Effect of fibre on piglet gut health

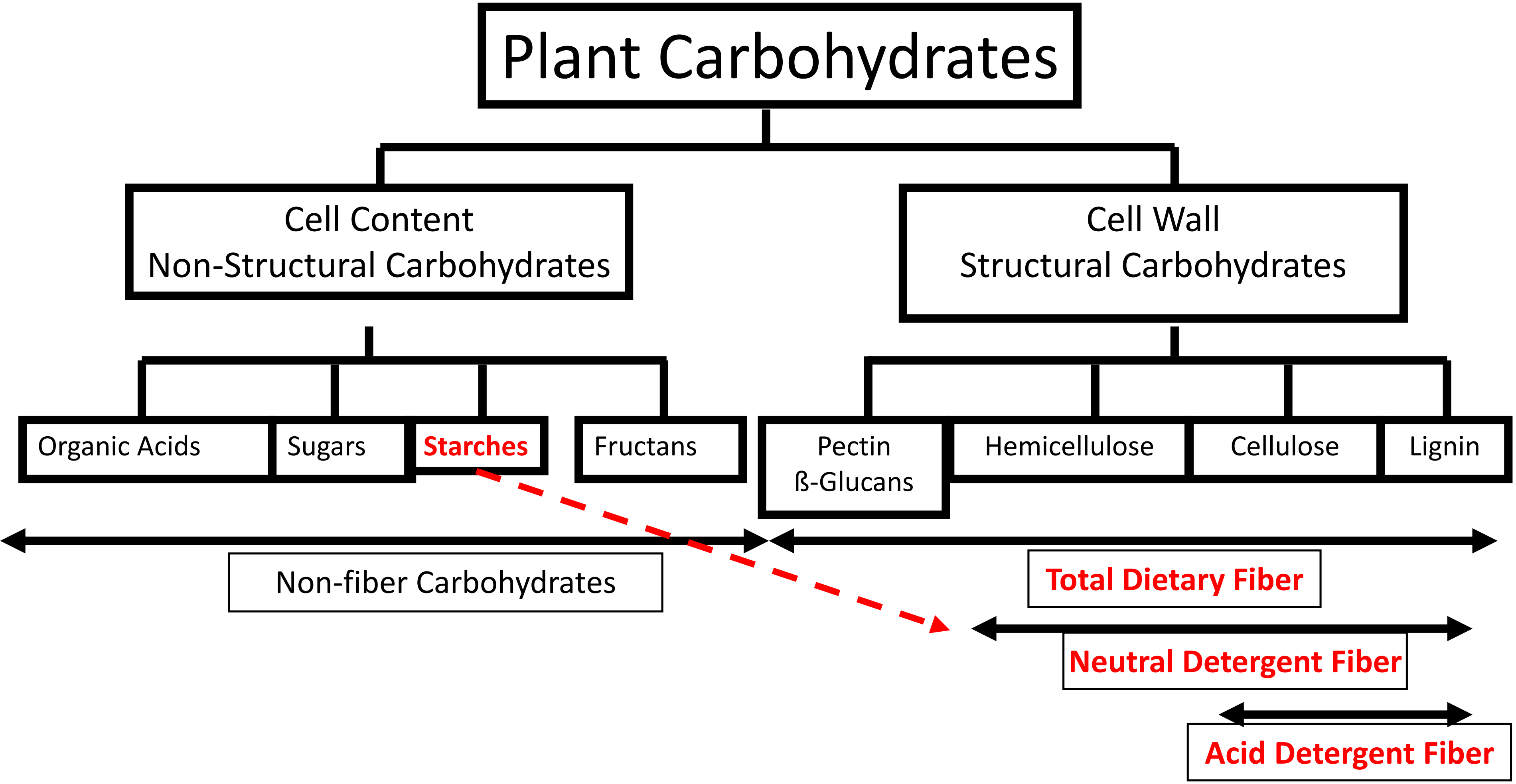
Ruurd T. Zijlstra

University of Alberta

Edmonton, AB, Canada

E-mail: ruurd.zijlstra@ualberta.ca

Fiber and Starch



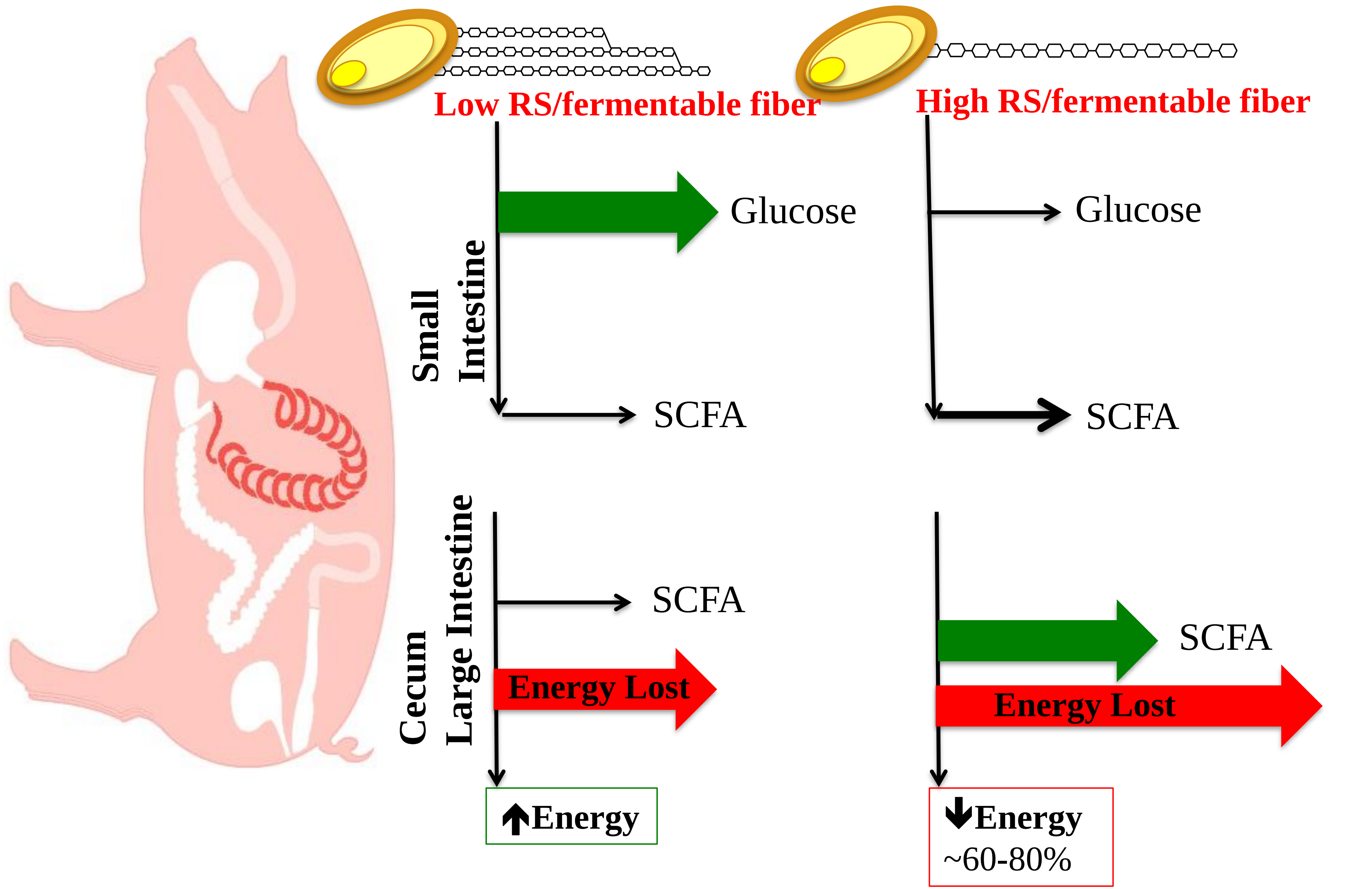
Not correct functionally, because resistant starch (RS) may act like fiber

Sugar, disaccharide (DP2), oligosaccharide (DP3-9), polysaccharide (DP≥10)

Problem and Partial Solution in Pigs

- Post-weaning diarrhea [short-term gut health]
  - Reduced feed intake & growth
  - Reduced gut wall integrity
  - Reduced digestibility
  - Unstable microflora
  - Inflammation
  - Protein fermentation
- Solution: Dietary antibiotics – but, pressure to remove
- Prebiotic (revisited)
  - Selectively fermented ingredient that allows specific changes, both in composition and/or activity in the gastrointestinal microflora that confers benefits upon host well-being and health (Roberfroid, 2007)
  - Mostly fermentable carbohydrates
    - Oligosaccharides, inulin, resistant starch, pectin, β-glucan
    - Feedstuffs vs. Feed additives

CHO Fermentation & Energetic Efficiency



1. Focus: Resistant Starch

- **Starch not digested into glucose but fermented into short-chain fatty acids (SCFA):** **[This is NOT the glycemic effect of starch]**

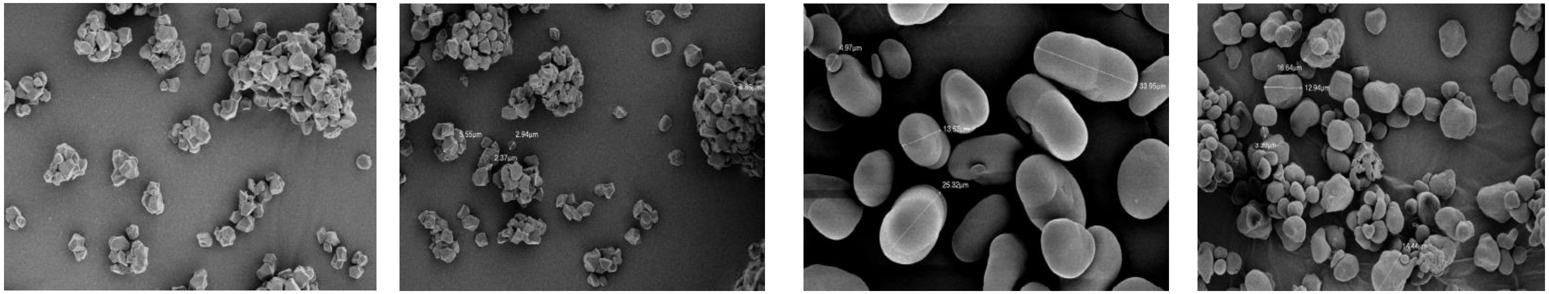
Impact on:

- **Microbial profiles & mediators**
- **Gut hormones**
- **Whole body energy metabolism**
- **Feed intake and growth**

2. Fermentable Fiber (Similar to resistant starch)

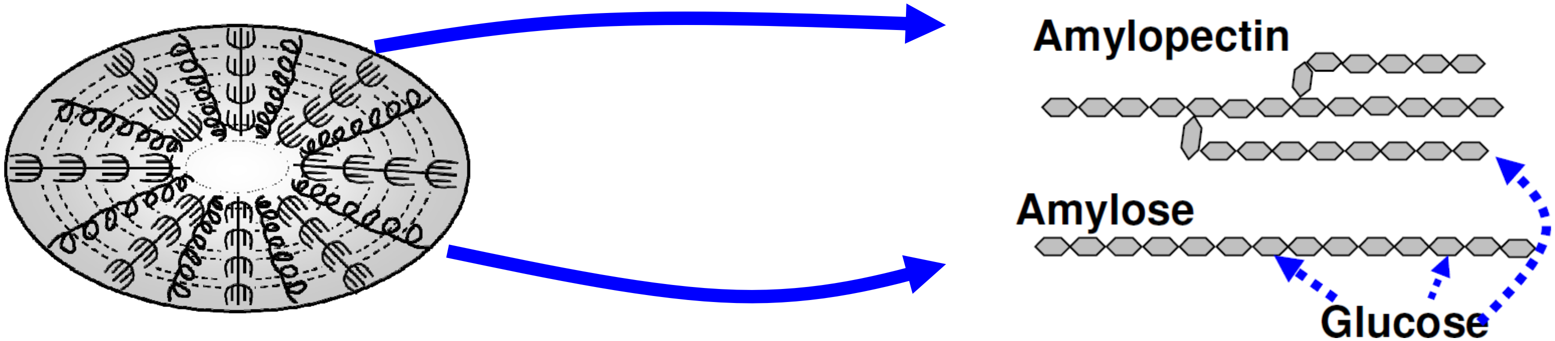
3. Gut health and growth performance

Use Starch Chemistry to Study Starch vs. Fiber



x 1000, electron micrograph

Source	Rice	Rice	Field pea	Corn
Amylose	0 %	18%	29%	63%
Resistant starch	3%	34%	61%	85%



