Opportunities & Challenges for Novel Protein Feedstuffs in Swine Diets

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Lots Happening with Ingredients

Lately, gradual decline of price of SBM

∆ **Supply and Demand: ↑ or ↓ price**

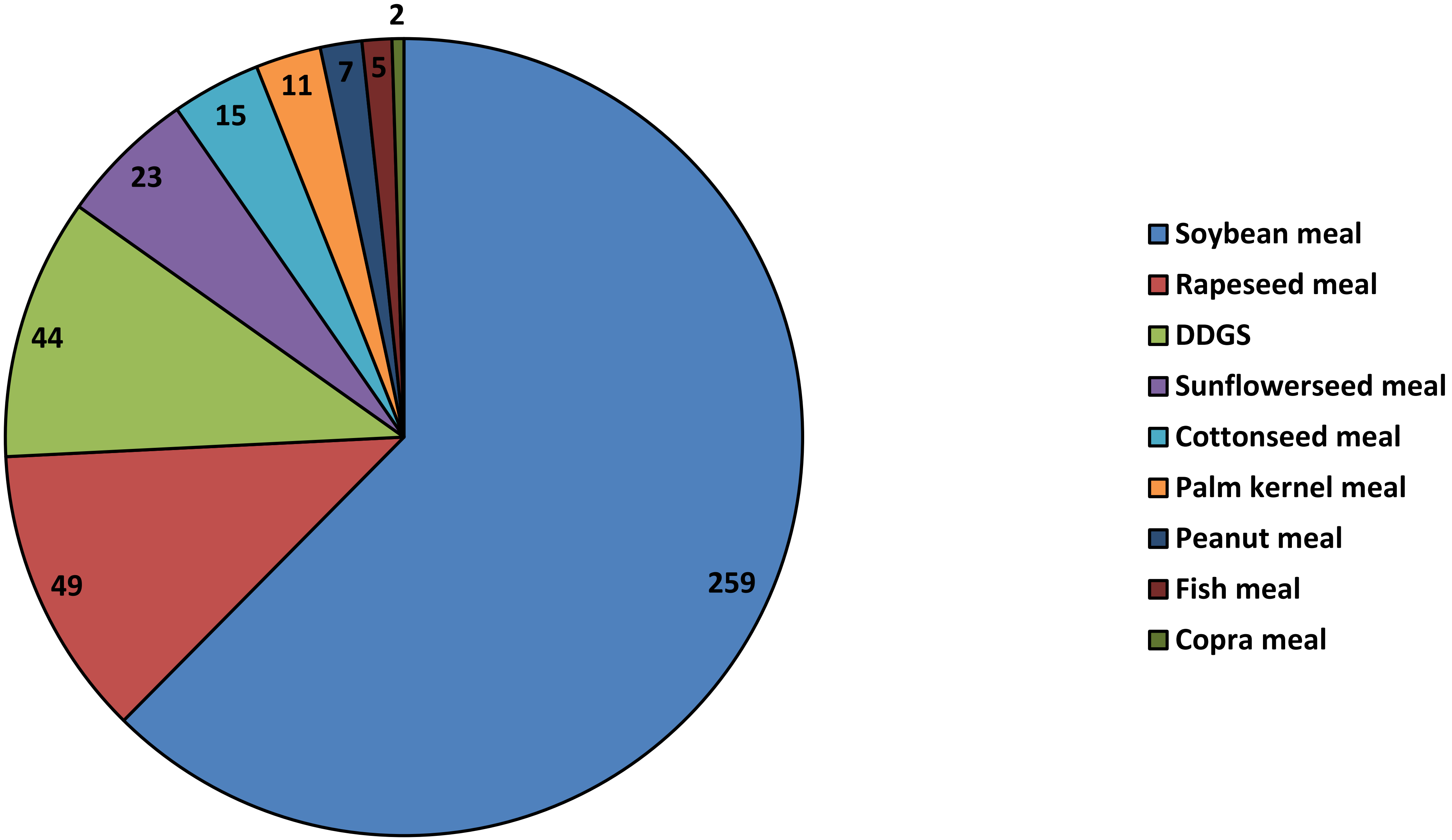
- **Bioeconomy**
  - **Used for fuel energy, etc.**
- **Human food**

plant-based ingredients

- **War**
  - **Eastern Europe**
- **Good harvest in USA (2024)**
- **Increased oilseed processing**
  - **USA and Canada**

(https://markets.businessinsider.com/commodities/soybean-meal-price)

Global: Major Protein Feedstuffs (MMT)



Globally, SBM by far most produced protein feedstuff. Also seen as quality standard

(USDA, 2024)

Importance of Ingredient Quality

Input

- Ingredients
- Intake

Output

Carcass Wt & Q

Animal

Growth (predictable)

Feed cost per unit of gain key driver for success, especially phase-3 in nursery and after: Replace SBM

See 2025 BPS proceedings

Composition of Seed Crops (%; as-fed)

Crop	Starch	Fiber	Protein	Fat
Canola	1	24	22	44
Flax	1	21	23	34
Soybean	1	24	43	16
Oats	39	31	11	5
Corn	63	11	8	4
Wheat	60	10	14	2
Barley	50	18	11	2
Field pea	43	15	22	1
Faba bean	39	14	27	1

Pulse grains { Field pea, Faba bean

(CVB 1994; NRC 2012)

Composition of Protein Feedstuffs (%; as-fed)

	Starch	Fiber	Protein	Fat
Soybean meal	1	17	47	2
Canola meal	2	32	38	4
Corn DDGS	3	28	27	11
Faba bean	39	14	27	1
Field pea	43	15	22	1

(CVB, 1994; NRC, 2012)

