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31 OCTOBER 2013

Physicochemical characterisation of dietary fibre and the implication for the gut environment

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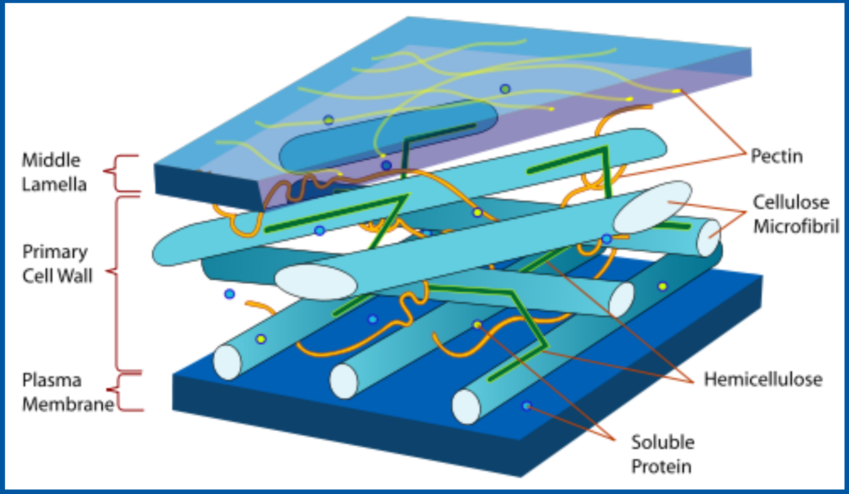

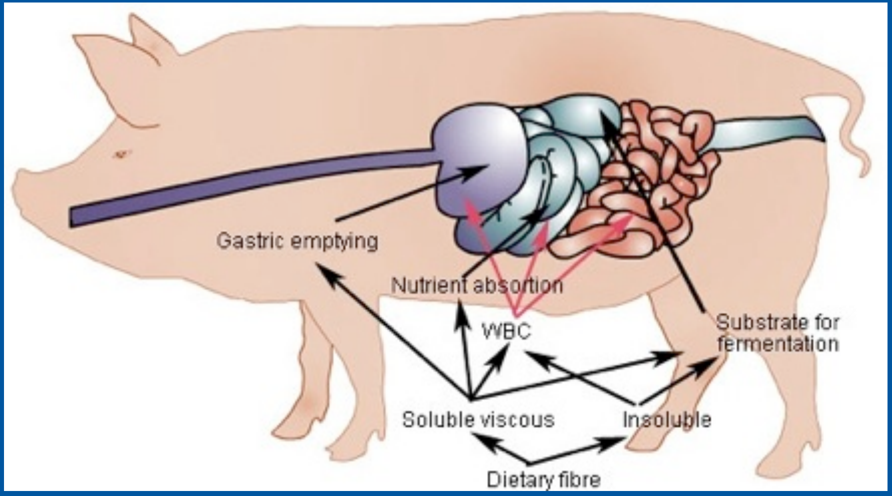

POINTS

- Introduction
  - Why dietary fibre and its physicochemical properties matters
- Fibres and physicochemical properties
  - Present naturally in the plant cell walls or as concentrates
- Fibres, physicochemical properties and the gut environment
- Studies with high-fibre diets for sows
- Studies with fibre enriched breads – pigs and humans
- Conclusions

Introduction

- A dietary pattern characterized by high intakes of fat, proteins from red meat, easily digestible carbohydrates and low intake of dietary fibre (DF) is a common feature for many people in affluent societies
- This dietary pattern may cause postprandial elevations of glucose and insulin, which may lead to overweight, obesity, metabolic disturbances clustered in the metabolic syndrome
- Consumption of whole-grains, largely attributed the cereal dietary fibres, have been inversely related to the prevalence of the metabolic syndrome, type 2 diabetes and weight gain
- The beneficial actions of DF are mainly attributed to their physicochemical properties and the physiological effects they induce

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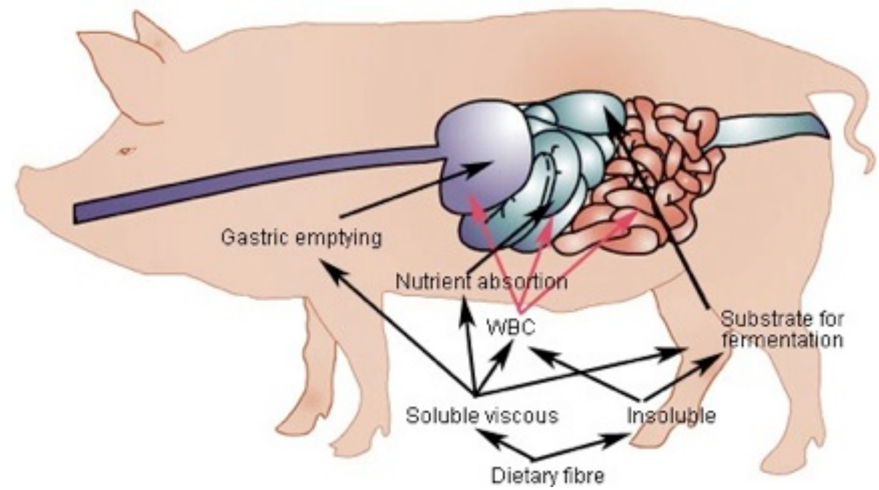
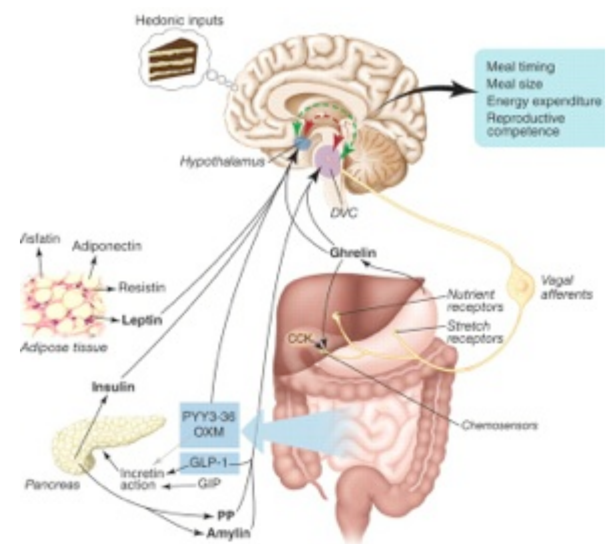
Actions of dietary fibre in the gut

- Influence the rheological properties of digesta – viscosity, water binding capacity, etc.
- Influence flow and bulkiness of digesta
  - Effects on the stretch receptors in stomach and small intestine thereby influencing food intake





Influence of dietary carbohydrate composition on ileal flow and composition

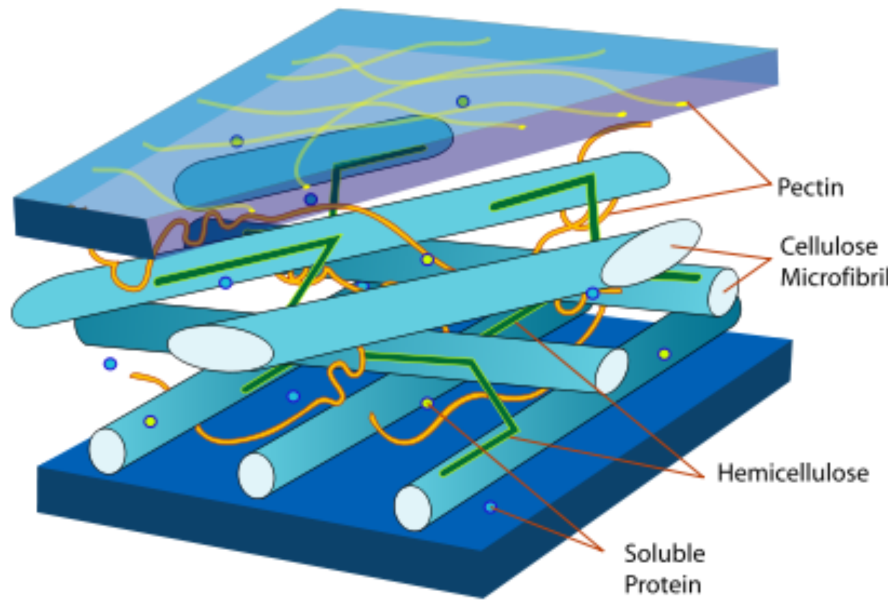
	Digesta	Marker	Digest CHO		NDC	
	flow, g/d	index	Sugars	Starch	Fructan	NSP
Low dietary fibre						
Diet		100	6	517	-	56
Ileum	2,126	652	7	17	-	366
Medium dietary fibre						
Diet		100	7	454	-	97
Ileum	2,584	472	8	12	-	372
High dietary fibre						
Diet		100	29	492	14	211
Ileum	3,785	345	8	28	20	514

CHO, carbohydrates; NDC, non-digestible carbohydrates; NSP, non-starch polysaccharides

Bach Knudsen et al. (2013)

