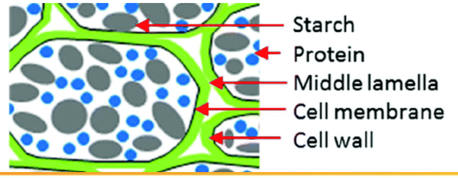


Cage effects: In vivo and in vitro digestion of starch in feedstuffs





Feedstuff	Fractional st. dig. rate (kd)
Tapioca	5.31±0.359
Wheat	1.59±0.056
Corn, hm	1.29±0.015
Corn, rm	1.38±0.043
Corn, waxy	1.19±0.021
Barley	1.25±0.036
Rice	1.30±0.019
Sorghum	1.11±0.061
Peas	0.65±0.029
Horsebeans	0.57±0.043
Common beans	0.88±0.065
Potato starch	0.34±0.019



Weurding et al. (2001); J Nutr 131: 2336-2342.

Conclusions

- Fibre represent the part of the feed that cannot be digested by the birds endogenous enzymes
- Different methods are available for the determination of fibre - the enzymatic-chemical-gravimetric method is the one that at present gives the most detailed information. However, what is measured analytical as soluble fibre is not necessarily soluble under in vivo conditions
- Fibre has a significant and negative effect on the nutritive value primarily because of the negative impact on nutrient digestibility brought about by the fibre being non-digestible by itself and impact of the fibre on the digestibility of other nutrients

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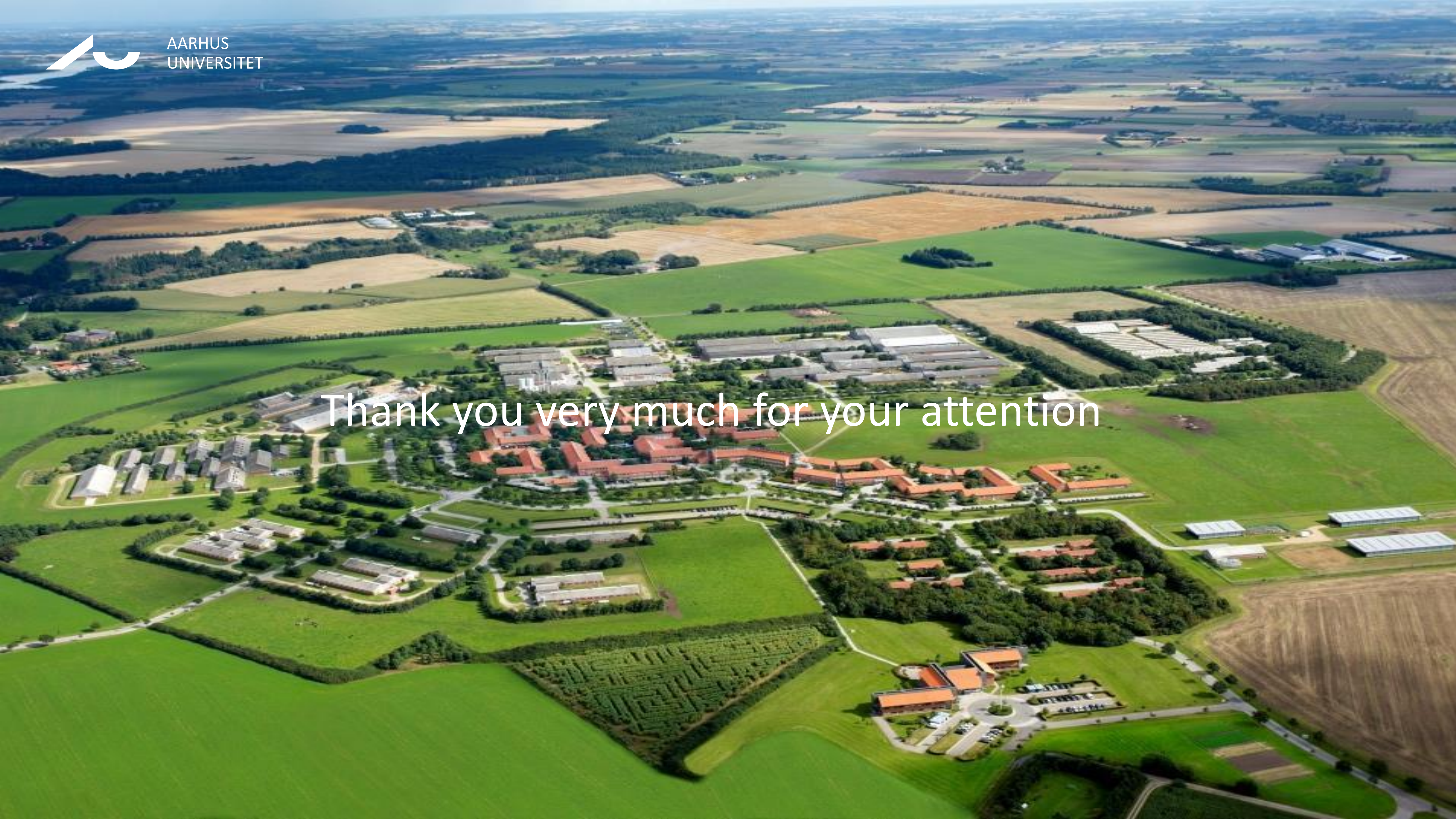

Thank you very much for your attention