Starch digestibility: amylose < amylopectin

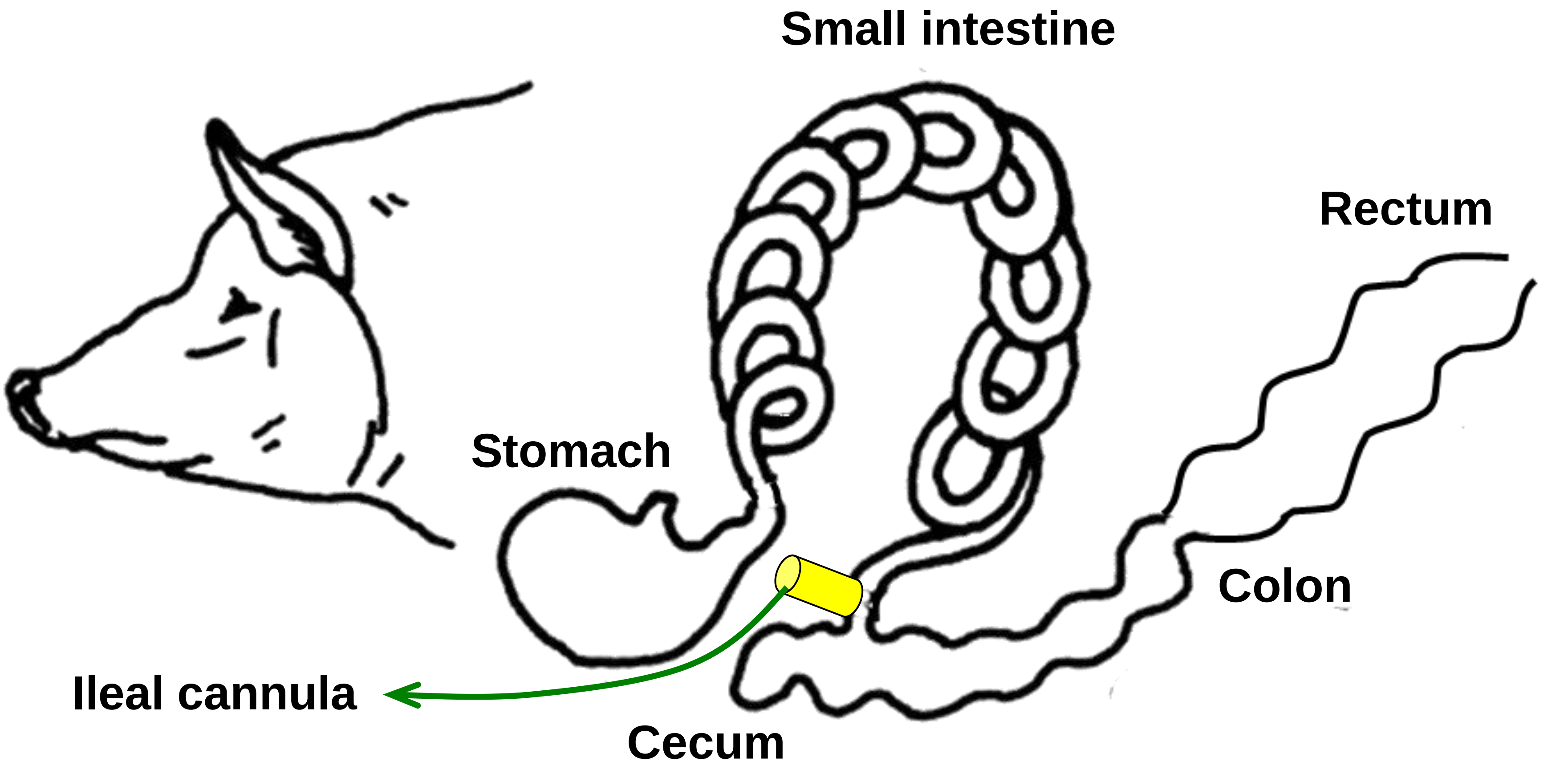
(Van Kempen et al., 2010; Regmi et al., 2011ab; Fouhse et al., 2015; J. Nutr.)

Four Diets

Ingredients	%, as fed
Starch	70
Casein	14
Fish meal	7.4
Cellulose	4
Canola oil	1
Minerals & Vitamins	3.2
Marker (Titanium oxide)	0.4

(Van Kempen et al., 2010; Regmi et al., 2011ab; ~Fouhse et al., 2015; J. Nutr.)

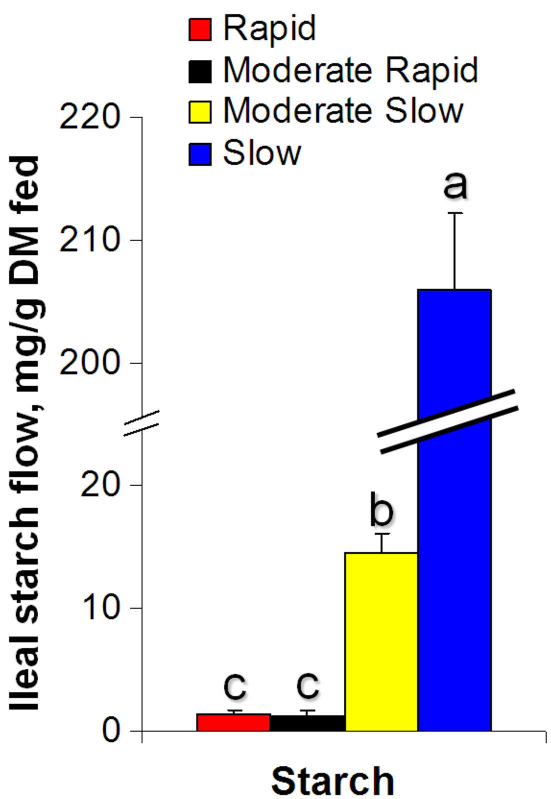
Ileal-cannulated pig

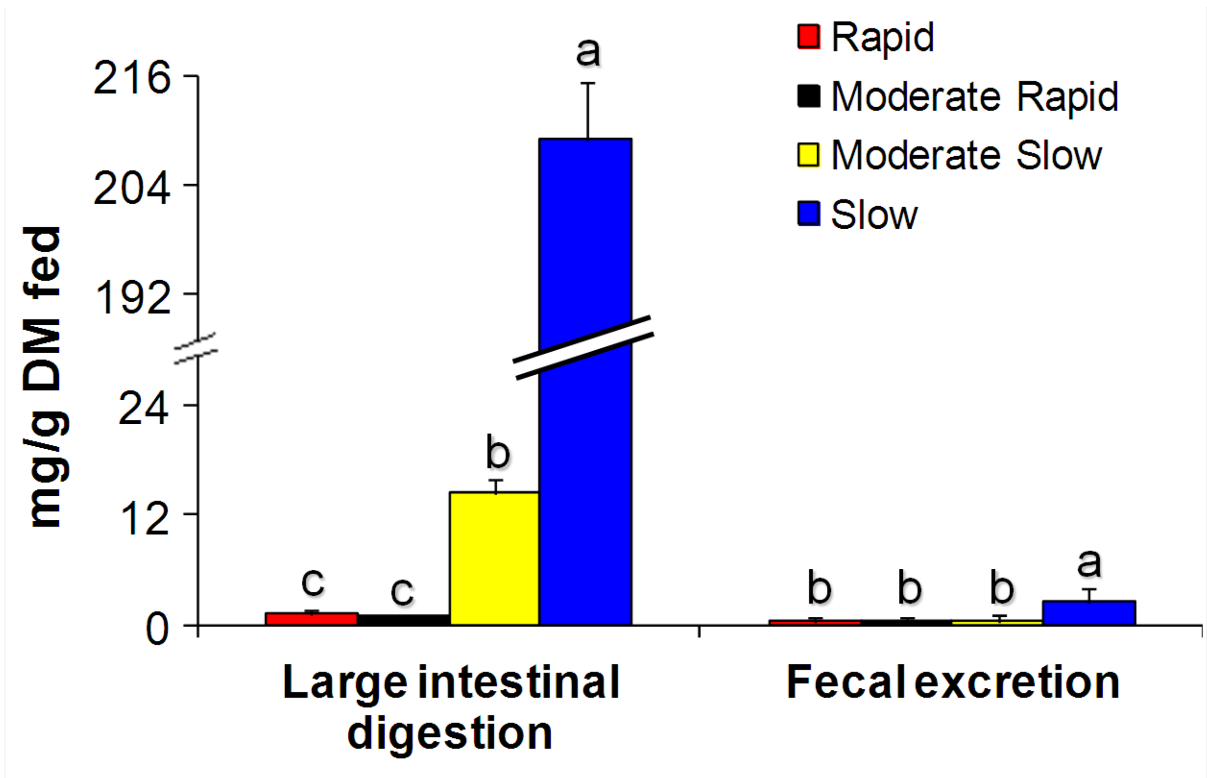


Total extent of digestion

- Can separate between small and large intestine

Starch Flow in Intestine; grower pig



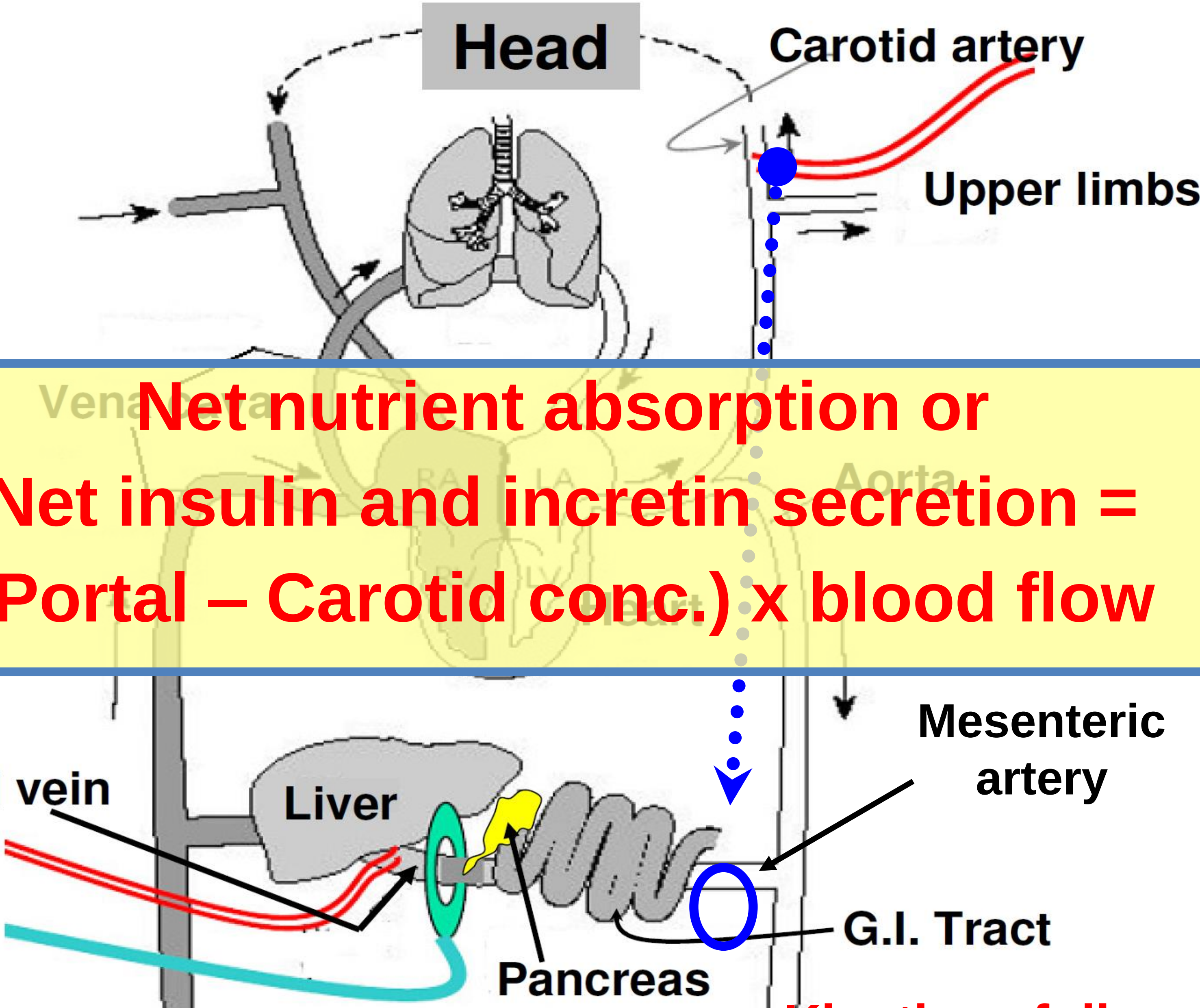


Major advantage of most RS: complete fermentation in hindgut
Changes in gene expression in the gut

(Regmi et al., 2011a; J. Nutr.)