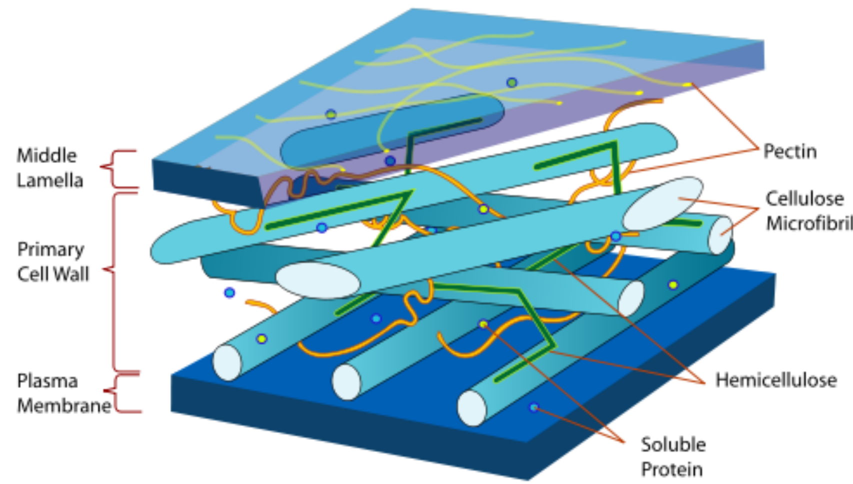
Fibres and physicochemical properties

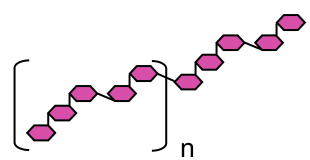
- The physicochemical properties – gelling, viscosity, and water binding capacity - of fibre are related to the chemical and structural organisation of the fibre matrix
- Big difference in properties between concentrated and natural sources

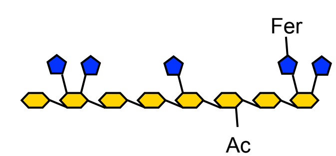


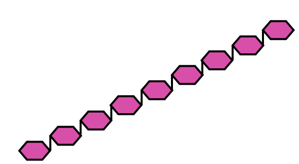
Physicochemical properties - concentrated vs. natural sources

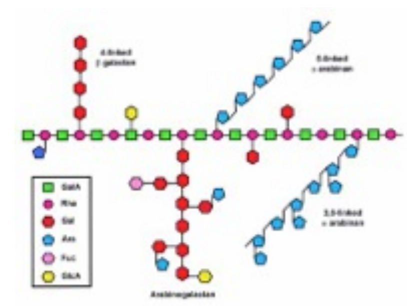
› The main difference in the physicochemical properties between concentrated and natural sources is that natural sources are a mix of polymers with cross-linkages keeping polymers in place whereas in concentrated sources typically one polymer dominate











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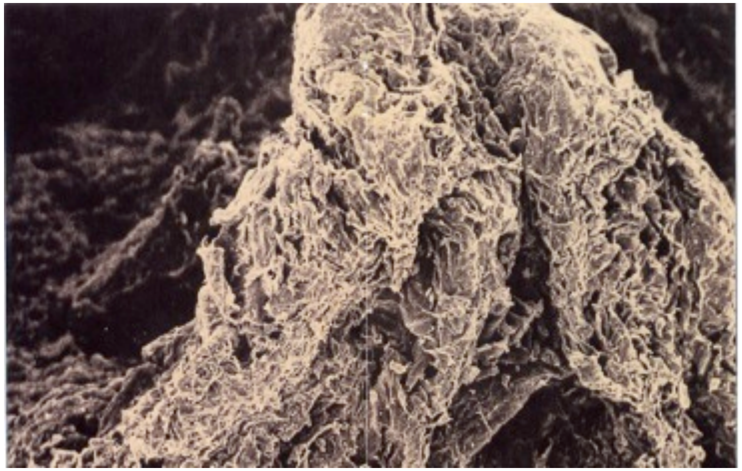
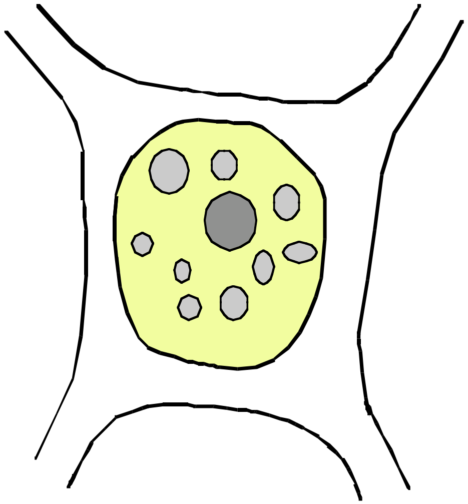
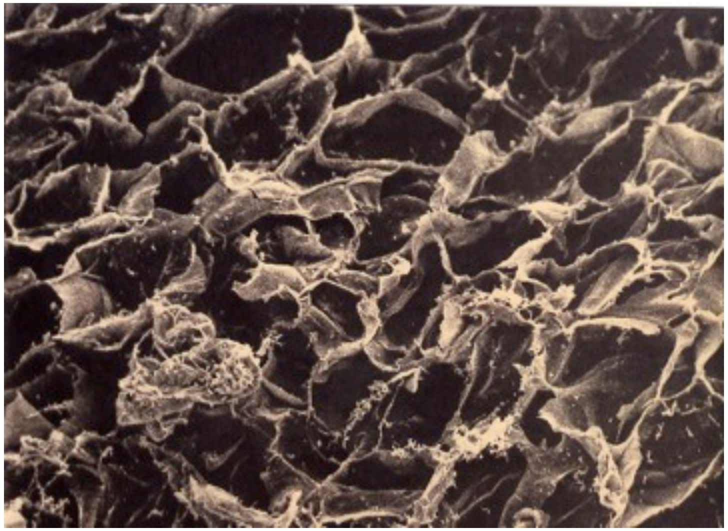
The physicochemical properties of fibre





Hydration



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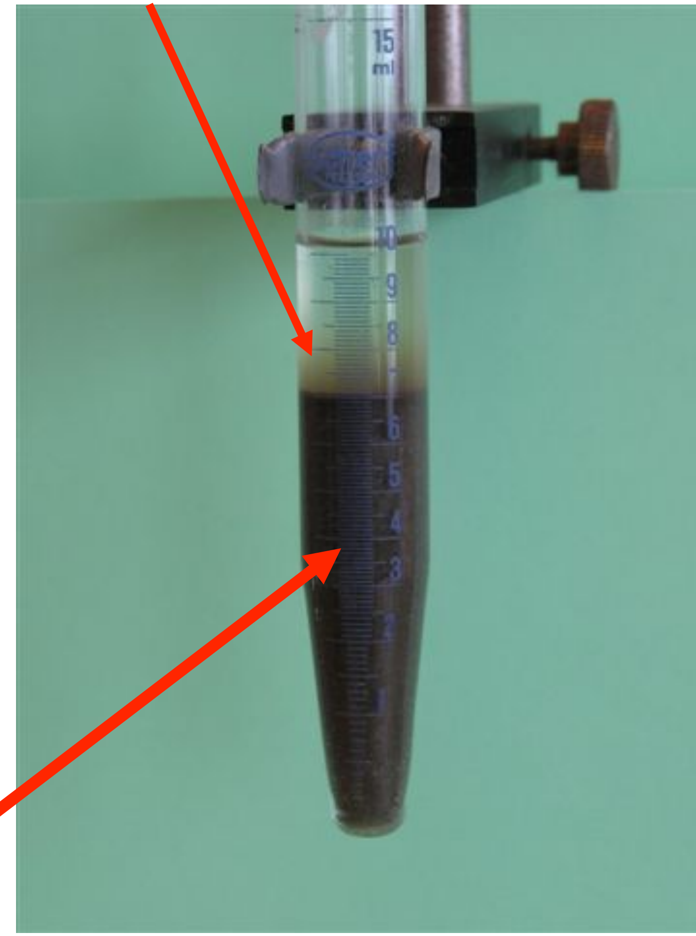
Physiochemical properties of insoluble and soluble fibre

Viscosity



Oat hulls

Water binding and swelling

Sugar beet pulp

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Model *in vitro* study

› A low fibre diet based on wheat and barley and four high-fibre diets with added fibre from barley hulls, pectin residue, sugar beet pulp and potato pulp at four different fibre levels: 22.5, 30.5, 37.5 and 45 % of DM

	Wheat	Barley	Barley hulls	Pectin residue	Sugar beet pulp	Potato pulp
Cellulose	2.0	4.5	16.4	44.1	20.7	22.0
NCP	9.9	12.3	29.6	30.2	37.6	33.6
Total NSP	11.9	16.8	46.0	74.3	58.3	55.6
Klason lignin	1.1	3.3	11.7	14.4	4.9	4.2
Dietary fibre	13.0	20.1	57.7	88.7	63.3	59.8
% soluble	22.3	31.8	6.2	12.1	40.3	38.5
WBC, kg/kg DM	1.4	1.9	3.7	9.0	9.7	13.8