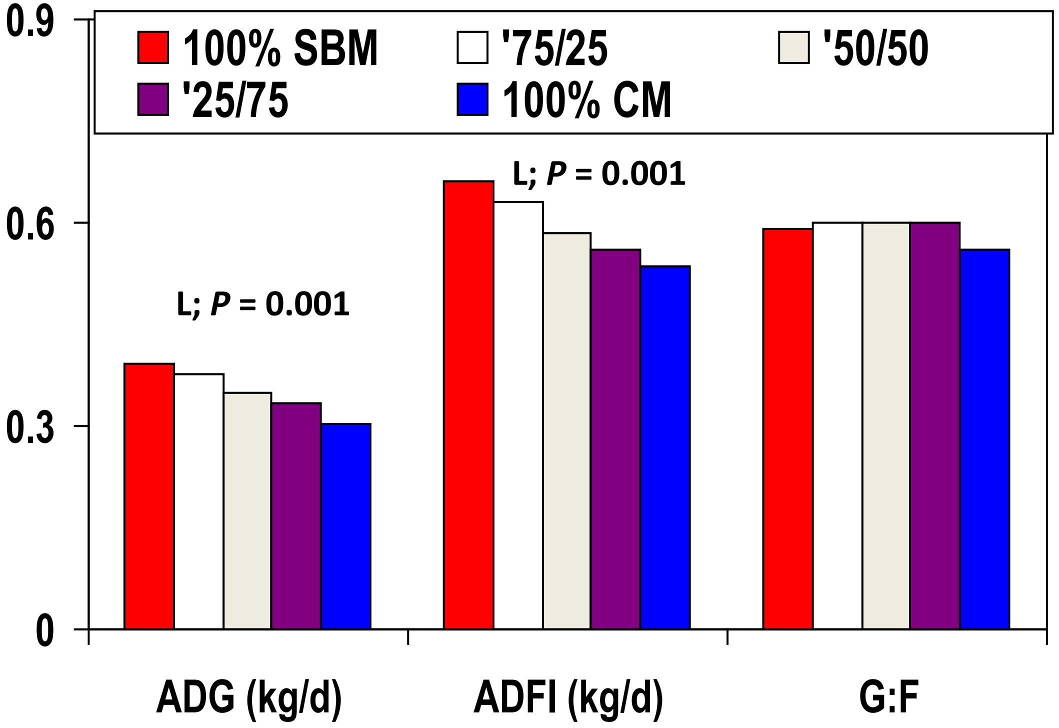
Novel Protein Ingredients

- Crop Development (breeding)
- Co-product Development (processing)

- To reduce feed cost, what can you change now?
  - Pick other ingredients
  - Increase inclusion level

History: Weaned Pigs

(Solvent-Extracted) Canola Meal



Performance was reduced when canola meal was included

%	Diets formulated to equal DE, CP, and total Lys				
Wheat	20	20	20	20	20
Barley	49.6	45.6	41.4	37.2	33
SBM	25.4	19	12.7	6.3	-
CM	-	8.8	17.6	26.5	35.3
Tallow	-	1.5	3.3	5.0	6.7
L-Lys.	.10	.12	.13	.14	.15

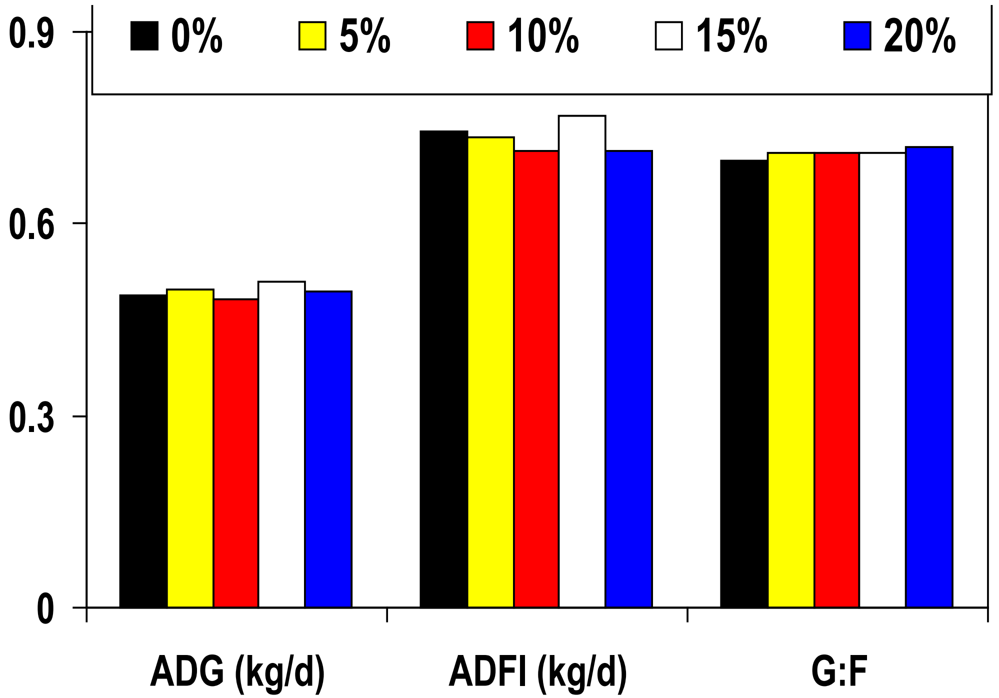
- Glucosinolates (ANF)
- Palatability
- Fiber
- Lower AA digestibility

Canola meal: 10 µmol total glucosinolates/g
One diet; steam pelleted

(Baidoo et al., 1987)

Weaned Pigs

Canola Meal



- Weaned at 3 wk
- Start diets 1 wk later for 4 wk

- Other feedstuffs?
  - Palatability
- Feedstuffs change
  - ↓ Glucosinolate

Performance was not reduced when (solvent-extract) canola meal replaced SBM

%	Diets formulated to equal NE and SID AA				
Wheat	57.9	57.8	56.7	56.1	55.5
L/PC/F	15	15	15	15	15
SBM	20	15	10	5	-
CMeal	-	5	10	15	20
Oil	3	3.5	4.0	4.5	5.0
L-Lys.	-	.08	.15	.23	.30
ADF	3.7	4.5	4.8	5.6	5.9
ATTDGE	86	85	84	84	82