***P* < 0.05**

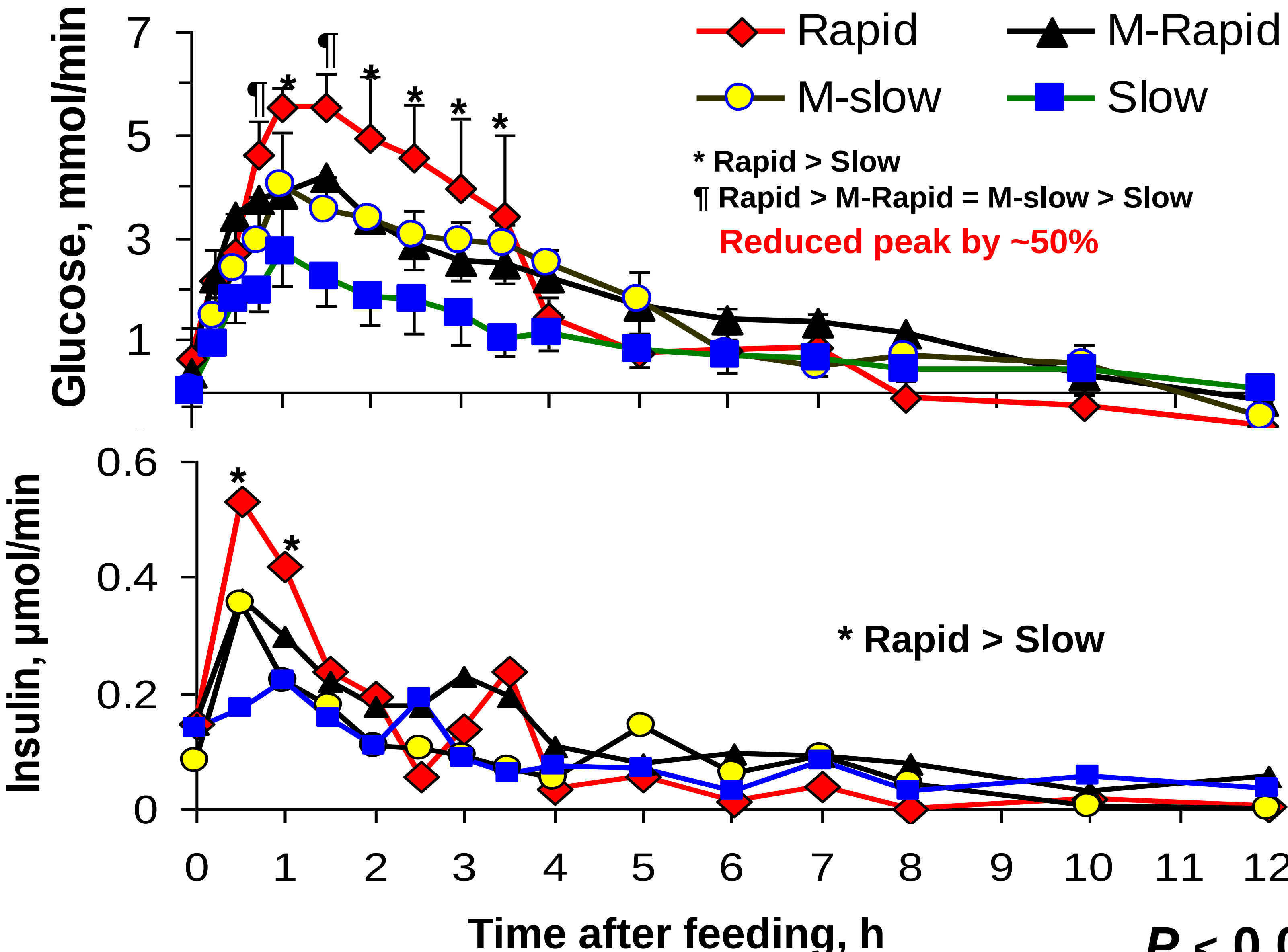
Portal-vein catheterized pig



Net nutrient absorption or
Net insulin and incretin secretion =
(Portal – Carotid conc.) x blood flow

Kinetics of digestion

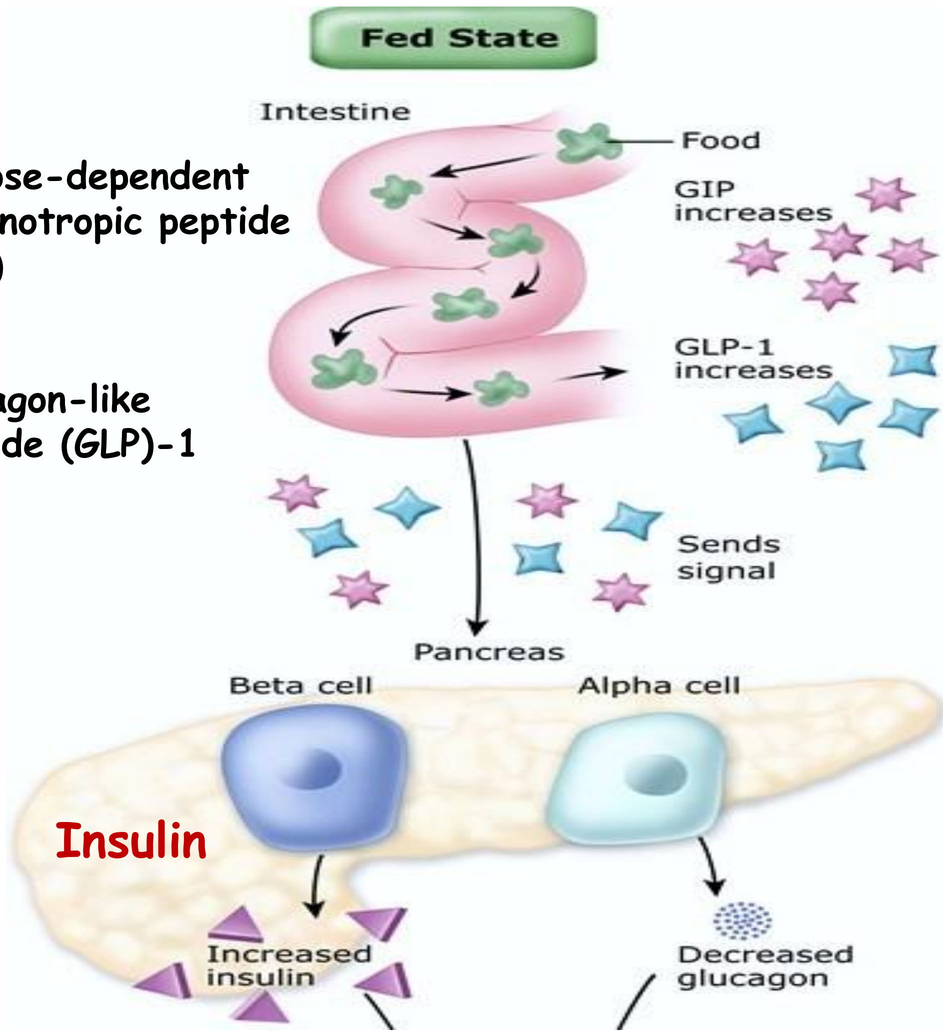
Glucose Absorption & Insulin Secretion



***P* < 0.05**

(Regmi et al., 2011a; J. Nutr.)

Incretins



Glucose-dependent insulinotropic peptide (GIP)

Glucagon-like peptide (GLP)-1

- **Incretin: gastrointestinal hormones in response to nutrients in gut**
- **Released from enteroendocrine**
  - **K cells, duodenum, jejunum; GIP**
  - **L cells, ileum; GLP-1**
- **Stimulate glucose dependent insulin secretion from pancreas**

(Hooda, 2010)

AUC of GIP and GLP-1 Secretion; grower pig

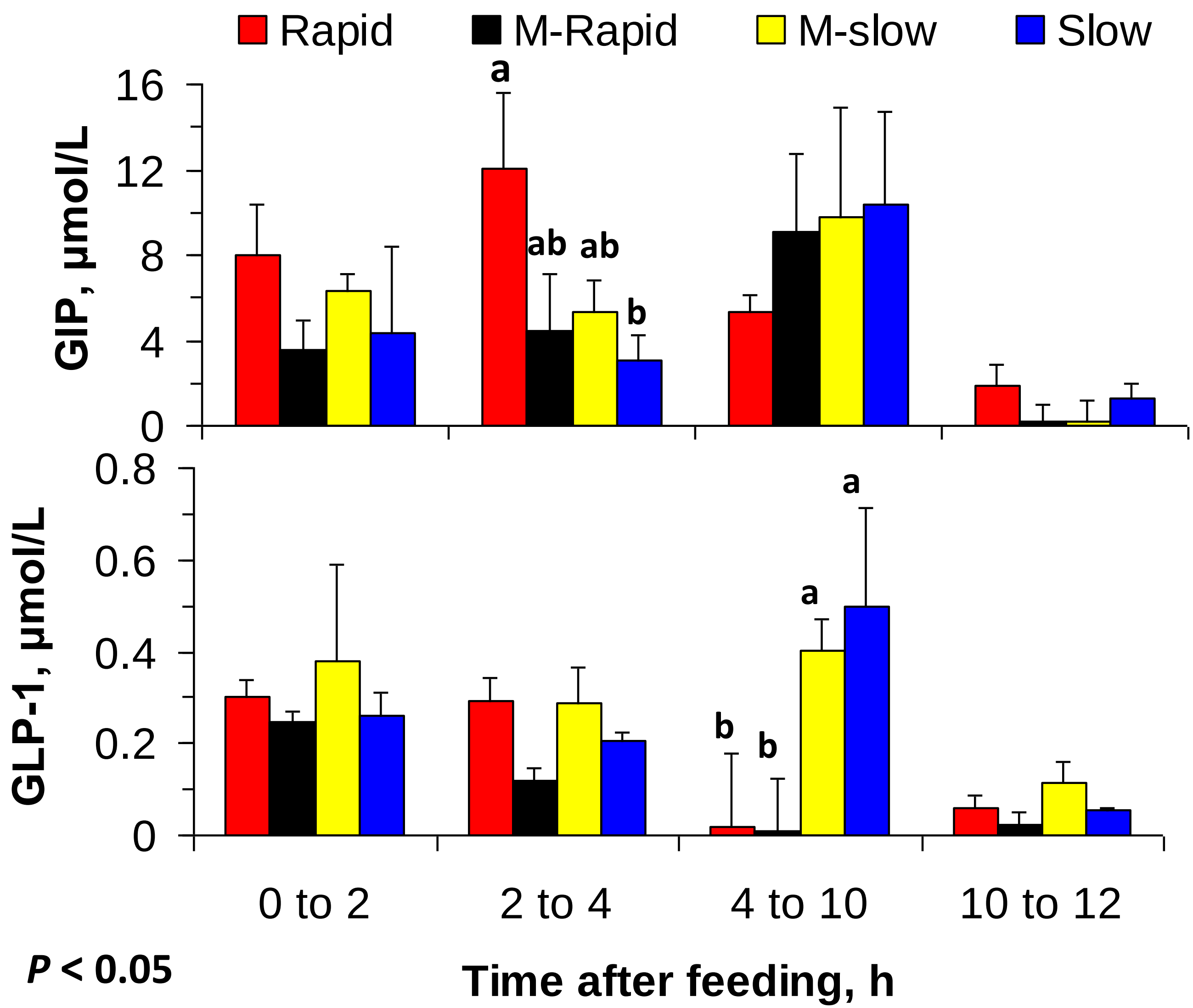
Area under curve (AUC) =

$$\frac{1}{2}\sum_{i=0}^{n-1}(t_{i+1}-t_i)(y_i+y_{i+1})$$

Where, t = time;

y_i = value at time i

(Matthews et al., 1990)