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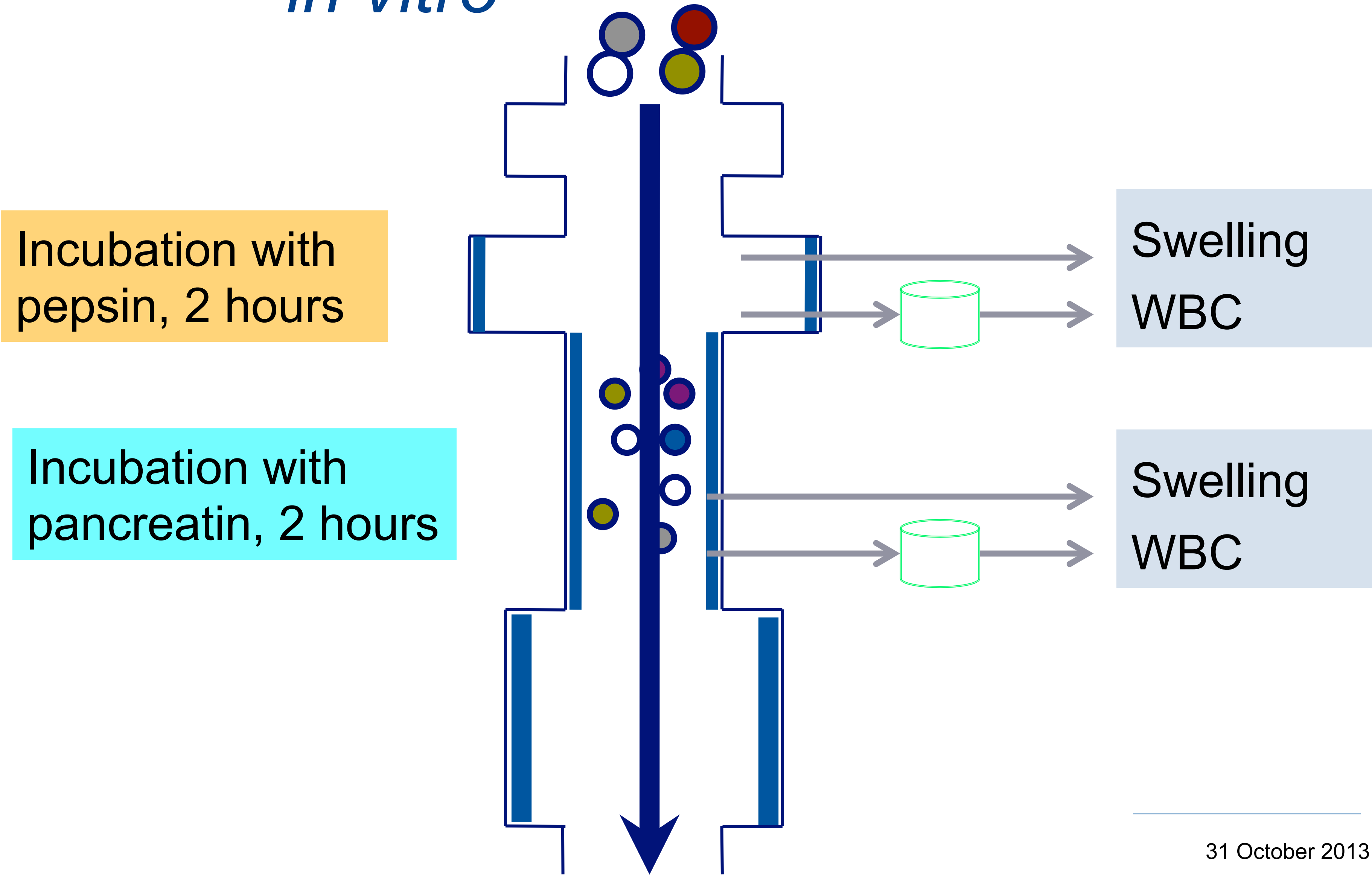
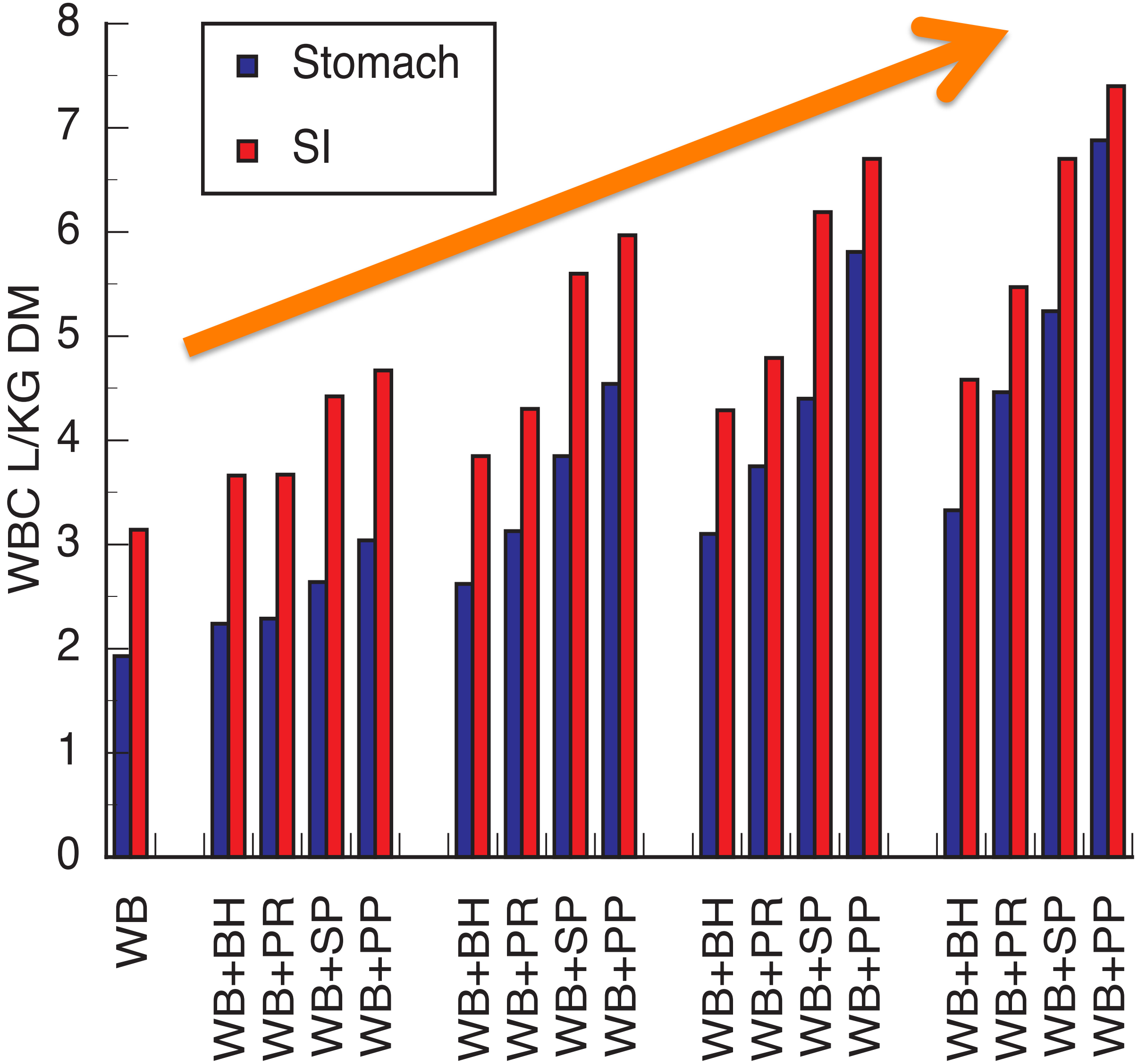
Physicochemical characterisation *in vitro*



Influence of DF on WBC in vitro



DF **17,5** **22,5** **30,5** **37,5** **45,0**

WB, wheat and barley

BH, barley hull

PR, pectin residue

SP, sugar beet pulp

PP, potato pulp

Bach Knudsen, unpublished

Possible effects of dietary fibre in the gastrointestinal tract

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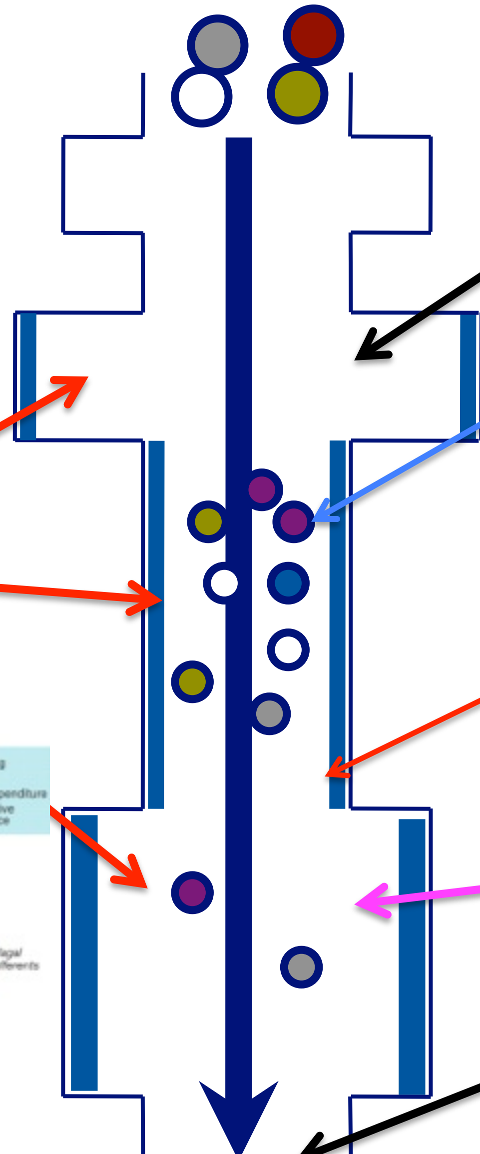
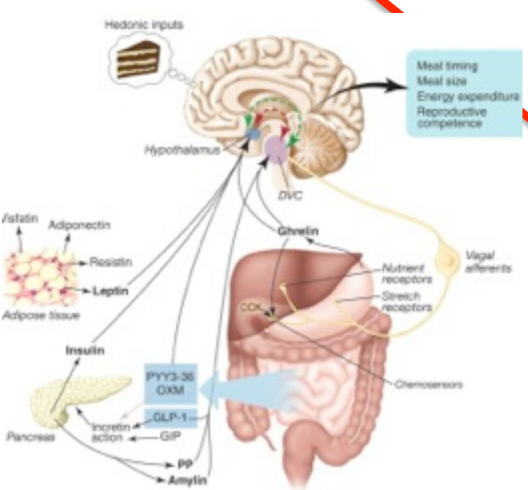
Bulk