} ↑ fiber
↑ undigested residue

- L, lactose
- PC, soy protein concentrate
- F, fish meal

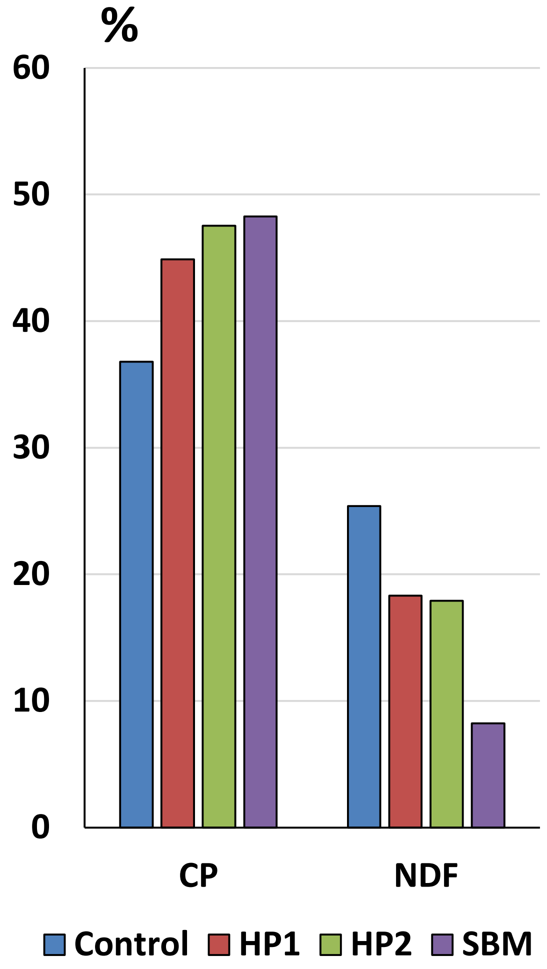
SE Canola meal: 3.8 µmol total glucosinolates/g
One diet; steam pelleted

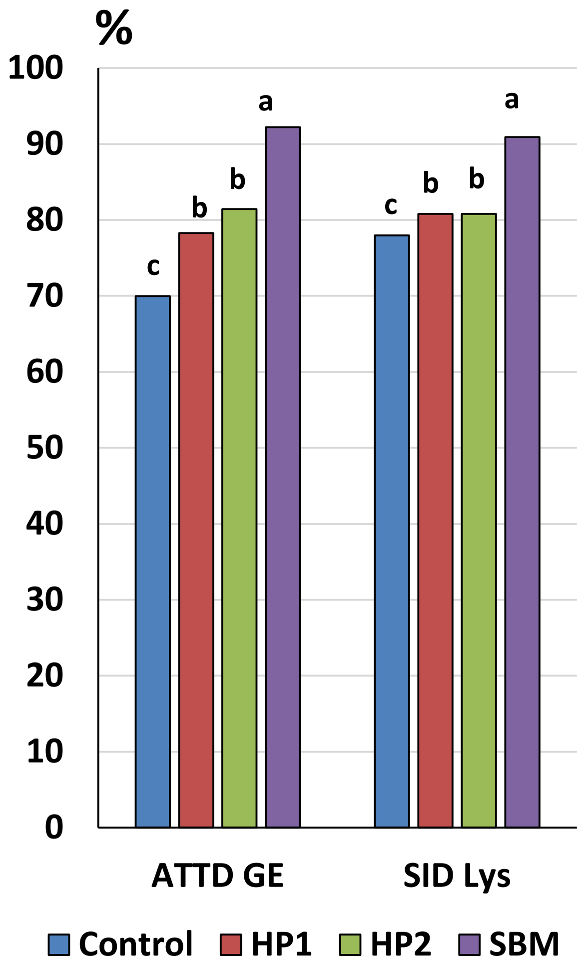
20% canola meal reduced feed price by $11.9 per MT and feed cost per unit of body weight gain by 2 cents/kg

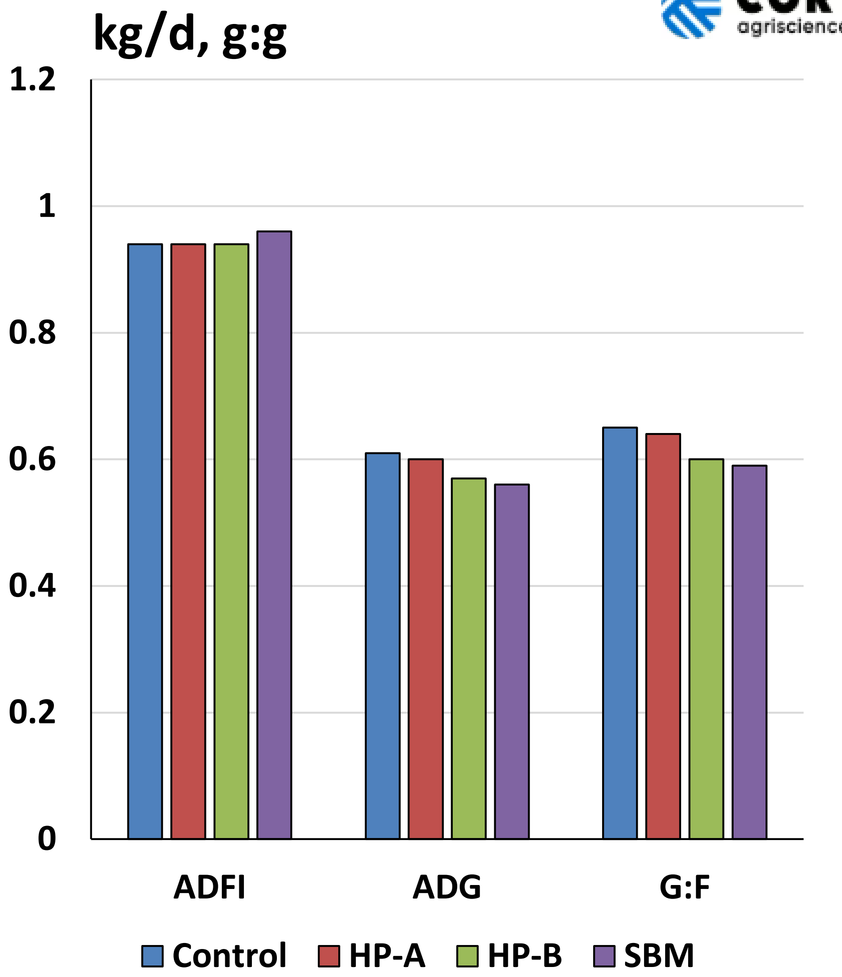
Note of caution: will also increase undigested protein; so best target phase-3 and later