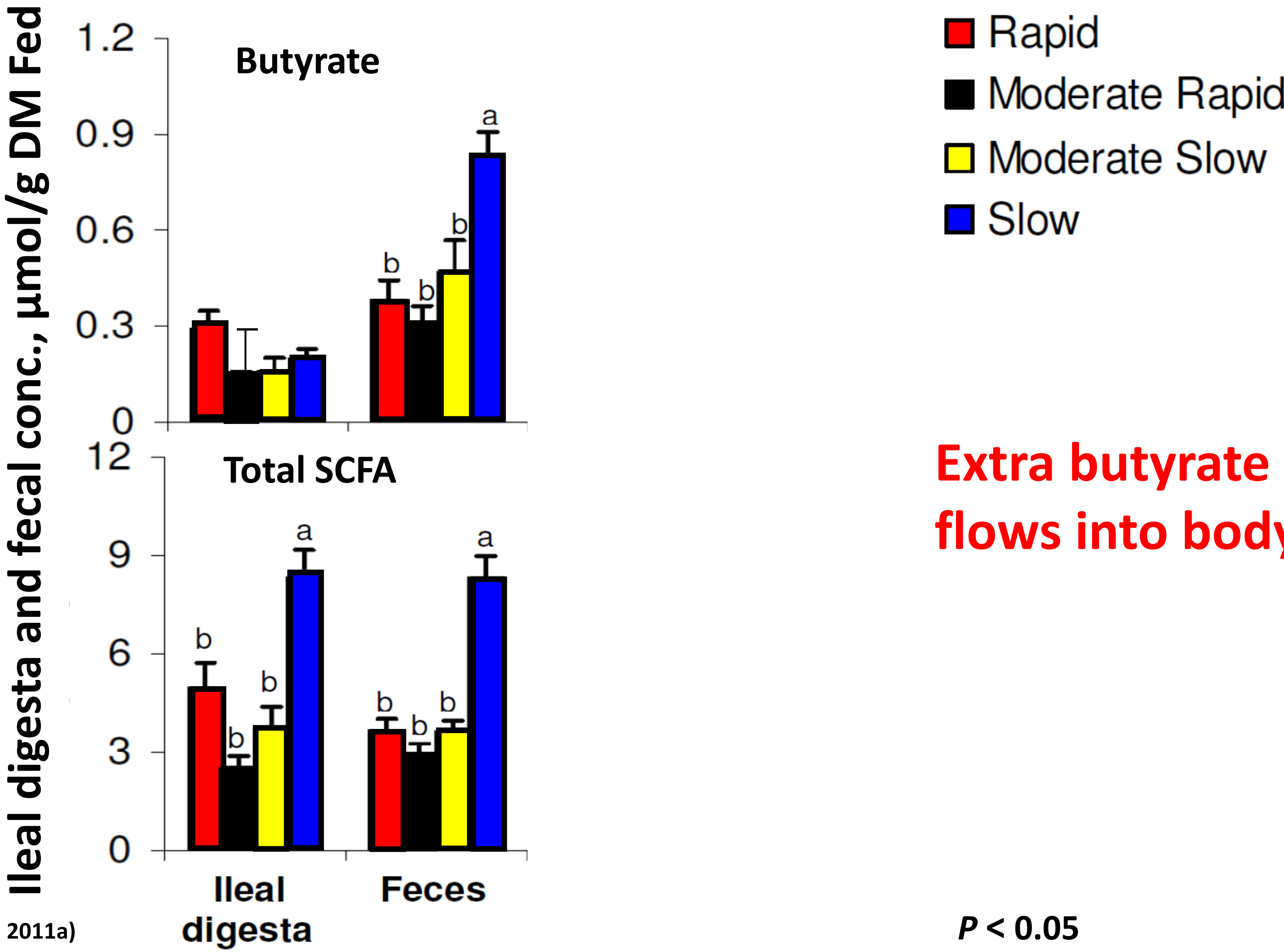


***P* < 0.05**

(Regmi et al., 2011a; J. Nutr.)

Glucose **SCFA**

Short-Chain Fatty Acids; grower pig

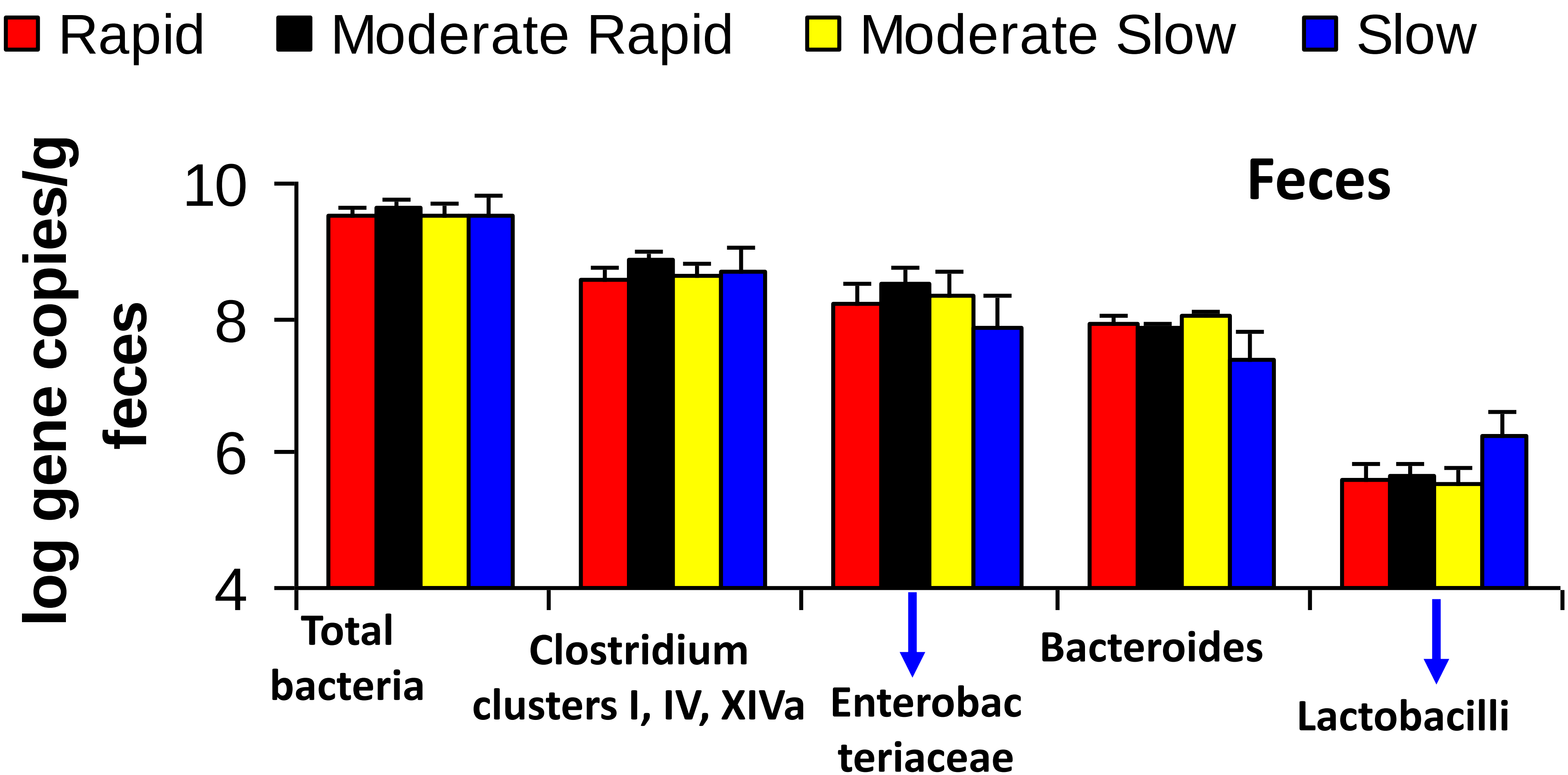


Extra butyrate flows into body

(Regmi et al., 2011a)

P < 0.05

Bacterial Populations; grower pig

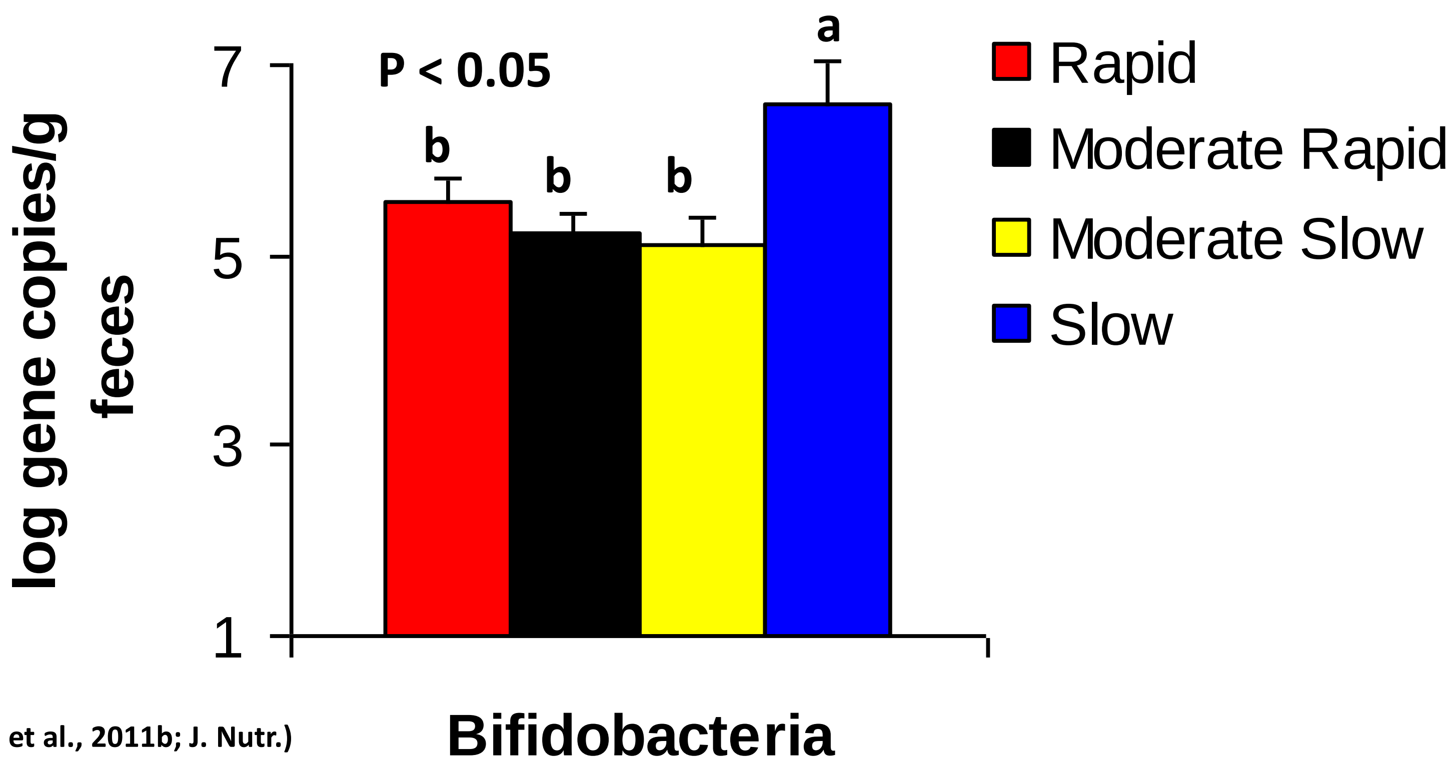


P > 0.05

PCR-DGGE: No effect of starch source on bacterial diversity

(Regmi et al., 2011b; J. Nutr.)