Slows the rate of gastric emptying

Decrease the rate and extent of nutrients absorbed from the small intestine

Increase the flow of digesta to the large intestine

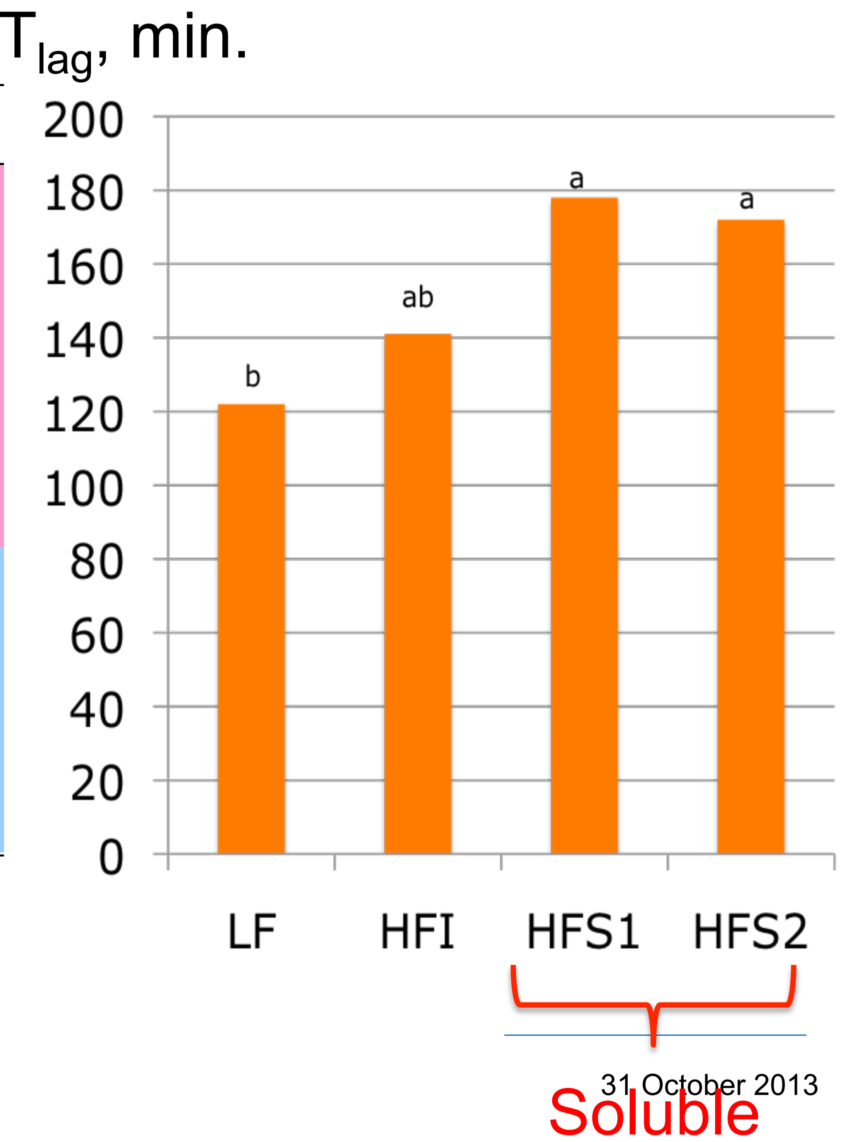
Increase the fermentation in the large intestine

Reduce total tract transit time

Soluble DF slows the rate of gastric emptying of the liquid phase

	LF	HFI	HFS1	HFS2
		g/kg		
Cereals	880	710	326	524
Pectin residue		400		
Potato pulp			455	
Sugar beet pulp	-			334
		g/kg DM		
Dietary fibre	167	256	376	307
Swelling, L/kg	3.81	5.17	7.23	6.95
WBC, kg/kg	1.70	2.65	4.72	4.26

LF: low fibre, HFI: high fibre pectin residue HFS1: high fibre potato pulp, HFS2, high fibre sugar beet pulp.



Jørgensen et al. (2009).

Studies with sows

- The main objective was to study the influence of type and levels of dietary fibre on the qualitative and quantitative aspects of carbohydrate assimilation and possible influence on the feeling of satiety in sows.

Diets

› A control diet and two high-fibre diets with high content of soluble and insoluble fibre, respectively were used.

	Control	HF-I	HF-S
Starch, % DM	51.8	23.9	21.7
Fibre, % DM	17.5 (4.4)[1]	45.3 (7.4)	43.0 (11.1)

[1]Soluble fibre.

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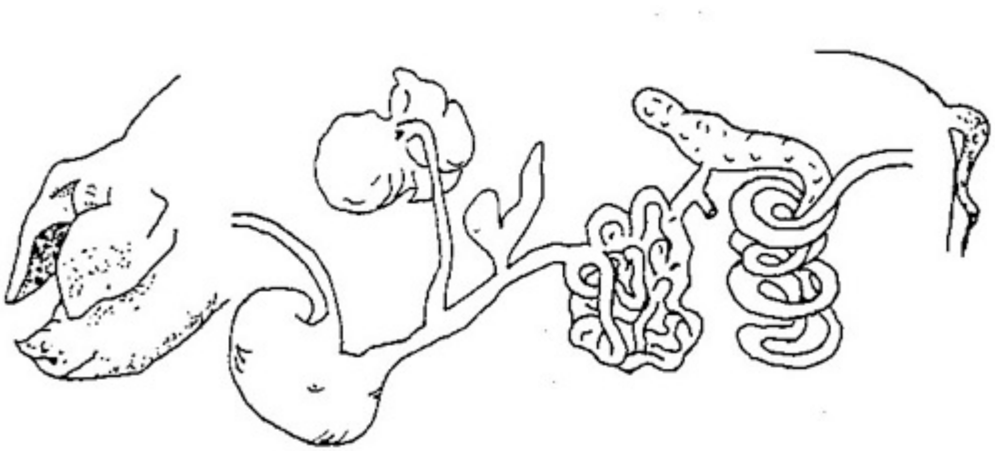
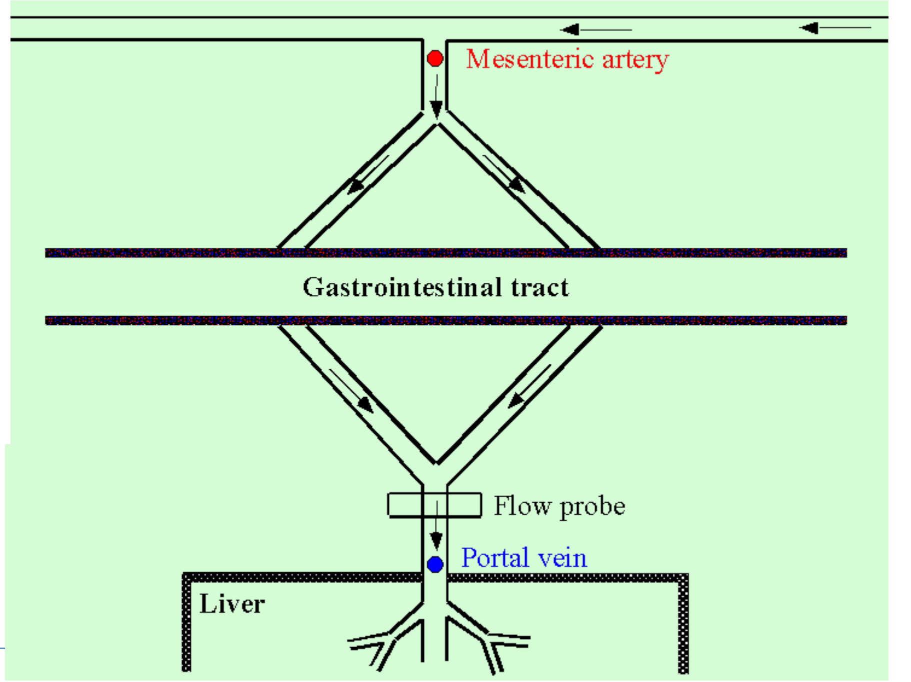
Animal models

Ileal cannulated sows



At slaughter, digesta were collected at different parts of the gastrointestinal tract

Catheterized sows



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Influence of fibre content and composition on gastrointestinal content and flow at ileum

	Low fibre	High fibre insoluble	High fibre soluble
		Content, kg	
Stomach	4.3[b]	5.6[a]	6.1[a]
Small intestine	1.5[b]	2.1[a]	2.4[a]
Large intestine	5.1[b]	8.6[a]	7.5[a]
		Flow, g/d	
Digesta	5,560[b]	9,519[a]	10,113[a]
Dry matter	544[b]	1,004[a]	972[a]
		Physicochemical properties, kg/kg DM	
WBC	3.77	4.55	4.43

WBC, water-binding capacity

Serena et al. (2009).

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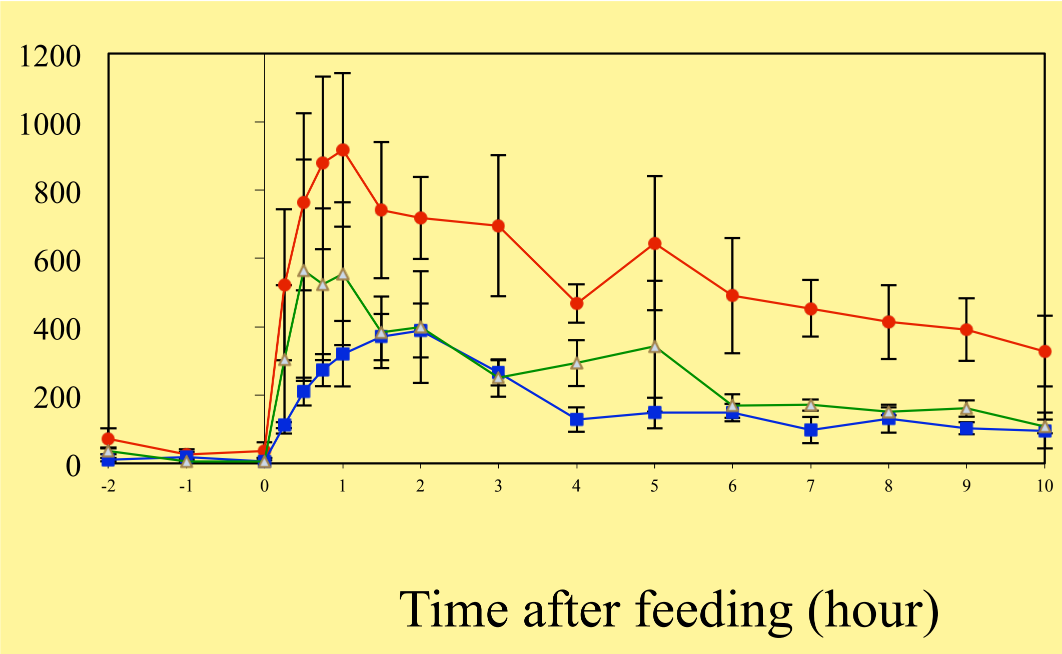
Influence of fibre content and composition on absorption of carbohydrate derived nutrients and insulin response

	Low fibre	High fibre insoluble	High fibre soluble
	Absorption, mmol/h		
Glucose	419[a]	189[b]	124[b]
Lactic acid	1.5[b]	2.1[a]	2.4[a]
Short-chain fatty acids	133[c]	218[b]	321[a]
	Concentration, pmol/L		
Insulin	138[a]	98[b]	87[b]

Serena et al. (2009).