(Landero et al., 2011)

Canola Breeding: High Protein Canola Meal







High protein (low fiber) hybrid canola meal [Probound; ↑10%-unit CP; ↓7.5%-unit NDF]
Large jump in protein content and AA digestibility
Technology exists, claimed protein content was unstable; so, project was discontinued

(Berrocoso et al., 2015; Parr et al., 2015)

Canola Co-Products

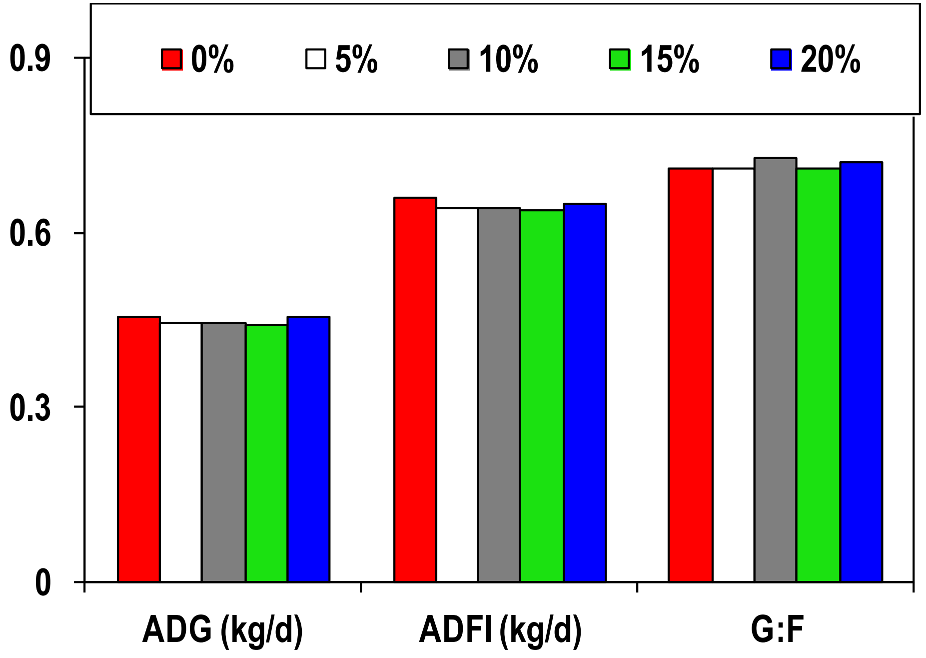
Item	*B. napus* co-product		
	Meal	Expeller	Cake
Protein (%)	38	39	25
NDF (%)	26	23	18
Fat (%)	3	10	20
NE (MJ/kg)	8.3	10.5	10.9
SID Lys (%)	1.45	1.72	0.85
Lys/CP (%)	5.6	5.8	5.6
Glucosinolates (µmol/g)	3.8	10.9	11.1

(Landero et al., 2001, 2012; Woyengo et al, 2016; Zhou et al., 2016)

Weaned Pigs

Canola Expeller

Performance was not reduced when canola expeller replaced SBM



- Other feedstuffs?
  - Palatability
  - “Buffer”

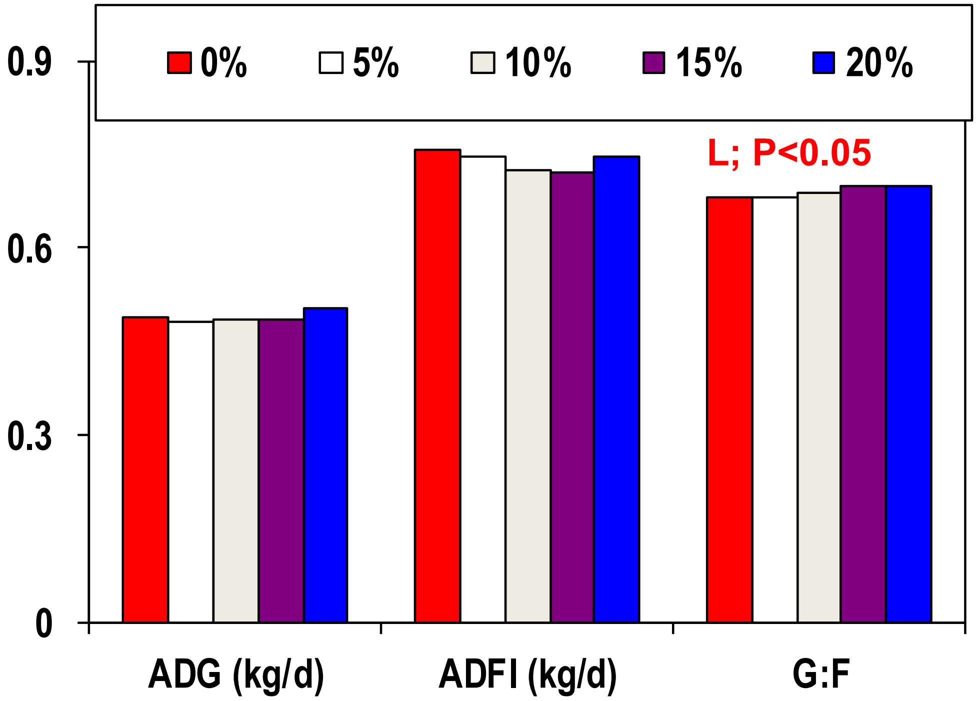
%	Diets formulated to equal NE and SID AA				
Wheat	55.9	56.2	56.6	57.0	57.4
L/PC/F	15	15	15	15	15
SBM	20	15	10	5	-
CExpeller	-	5	10	15	20
Oil	5.0	4.5	4.0	3.5	3.0
L-Lys.	.02	.09	.16	.22	.29
ADF	3.3	3.8	4.8	5.4	6.0
ATTDGE	85	85	84	83	83