Bifidobacteria; grower pig



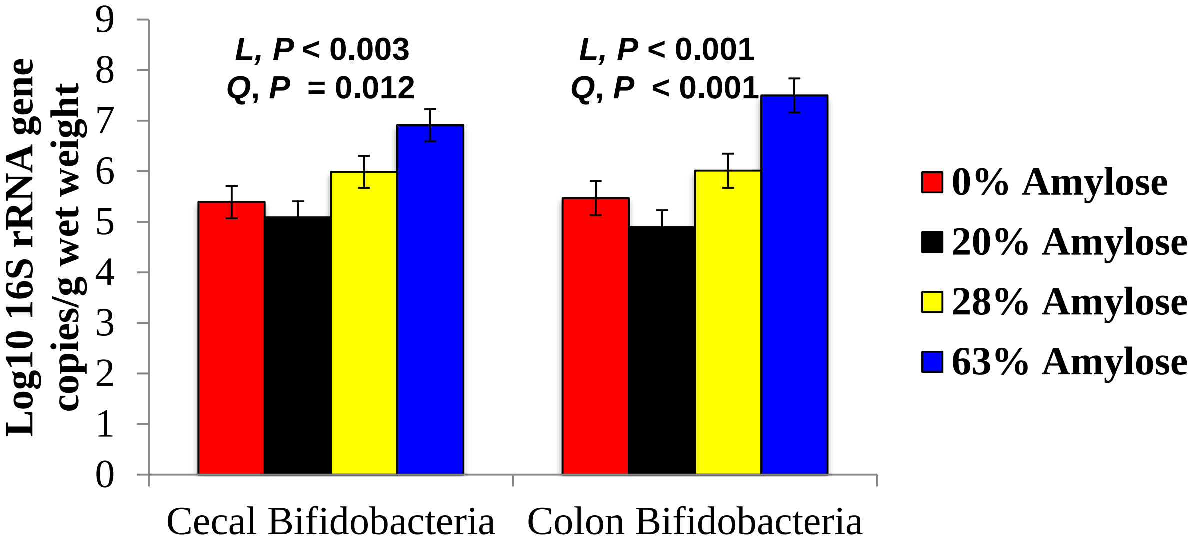
(Regmi et al., 2011b; J. Nutr.)

Fermented Starch is a Prebiotic

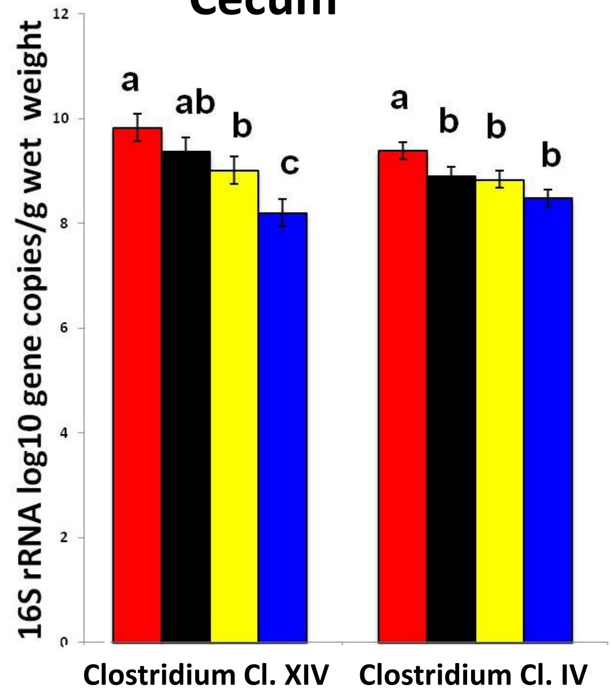
- Bifidogenic effect of resistant starch (matches Topping et al.)
- Overall, relatively minor changes in microbiome numbers/g , but total increases (more g), and measured changes are unique

Evidence of fermentation; weaned pig

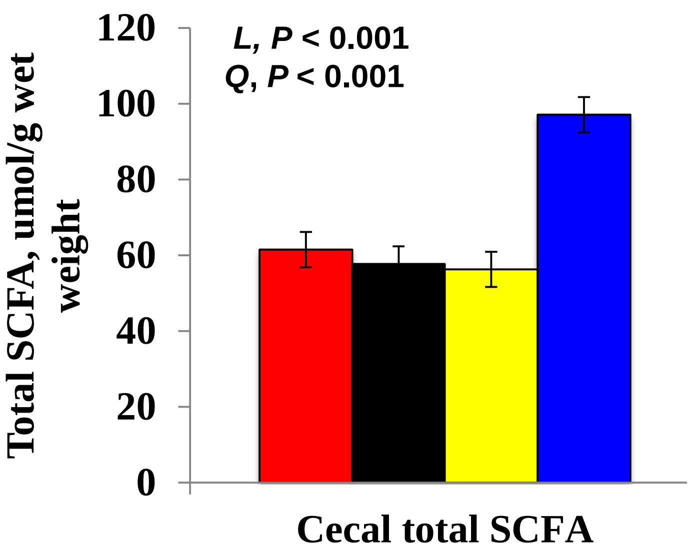
Bifidobacteria



Cecum



Short chain fatty acids

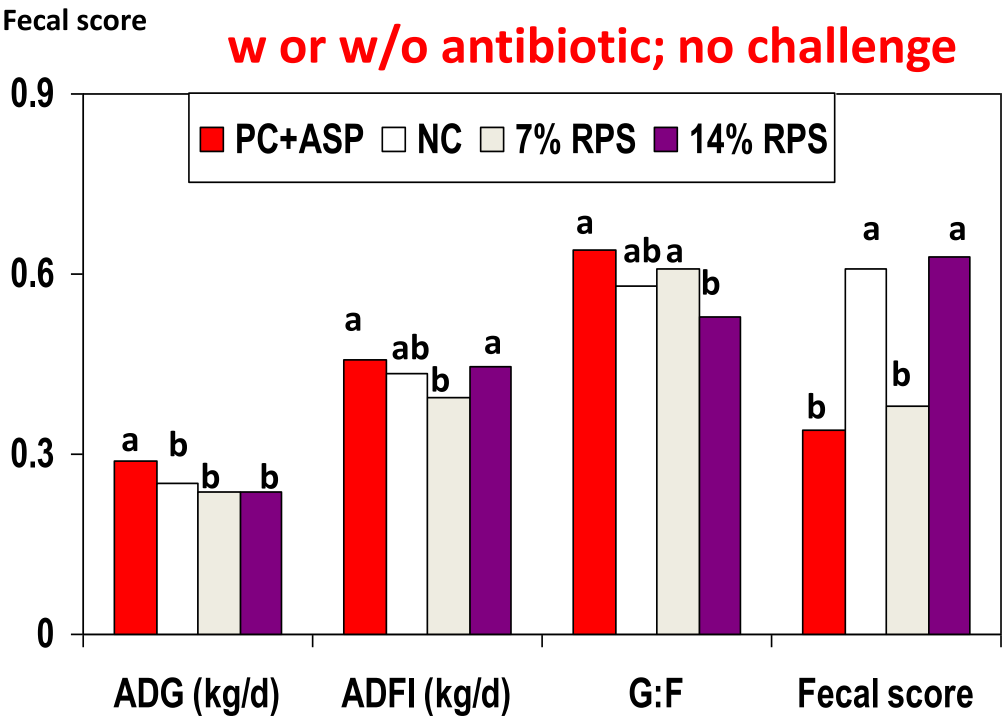


Do these changes in microbiota in digesta and feces really matter?

(Fouhse et al., 2015)