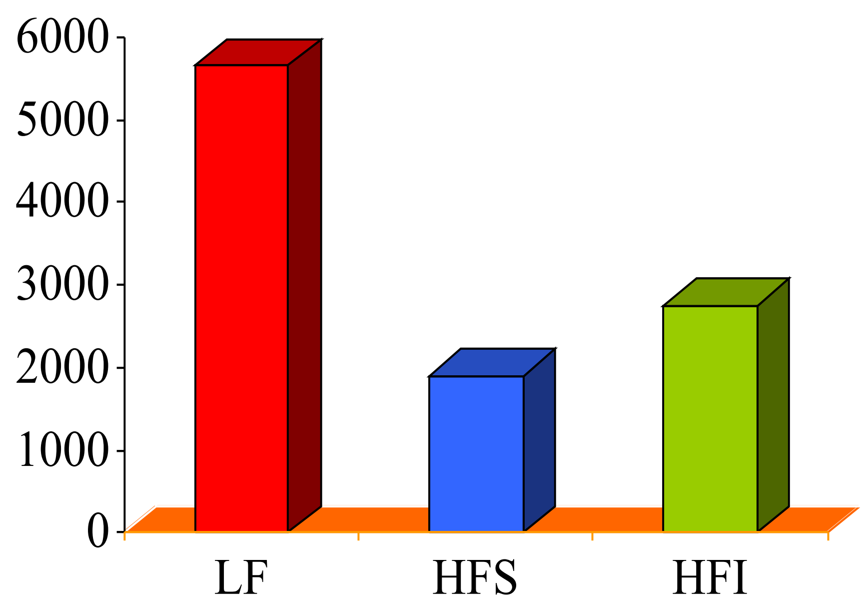
Glucose absorption (mmol/h)

Low fibre (LF; ——●——);

High fibre S (HFS; ——■——)

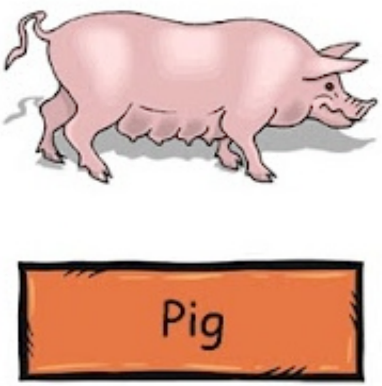
Hig fibre I (HFI; —▲—).

Accumulated glucose absorption 0-10 hours after feeding (mmol)



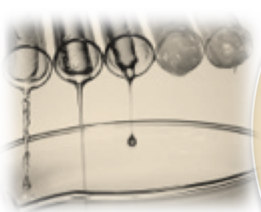
Serena et al. (2009).

Study with fibre enriched breads – The BioFunctional Carbohydrate project



In vivo animal studies

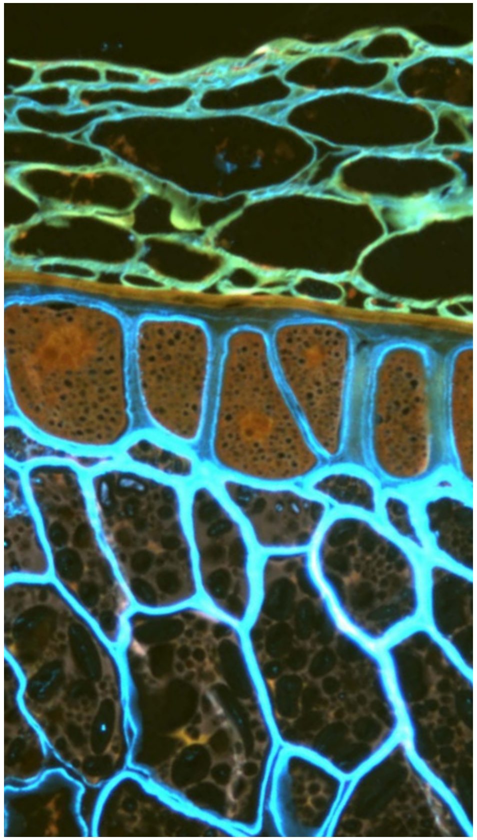
Acute human studies

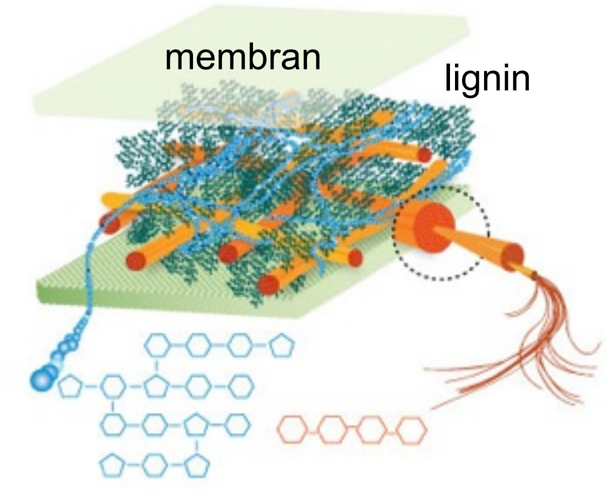


Chemical, Physicochemical and In vitro studies

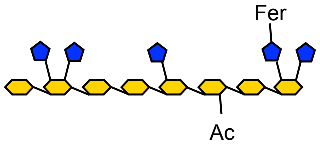
Long-term intervention studies with ZDF rats

Arabinoxylan and β-glucan in cereals

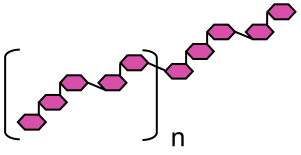




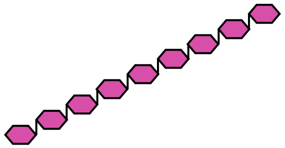
	Dietary fibre	β-Glucan	AX
Wheay, whole grain	10-13	0.8	8
Wheat flour	3	0.4	2.2
Rolled oats	11-13	4-5	2.5
Rye, whole grain	15-18	1.5	9-10



Arabinoxylan



ß- (1,3)(1,4)-glucan

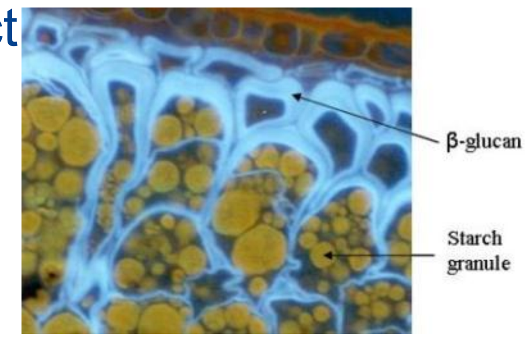


Cellulose = ß-(1,4)-glucan

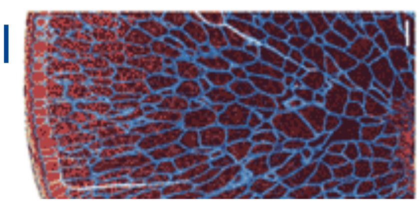
Extraction of ß-glucan and arabinoxylan

› β-glucan is highly soluble and relatively easy to extract from oats and barley

› Commercial products are evailable on the marked
  › PromOat™ - extracted from oats
  › Glucagel™ - extracted from barley



› Arabinoxylan has a more complex structure and a higl proportion is as insoluble fibre
  › In wheat, only arabinoxylan in the endosperm is soluble
  › No commercial products are at present available



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BioFunctional CHO

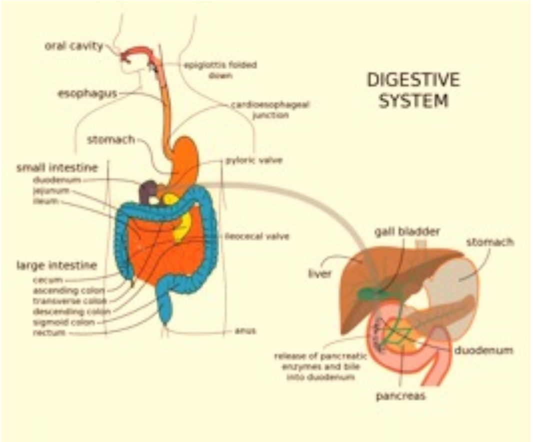
β-glucan and Arabinoxylan

Chemical and physiochemical characterisation

Breads
Chemical and in vitro characterisation

Digestion and metabolism
- Ileal cannulated and catheterised pigs
- ZDF rats
- Humans with MeS