Canola expeller: 10.9 µmol total glucosinolates/g
One diet; steam pelleted

20% canola expeller reduced feed price by $29.8 per MT and feed cost per unit of body weight gain by 4 cents/kg (Landero et al., 2012)

Weaned Pigs

Canola Cake



- **Other feedstuffs?**
  - **Palatability**
  - **"Buffer"**

HL Oil Mill
COLDED PRESSED CANOLA MEAL & OIL

Performance was not reduced when canola cake replaced SBM

%	Diets formulated to equal NE and SID AA				
Wheat	51.9	53.8	55.7	57.6	59.5
L/PC/F	15	15	15	15	15
SBM	25	19	12	6	-
CCake	-	5	10	15	20
Oil	4.4	3.6	2.7	1.9	1.1
L-Lys.	.09	.21	.33	.45	.57
ADF	4.4	4.2	5.7	6.8	6.4
ATTDGE	86	86	86	85	85

Canola cake: 11.1 μmol total glucosinolates/g
Two diets; first diet cold pelleted

Canola cake has even greater value for pork producers

Canola expeller and cake: good opportunities for pigs with high energy demand

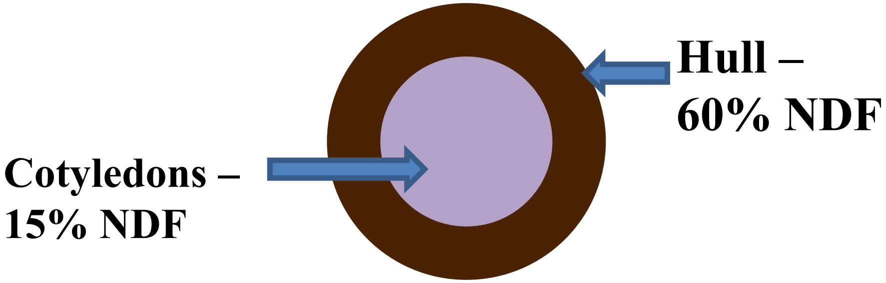
(Zhou et al., 2016)

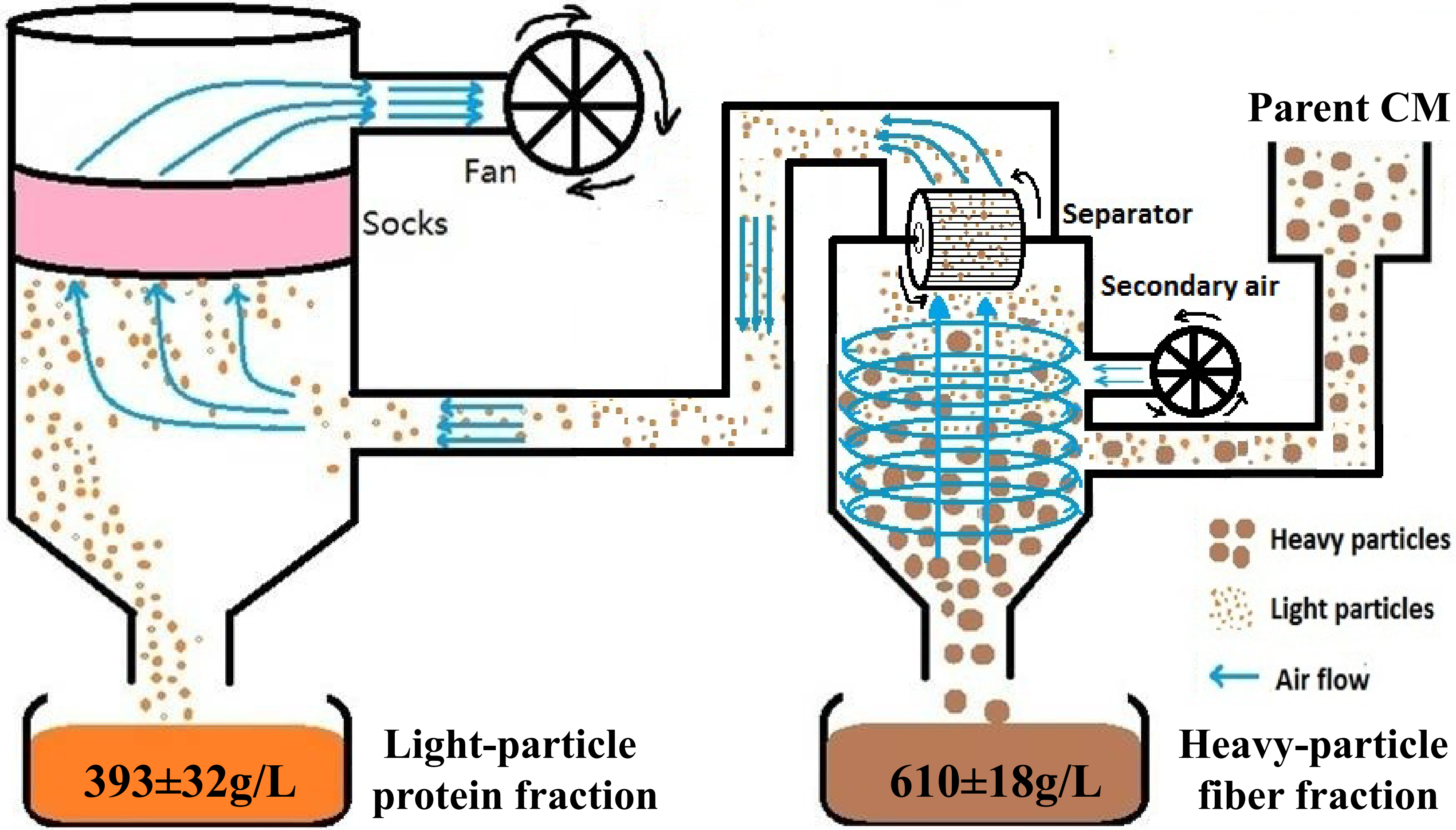
Considerations Further Processing: Fractionation