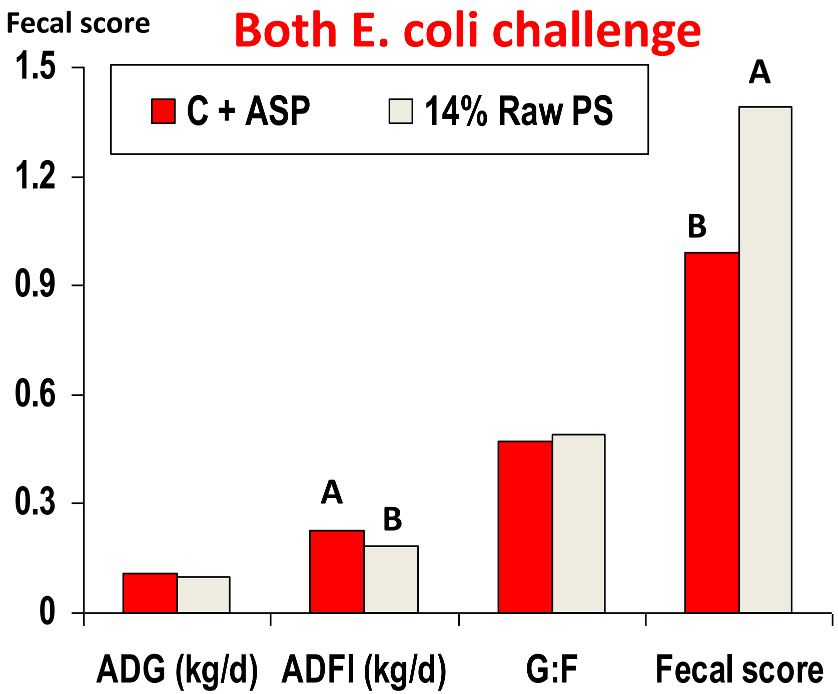
Meaning for Gut Health; Weaned pig

w or w/o antibiotic; no challenge



(Bhandari et al., 2009); mechanism not clear

Both E. coli challenge

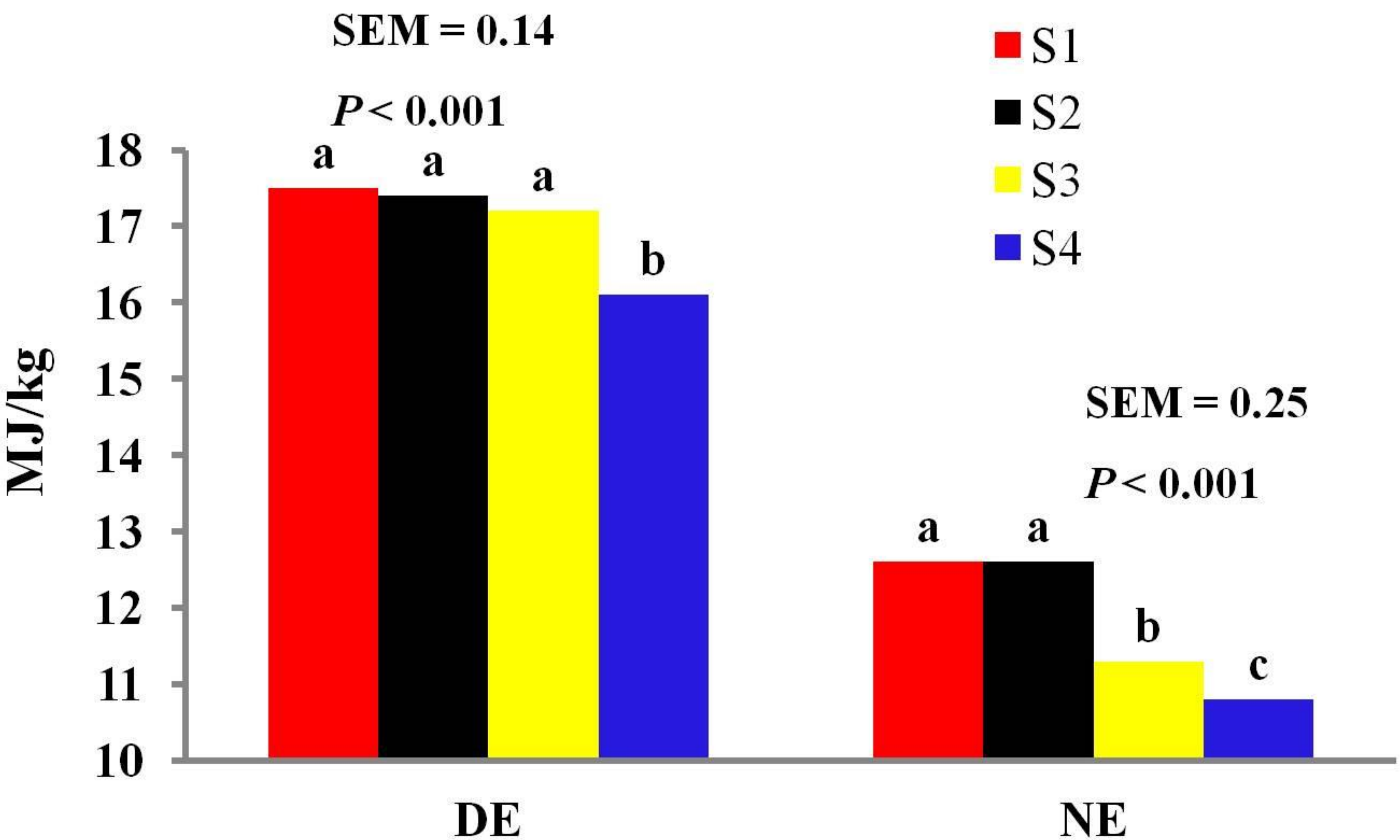


(Krause et al., 2010); mechanism not clear

Fecal score: 0-3

Impact of RS requires further clarification

Energetic Efficiency; grower pig

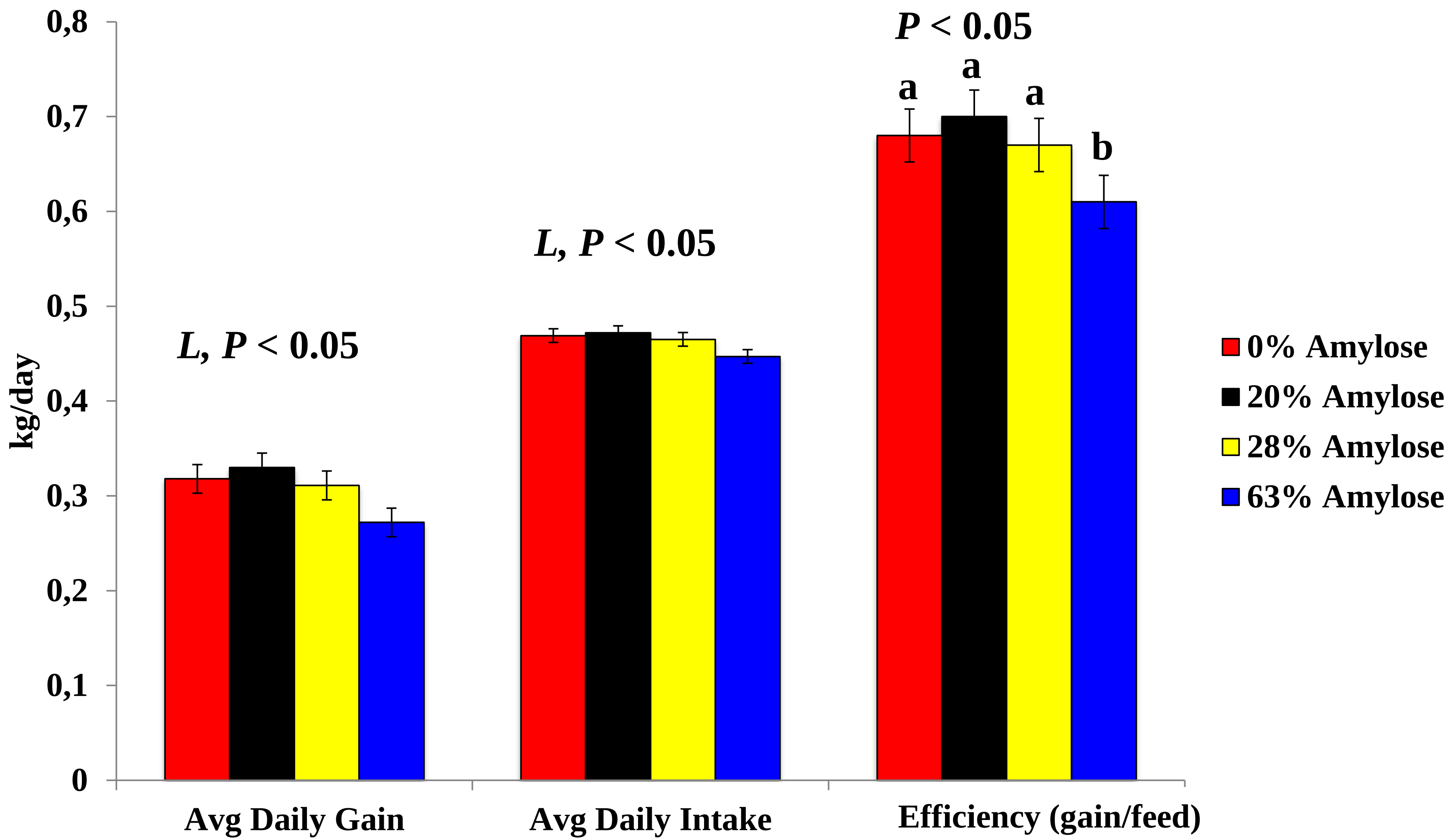


(lower ATTD of CP; microbial protein)

(indirect calorimetry)

(Yanez et al., 2012 DPP; meal-fed pigs)

Growth performance; weaned pig

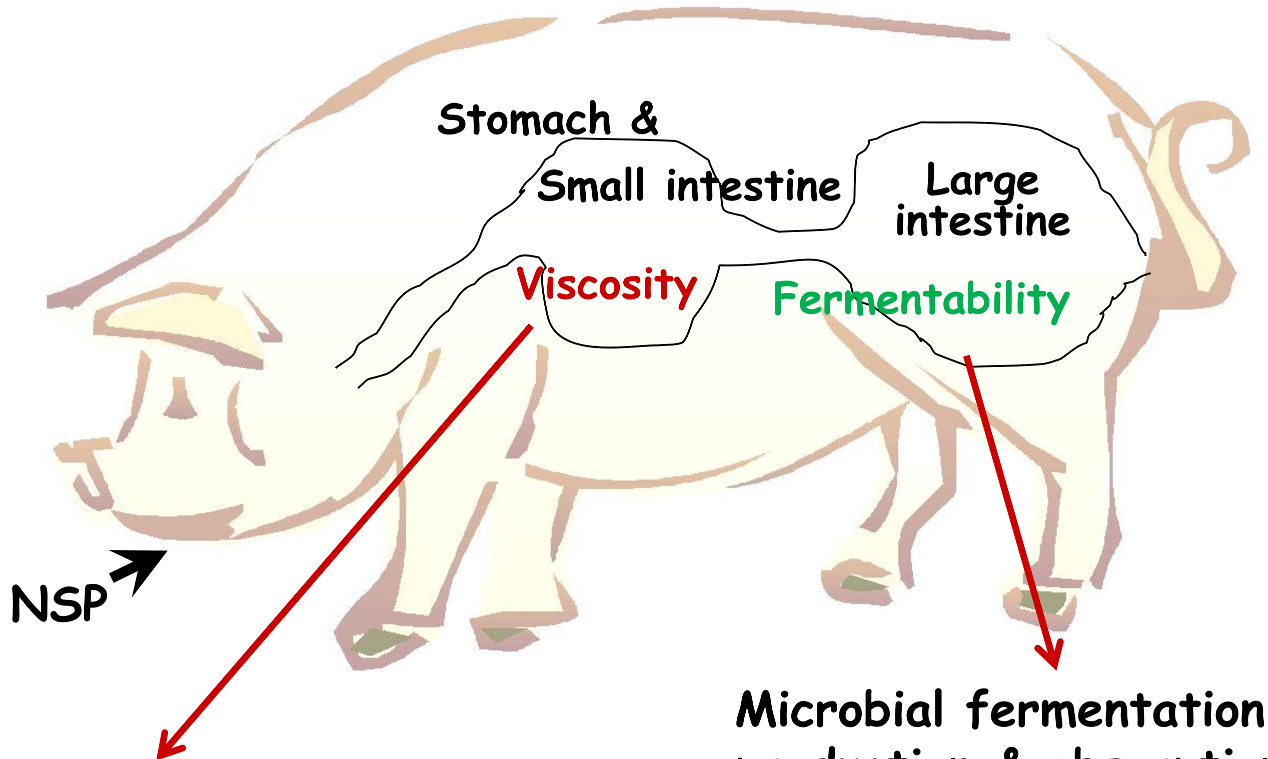


(Fouhse et al., 2015)

↑ RS, ↓ growth; ↓ glycemic response, may ↑ efficiency

Functional Characteristics
- Fiber -

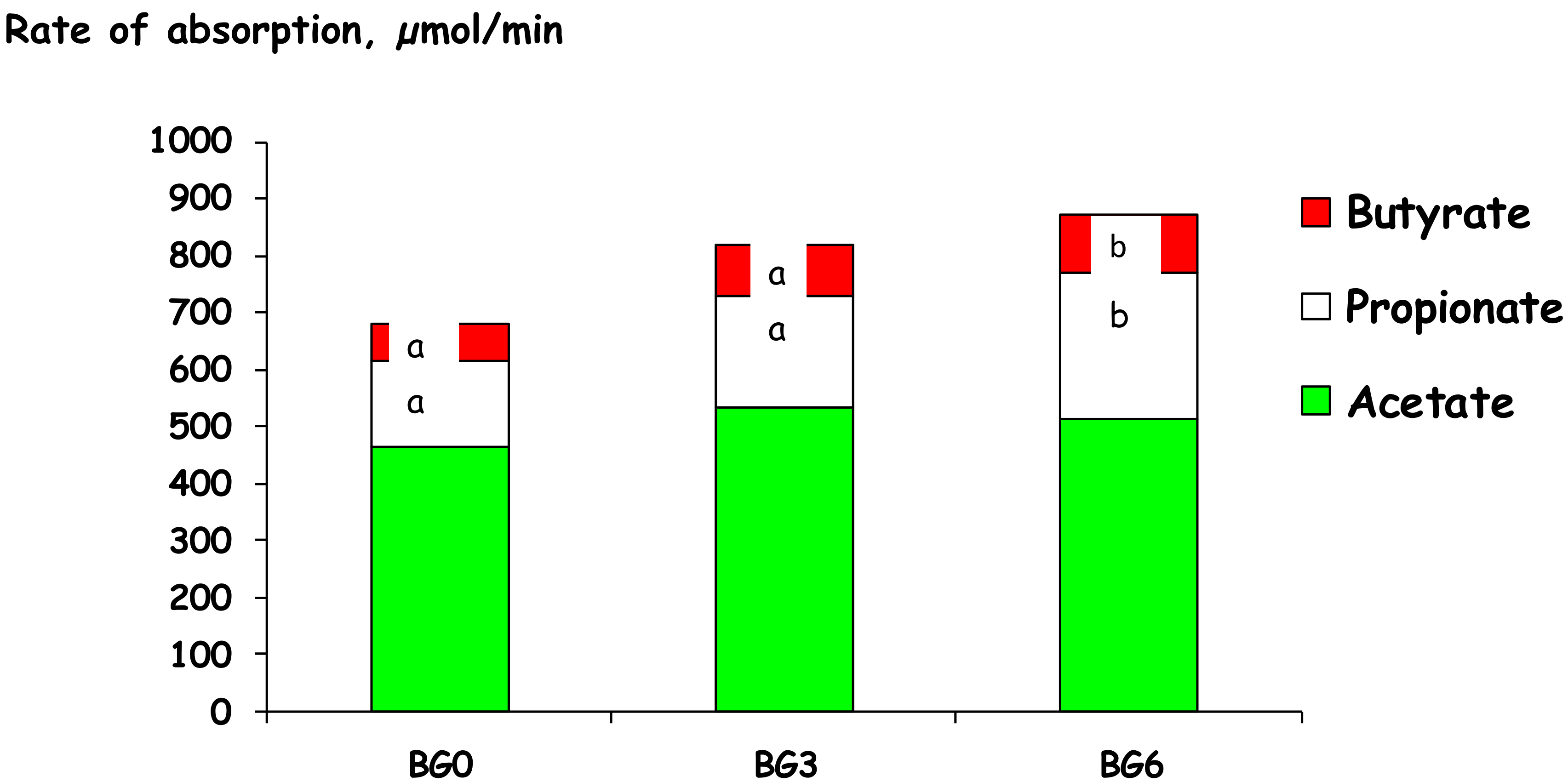
Functional properties, viscosity & fermentability, important for physiological effects of NSP in the gut (Dikeman and Fahey, 2007)



Digesta flow, nutrient digestion, absorption and hormones kinetics
Negative

Microbial fermentation, SCFA production & absorption, gut health
Positive
(Metzler-Zebeli et al. 2011)