Second meal effects of AX rich diets provided as porridge



Arabinoxylan and ß-glucan in bread

› White wheat bread low in fibre
› Commercial whole grain bread without and with kernels
› Wheat bread with added arabinoxylan
› Wheat bread with added β-glucan

arabinoxylan concentrate

oat β-glucan concentrate + cellulose (1:1 on DF basis)

WF

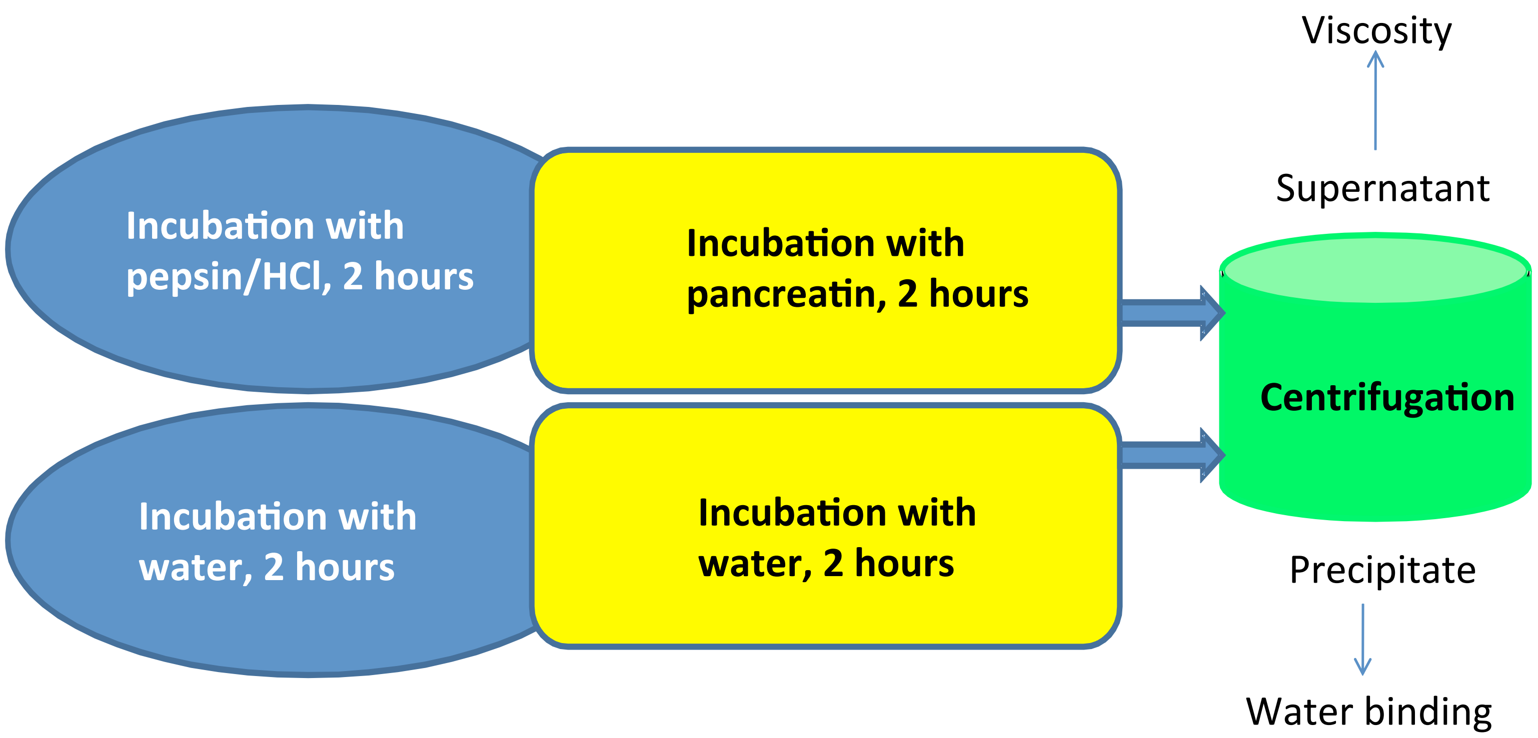
GR

RK

AX

BG

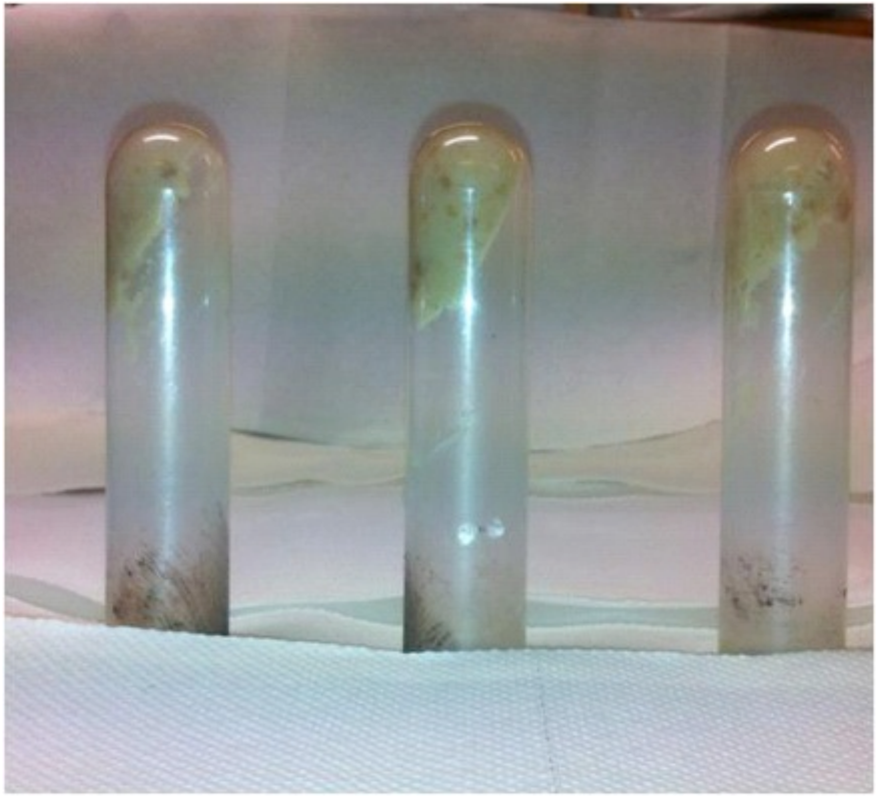
Physicochemical characterisation *in vitro*