Processing seed	Advantages	Disadvantages
Grinding	Low cost	No separation of fractions
	Adequate for mature GI-tract	Inadequate for high nutritional demands
Dry fractionation	Reasonable separation macronutrients	Medium cost
	Titration semi-purified macronutrients	
	High nutritional demands	
Wet fractionation	Best separation plus removal ANF	High cost (drying required)
(+ extra processing)	Titration individual macronutrients	
	Very high nutritional demands	

Overall, monogastric animal nutrition perspective
Fractionation especially attractive for animals with low digestive capacity/immature GI tract
[young pigs, aquaculture, petfood]

Air classification canola meal

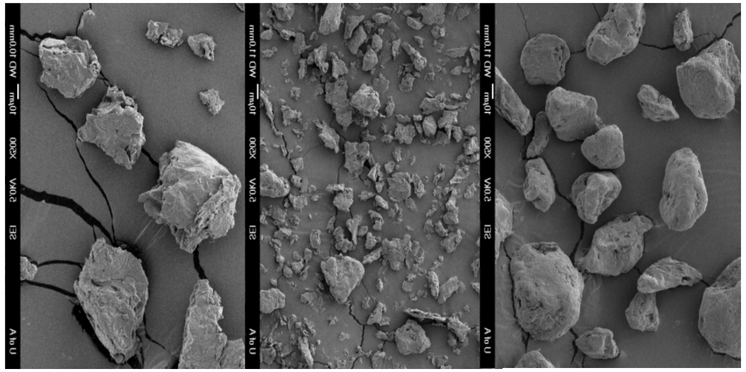


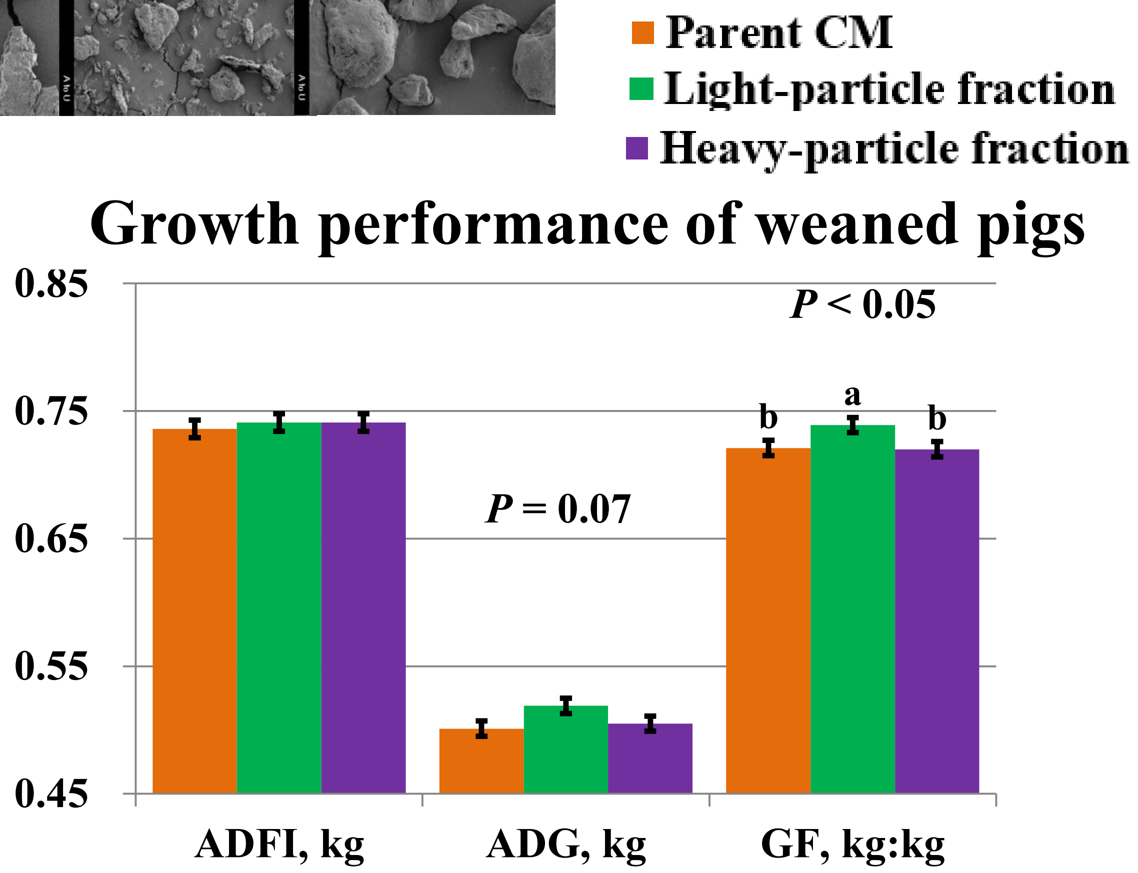


(Zhou et al. 2013)

Air classification canola meal

As-is basis	*B. napus* Parent	Light	Heavy
Moisture, %	10.5	7.7	8.8
Crude protein, %	38.1	41.0	37.7
ADF, %	19.8	13.8	23.0
NDF, %	27.4	19.3	30.1
Particle size, µm	636±2	21.6±22	71.0±40
Glucosinolates, µmol/g	4.1	4.8	4.3