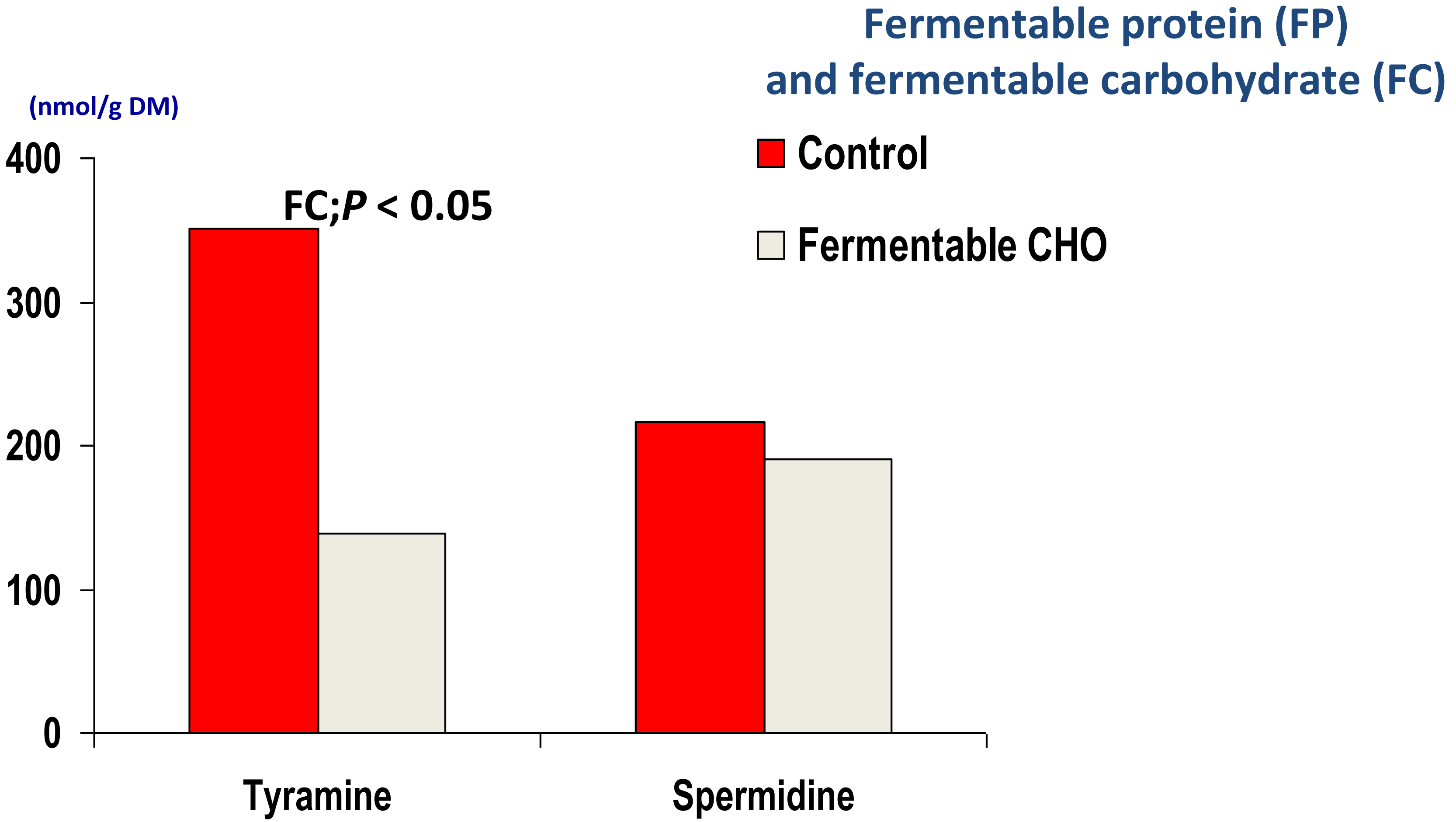
Net flux of SCFA absorption; grower pig



- **β-glucan increased Propionate and Butyrate absorption rate**
  - **Increased fibre: increased thickness of gut wall & gut fill**
  - **Important role of butyrate**

Hooda et al. (2010) J. Nutr.

Fermentable Fiber and Gut Health; grower pig



Undigested proteins may become fermentable substrate
Protein fermentation: Amine production

(Jeaurond et al. 2008)

Cereal Grains

Content, % DM	Hull-less barley			Hulled barley	Wheat
	Highly fermentable, high β-glucan (HFB)	Highly fermentable, high amylose (HFA)	Moderately fermentable (MFB)	Low fermentable hulled barley (LFB)	Low fermentable wheat (LFW)
Crude protein	20	17	16	14	20
Amylose	0	18	11	11	12
Total β-glucan	10	7	5	4	1
Total dietary fiber	22	18	15	17	14
ADF	5.5	6.2	6.2	9.4	6.4
Viscosity, mPa × s	342	316	303	319	0

Cereal grains were characterized in detail in ileal-cannulated grower pigs

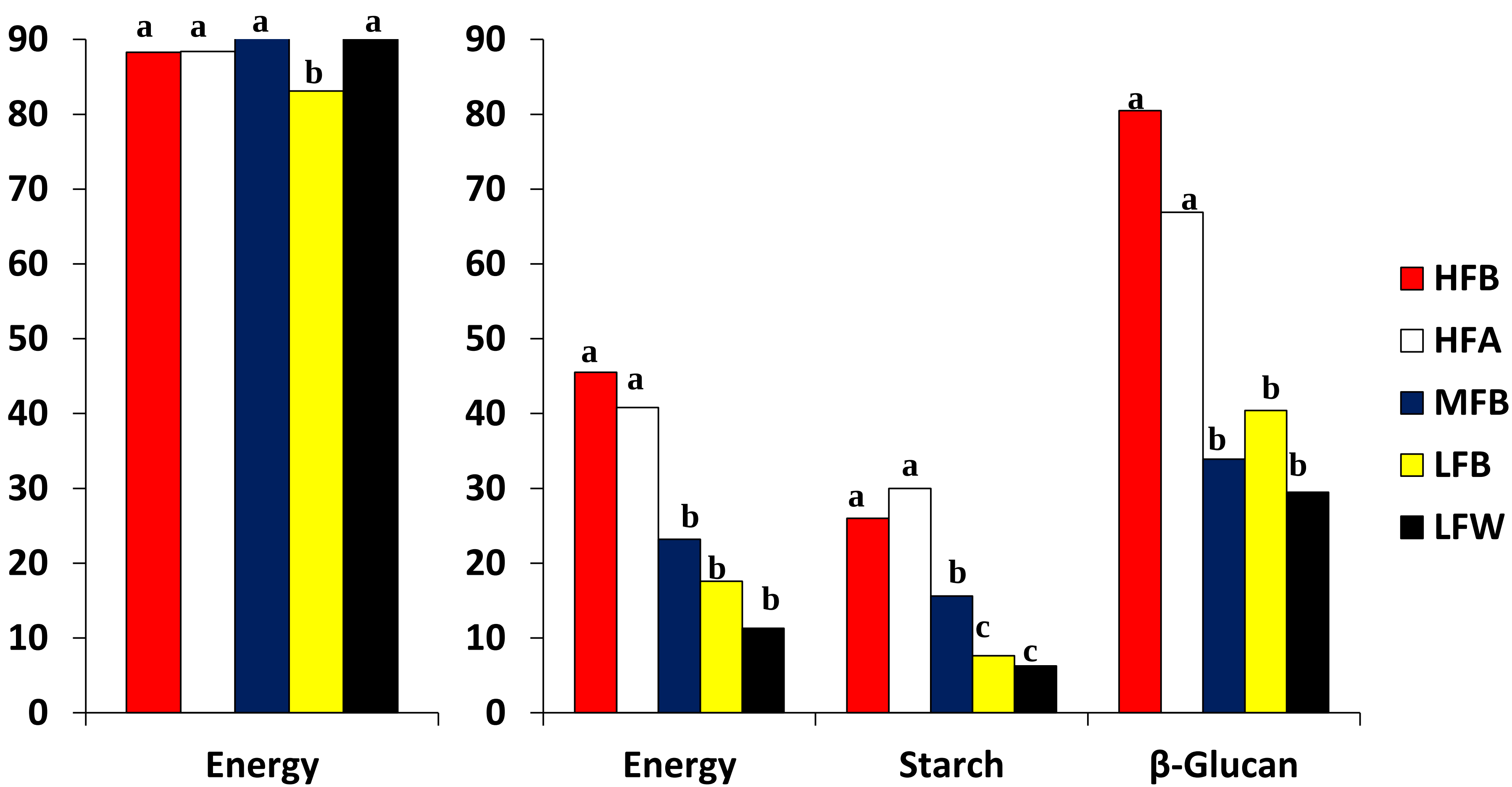
(Fouhse et al., 2017a,b; J. Nutr.)

Total tract digestibility

ATTD (%)

Large intestine fermentability

ATTD – AID (%)

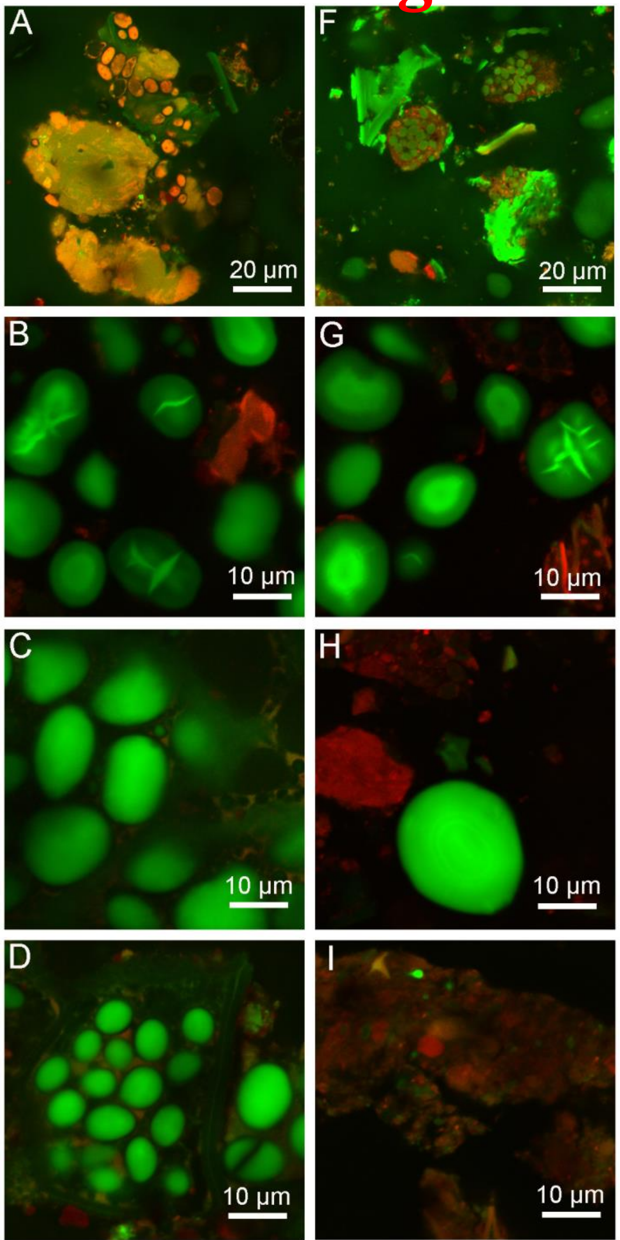


DE & ME are poor indicators of energy and carbohydrate flow within the gut

(Fouhse et al., 2017a; J. Nutr.)