Physicochemical properties

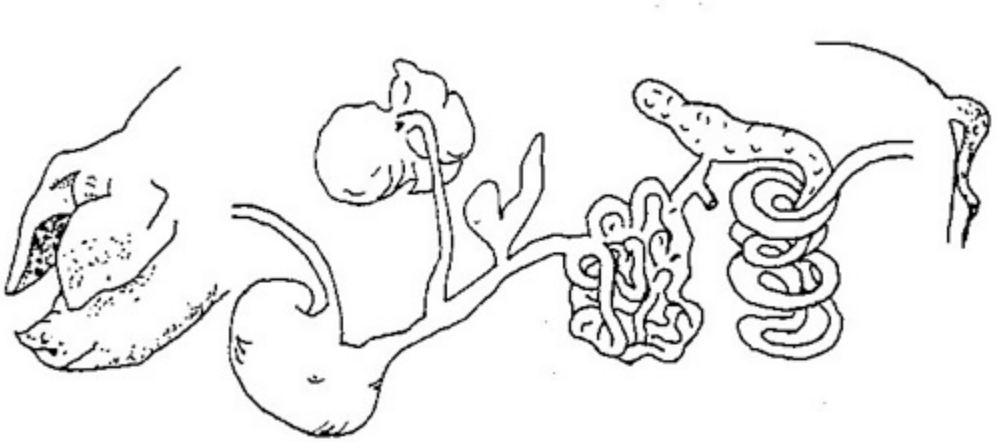
› Viscosity

› Water binding capacity



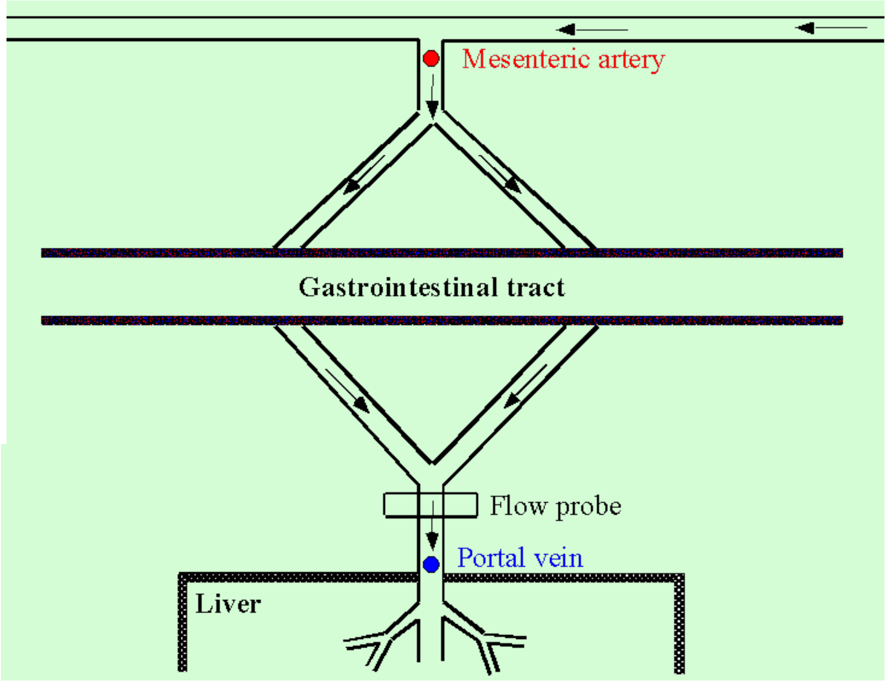
ANIMAL MODELS

Ileal cannulated pigs

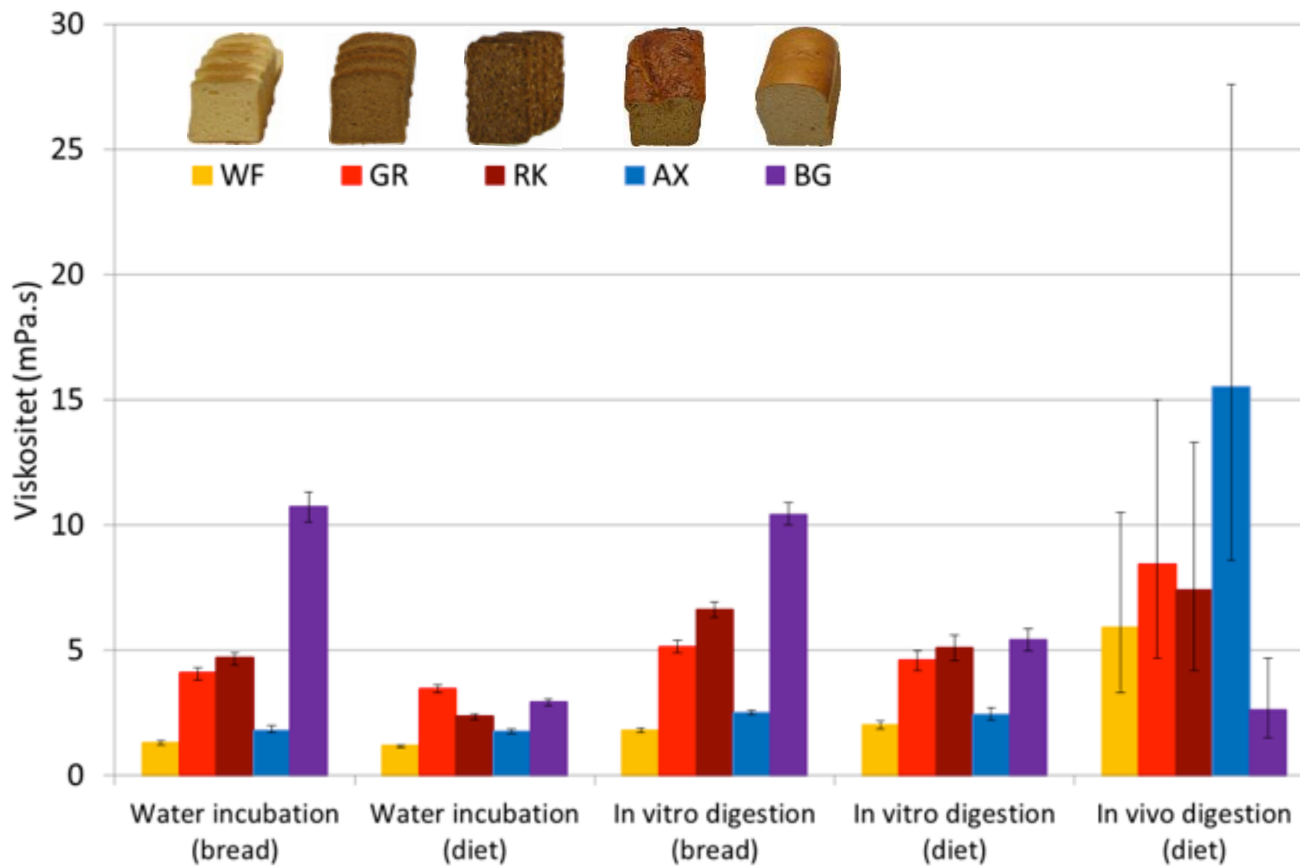


Collection of digesta from ileum

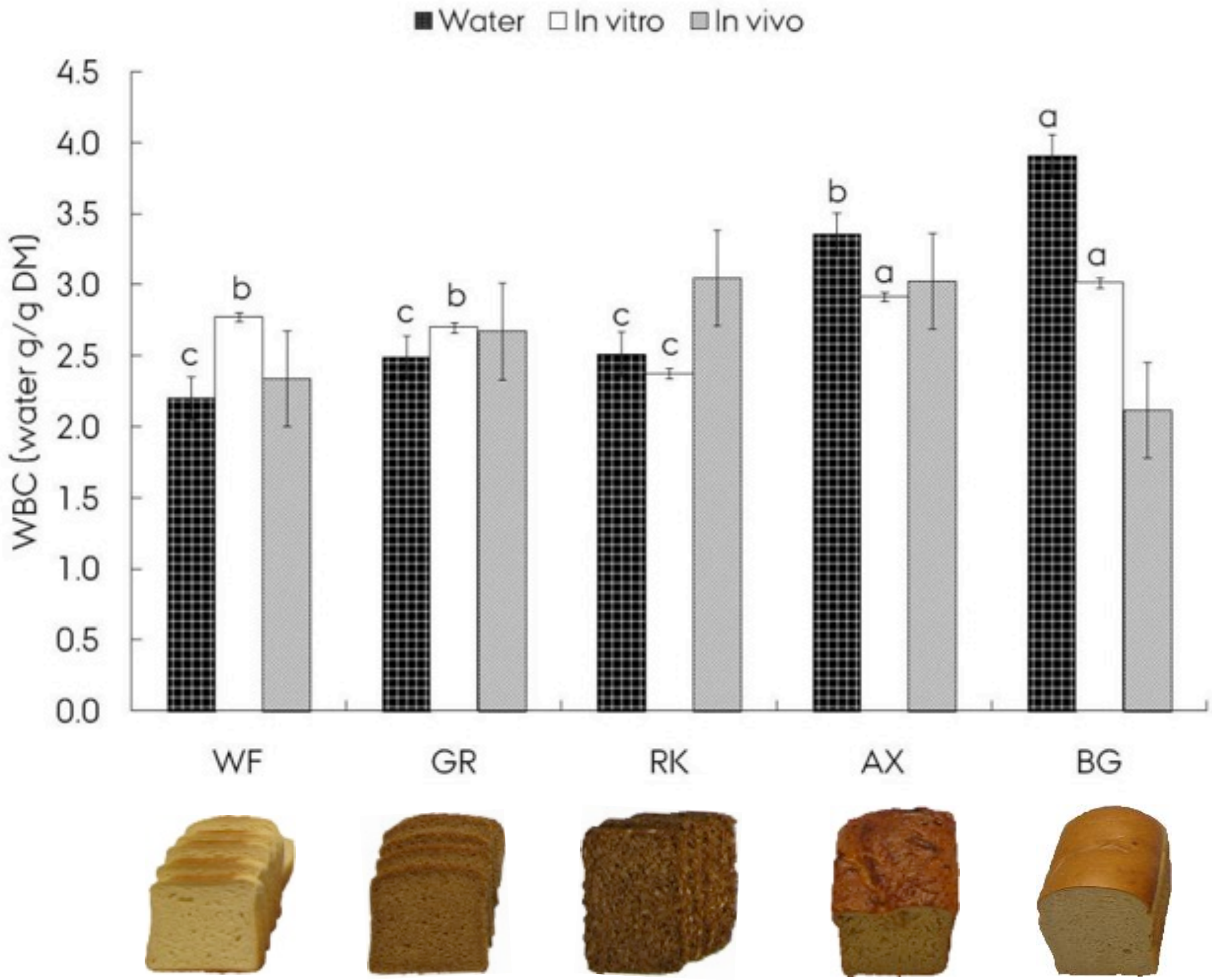
Catheterized pigs



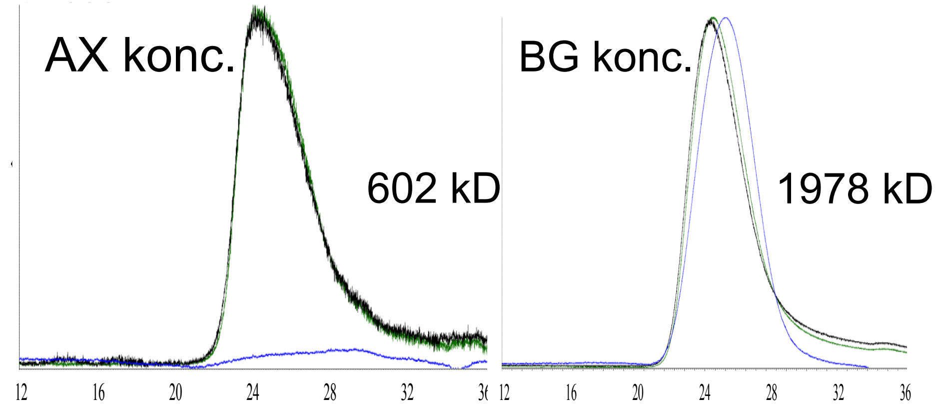
VISCOSITY

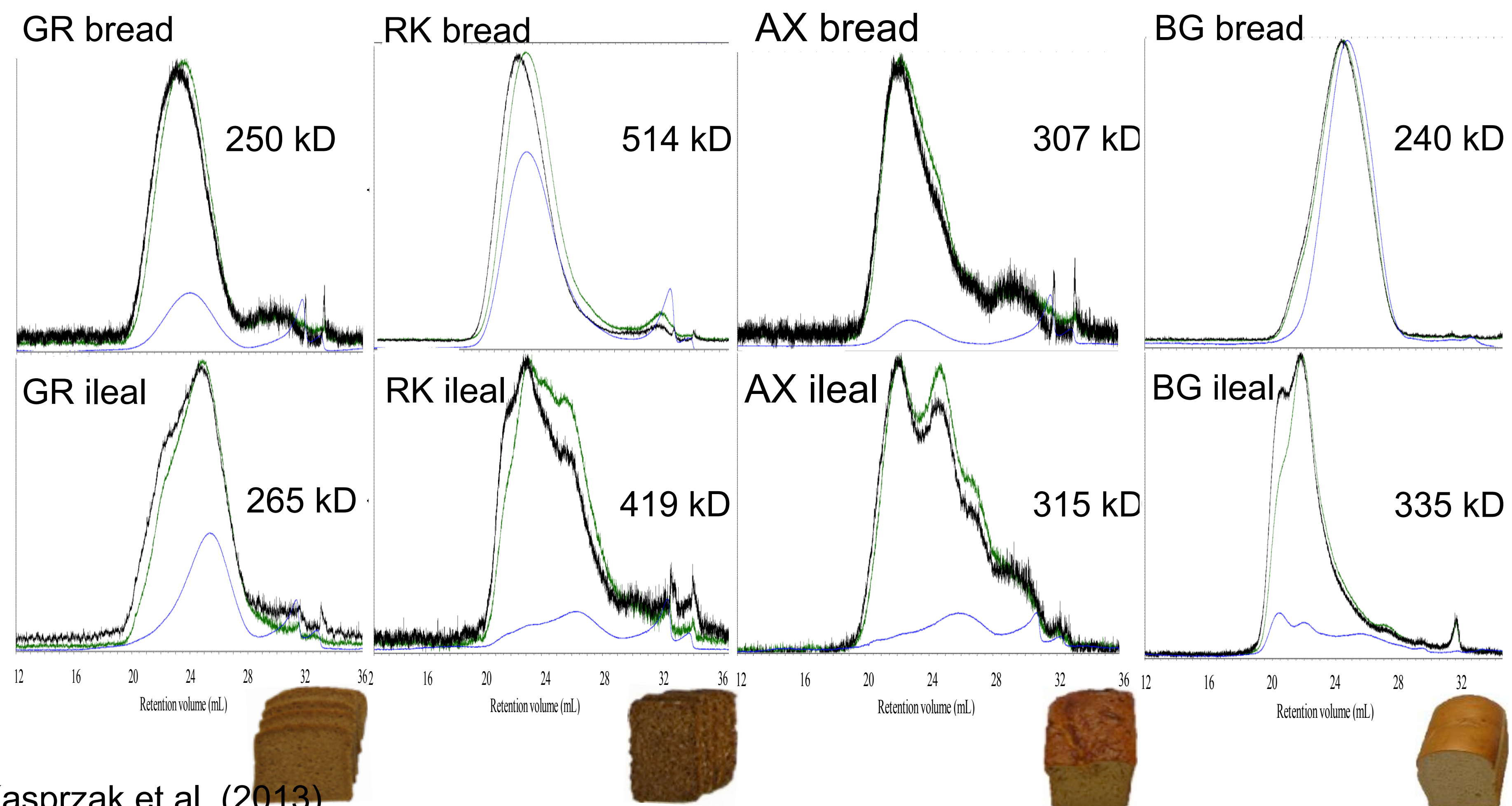

Viskositet (mPa.s)
30
25
20
15
10
5
0
WF
GR
RK
AX
BG
Water incubation (bread)
Water incubation (diet)
In vitro digestion (bread)
In vitro digestion (diet)
In vivo digestion (diet)

WATER BINDING CAPACITY



Molecular weight





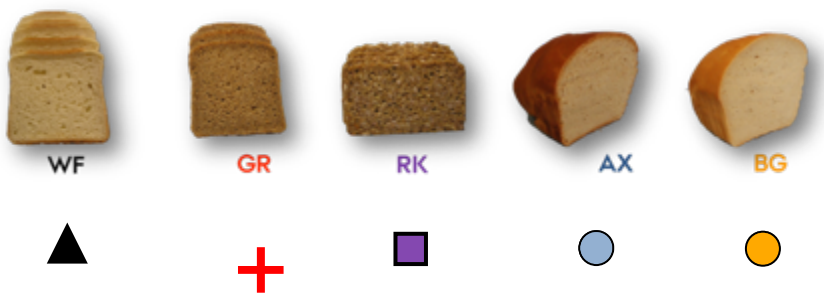
Kasprzak et al. (2013)

Digestibility of dietary fibre in the small intestine

	WF	GR	RK	AX	BG
NSP	17^{bc}	27^{abc}	29^{a}	13^{c}	38^{a}
Arabinoxylan	28	27	32	11	31
NSP glukose	16^{c}	35^{ab}	34^{b}	29^{bc}	43^{a}
β-glukan	87^{a}	66^{b}	67^{b}	81^{a}	81^{a}
Cellulose + RS	-5	11	10	14	14