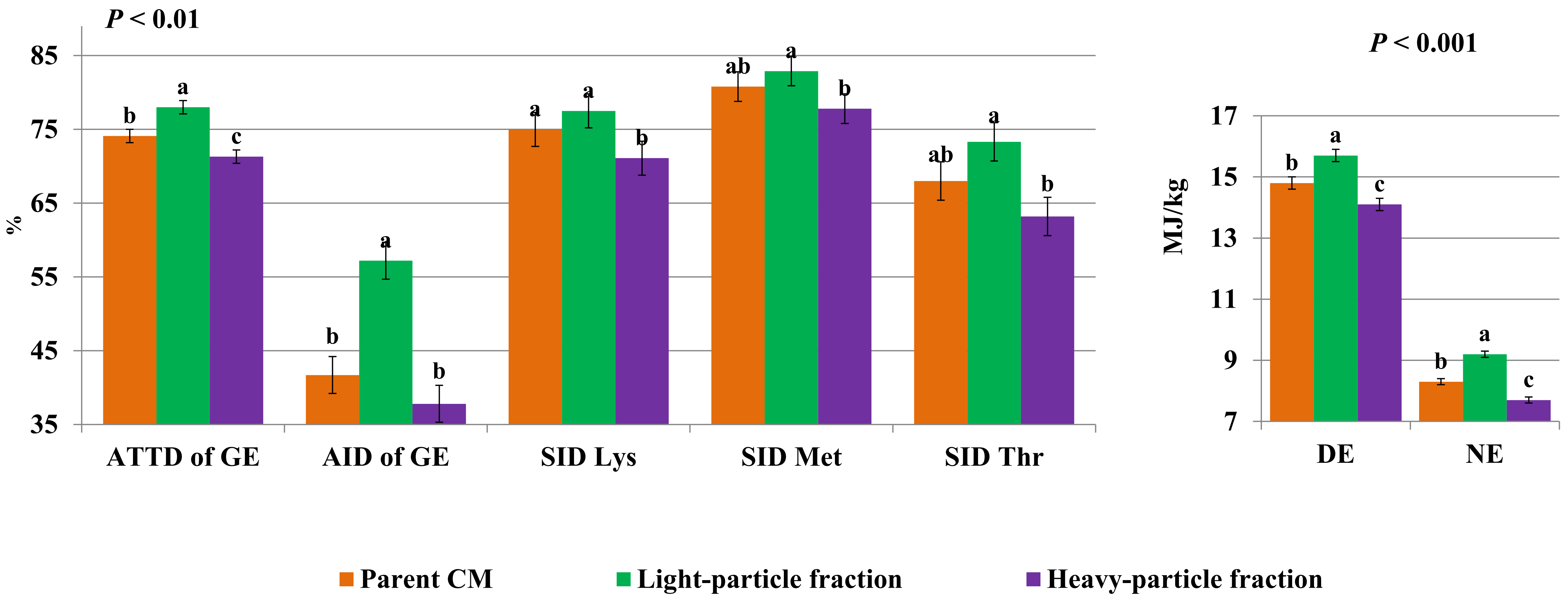


Air classification of canola meal supports mild separation of protein and fiber using particle density

At 20% dietary inclusion, reducing fiber increased feed efficiency

(Zhou et al. 2013)

Air classification canola meal



Low fiber fraction of canola meal has greater energy and amino acid digestibility

(Zhou et al. 2015)

Sieving canola meal

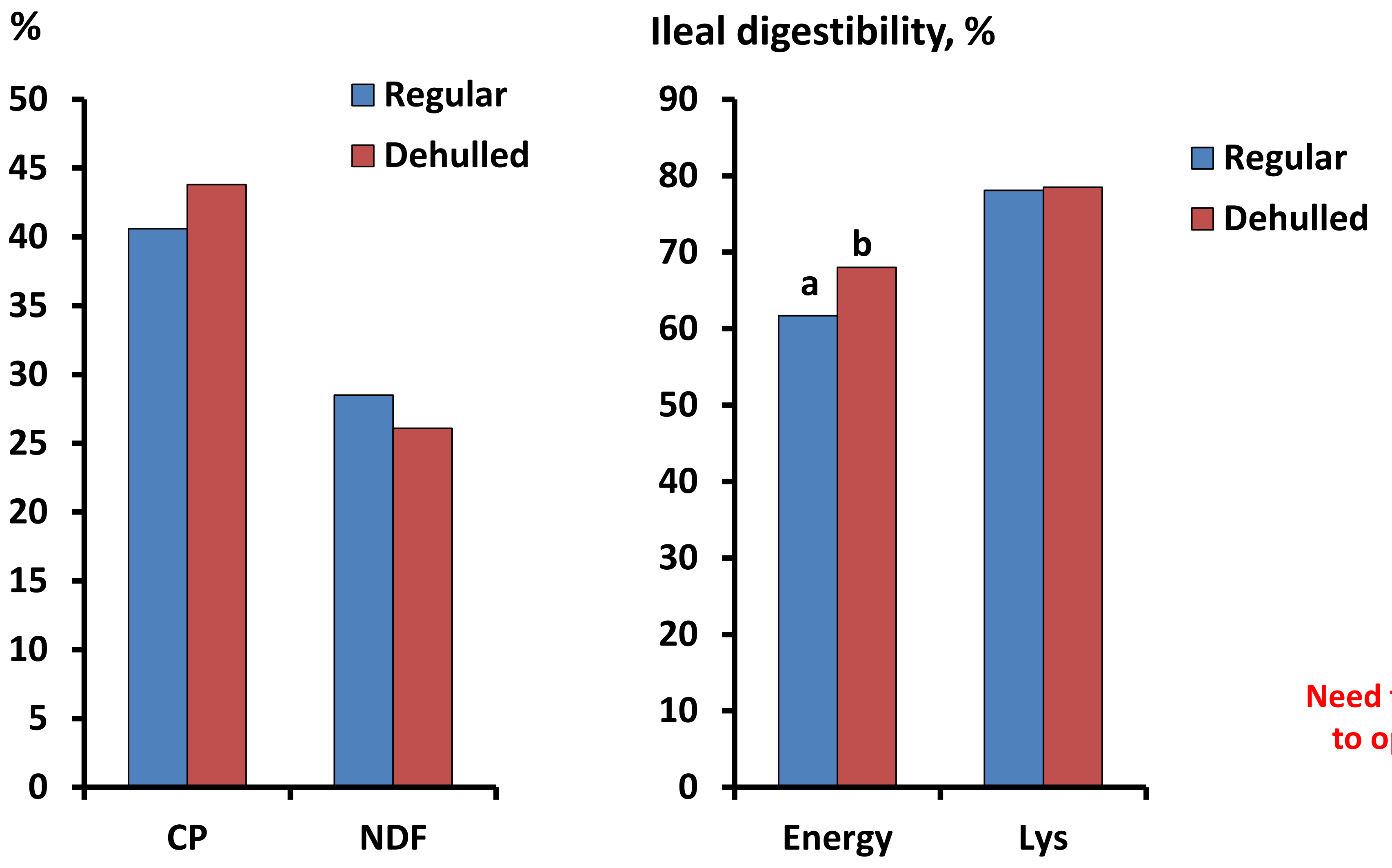
Table 2. Yield, and neutral detergent fiber (NDF) and crude protein (CP) contents of conventional *Brassica napus* and yellow *Brassica juncea* meal fractions produced by sieving (g kg^{-1}, as-is basis).