Not just nutrient flow, also physical structure

Diets **Digesta**



HFB: High-fermentable, high β-glucan

HFA: High-fermentable, high amylose

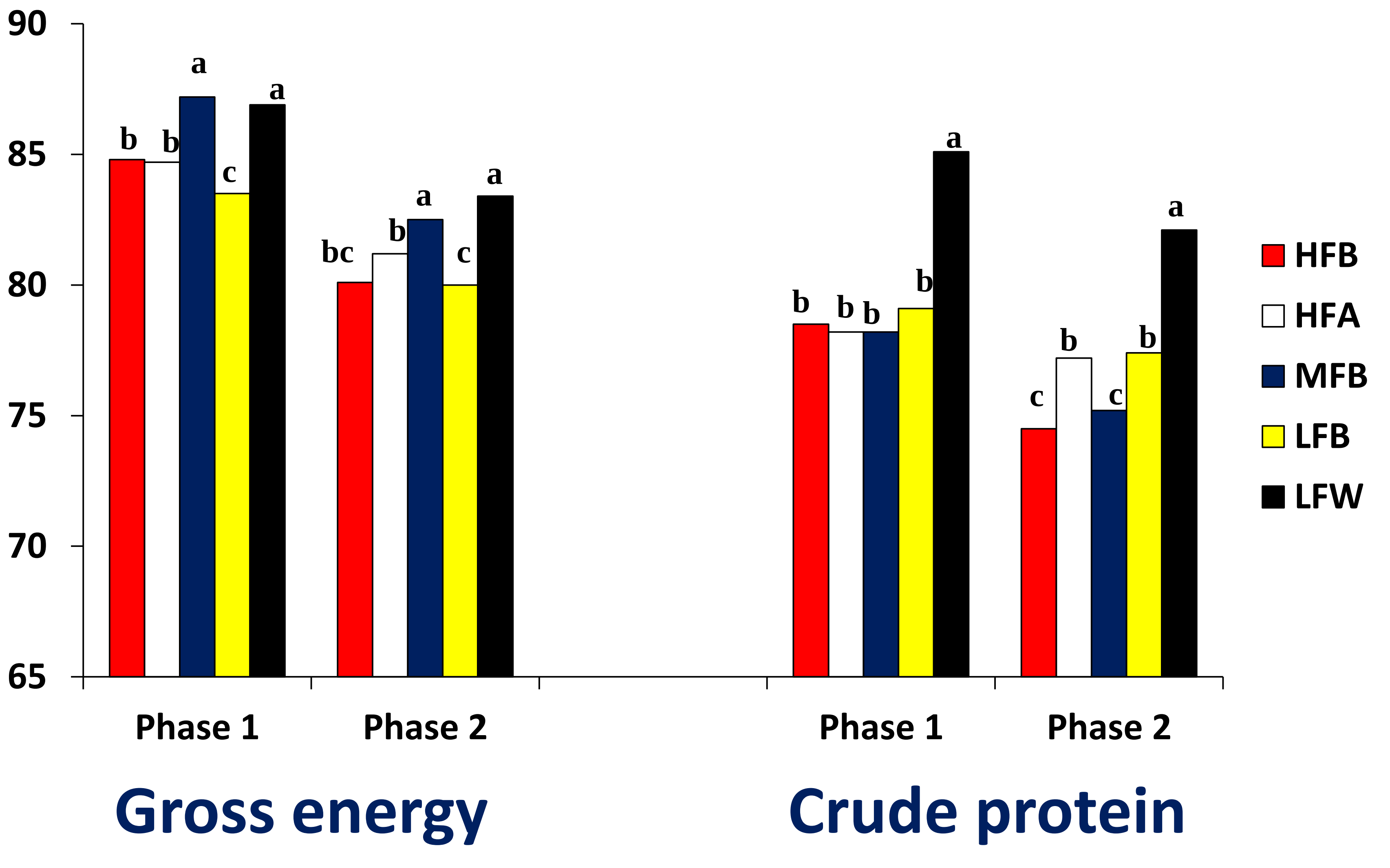
MFB: Moderate-fermentable

LFB: Low-fermentable

The role of undigested residue is poorly defined

(Fouhse et al., 2017a; J. Nutr.)

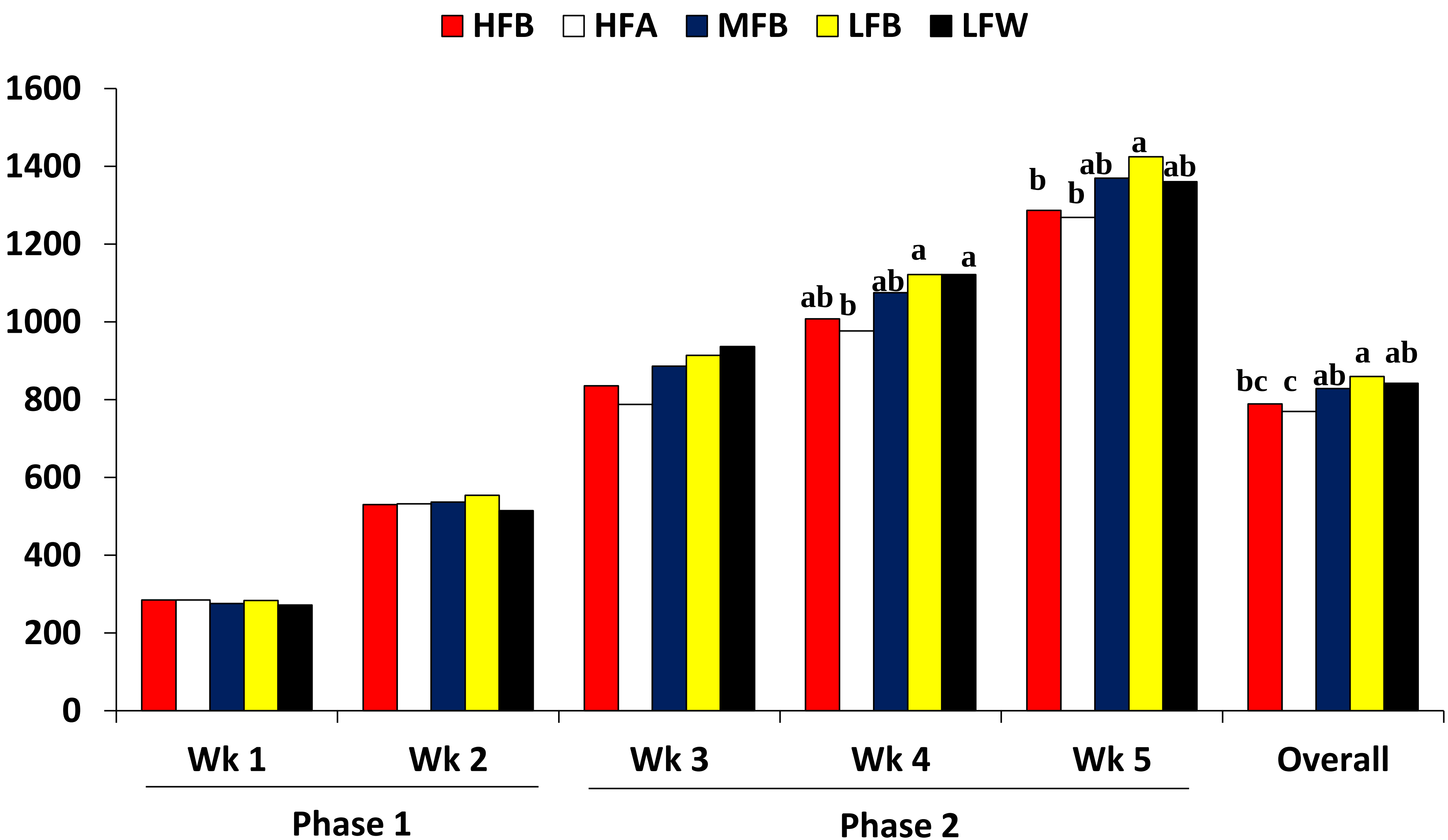
Diet ATTD (%)



Crude protein digestibility lower ($P < 0.05$) for barley than wheat

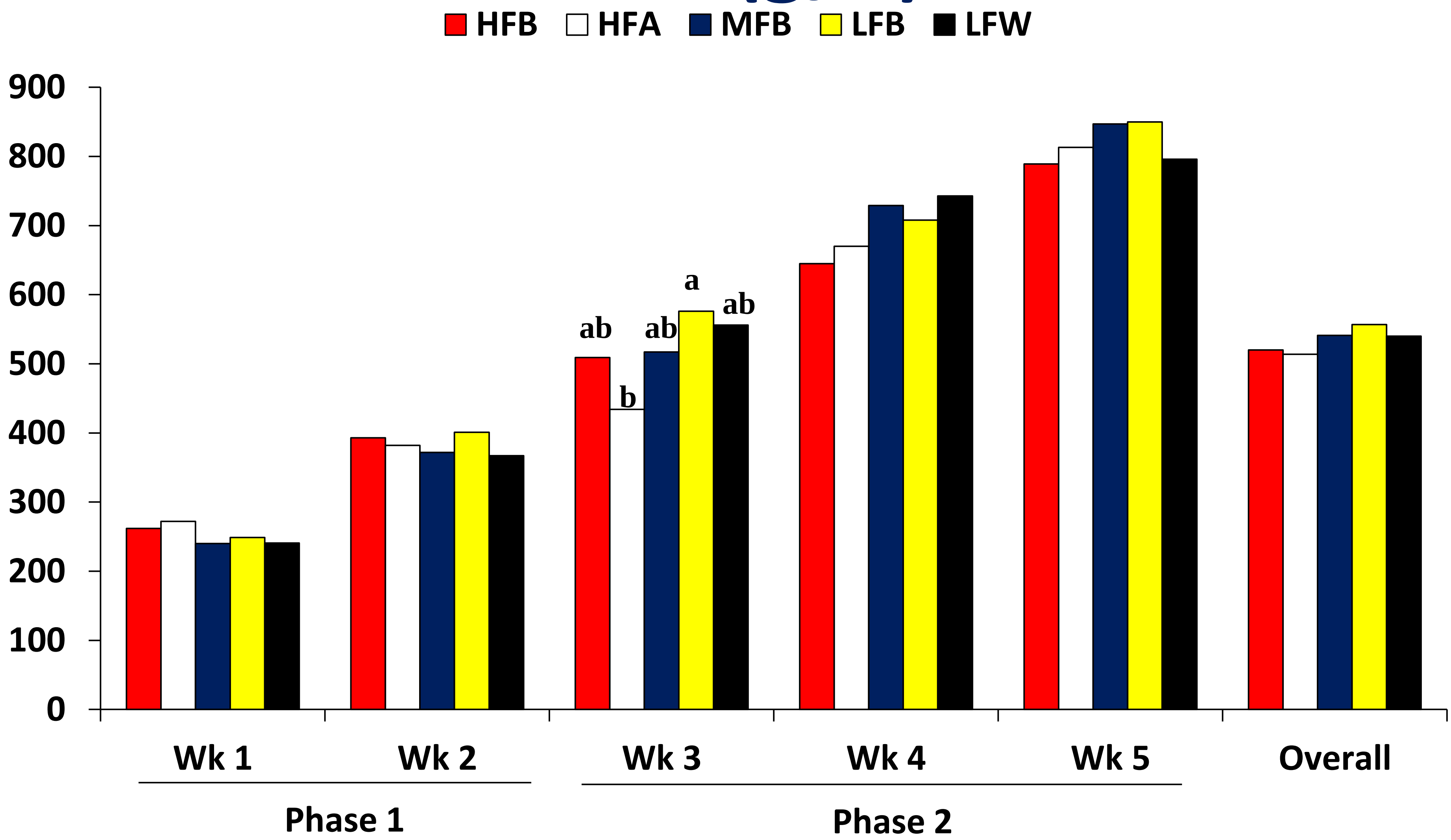
High but not medium fermentable carbohydrates reduced ($P < 0.05$) energy digestibility

ADFI (g/d)



Fermentable carbohydrates reduced ($P < 0.05$) ADFI at the end but not start of the trial

ADG (g/d)



Starch and fiber fermentation did not affect ADG (*P* > 0.05)

Final BW tended to be lower (P < 0.10) for HFB and HFB than LFB

Increased gut fill may mask effects of reduced empty body weight/lean gain

Balance between Growth and Health

In pigs

Resistant starch or β-glucan → Ileum → Low starch digestion → Reduced energetic efficiency

Ileum → > starch into the large intestine

> starch into the large intestine → Bacteria population → Increased *Bifidobacteria*

> starch into the large intestine → Bacterial activity → Increased production of SCFA, butyrate

Conclusions

- **Dietary carbohydrates have strong prebiotic activity**
  - **Change composition and activity of microbiota**
  - **Strongly associated with indicators of gut health**
- **Benefit during intestinal disease challenge unclear**
  - **Research priority**
- **Balance prebiotic activity with whole body energy metabolism**
  - **Too much activity will reduce growth**
- **Implications**
  - **Diet ingredient carbohydrate composition changes diet prebiotic activity and may affect prebiotic activity of food additives**
- **Diet formulation for low–diarrhea weaning pig diets**
  1. **Stimulate feed intake directly after weaning; no feed: gut damage;**
  2. **Include reasonable amount of fermentable carbohydrates;**
  3. **Prebiotic activity can come from feedstuffs or feed additives.**

Effect of fibre on piglet gut health

Ruurd T. Zijlstra

University of Alberta

Edmonton, AB, Canada

E-mail: ruurd.zijlstra@ualberta.ca