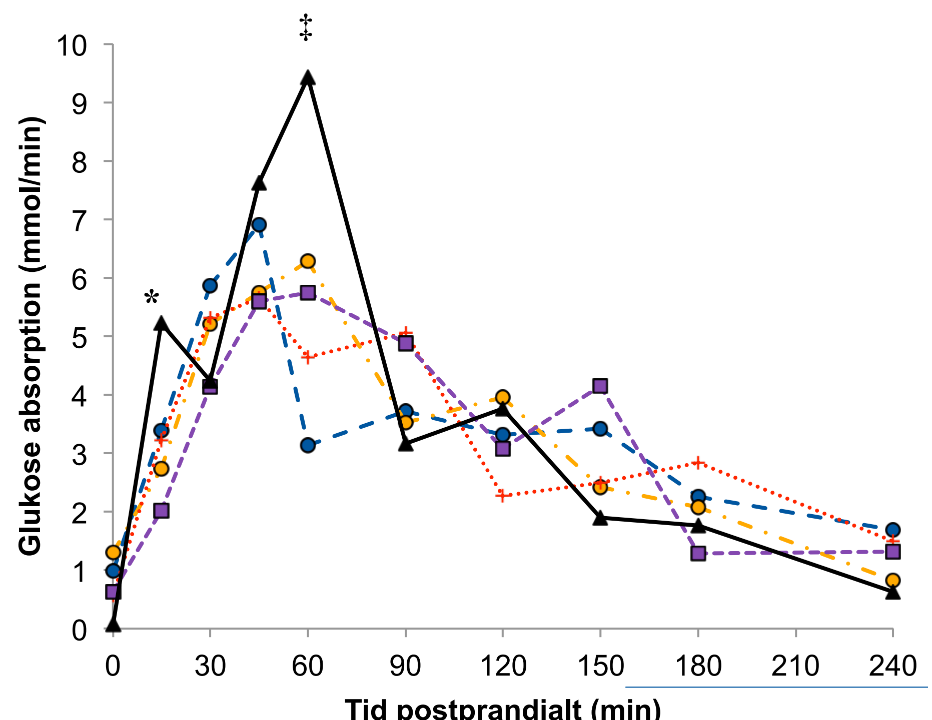
Kasprzak et al. (2013)

Glucose absorption



P-values
- Diet: 0.69
- Time: < 0.001
- Diet × Time: 0.04

* WF > RK (*P* = 0.05)
‡ WF > AX (*P* = 0.02)



Christensen et al. (2013)

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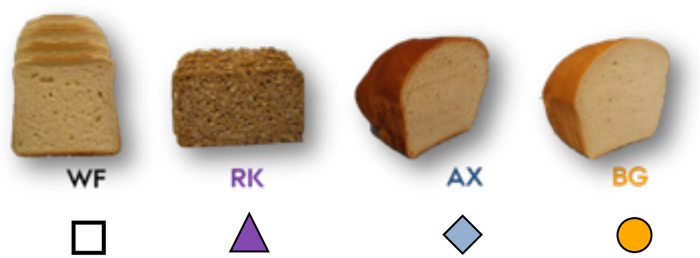
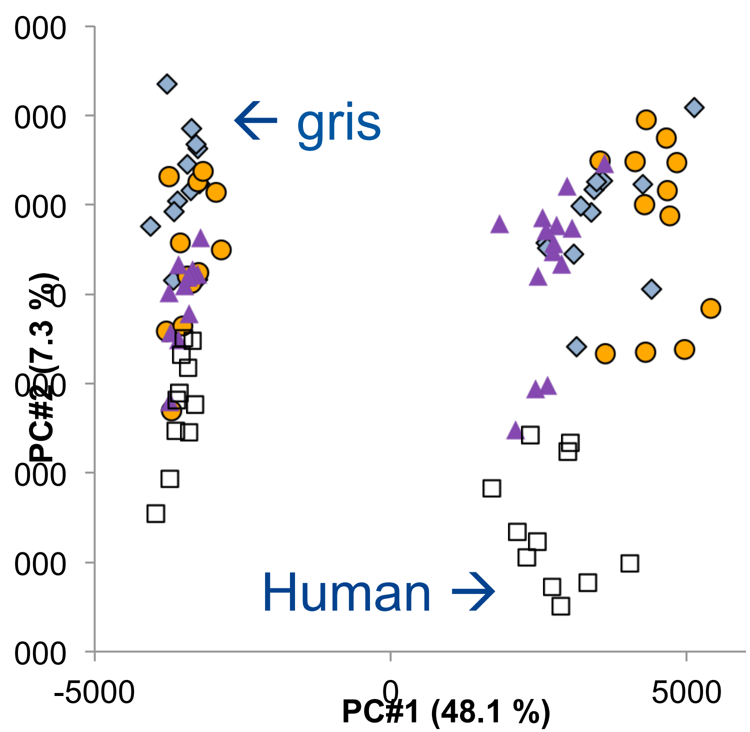
Influence of different breads on the metabolome of pigs and human subjects

- 30 min postprandial



- PCA-scores plot
  - Same “breadpattern” on pigs and humans in PC#2



Christensen (2013)

Conclusions

- Fibres are an important components of all but a few feed- and foodstuffs
- Fibres have important implications for the physicochemical properties of digesta
- Level and type of fibres are of importance when influencing gastric emptying and rate and extent of nutrients absorption from the small intestine

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Thank you very much for your attention

31 October 2013