		B. napus, black			*B. juncea*, yellow		
Fraction	Sieve size (μm)	Yield	NDF	CP	Yield	NDF	CP
Parent meal			236	369		159	411
Fine 1	<250	114	148	417	114	87	467
Fine 2	250–355	98	193	396	111	109	451
Medium	355–600	217	271	354	220	168	399
Coarse	>600	572	246	361	554	162	399

Separation based on particle size provided separation of macronutrients, especially fiber

(Mejicanos et al. 2017)

Tail-end Dehulling of Canola Meal



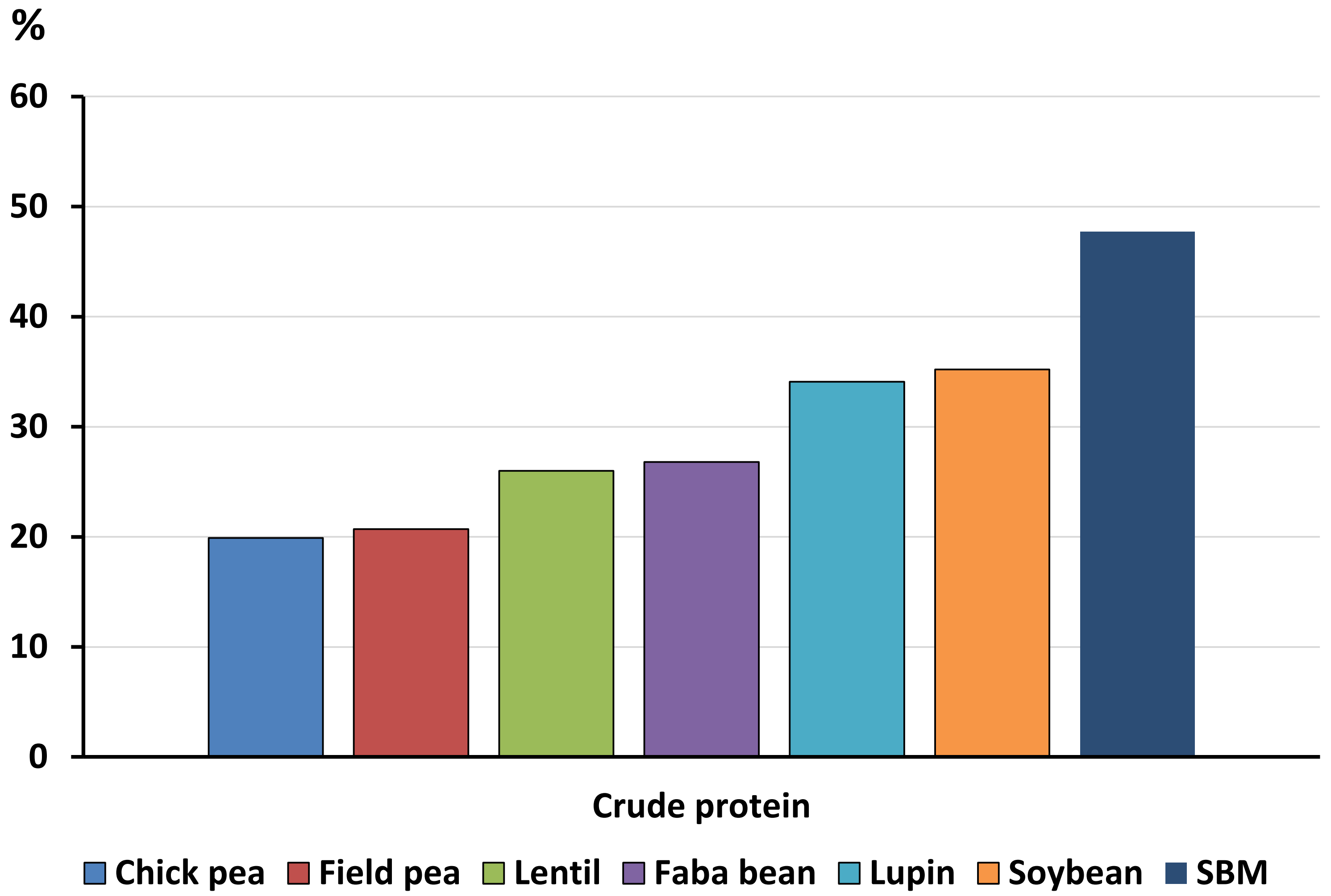
Need for other technology to open canola protein

Partially dehulled using 35-mesh sieving screen
Digestibility measured in growing pigs

(de Lange et al., 1998)

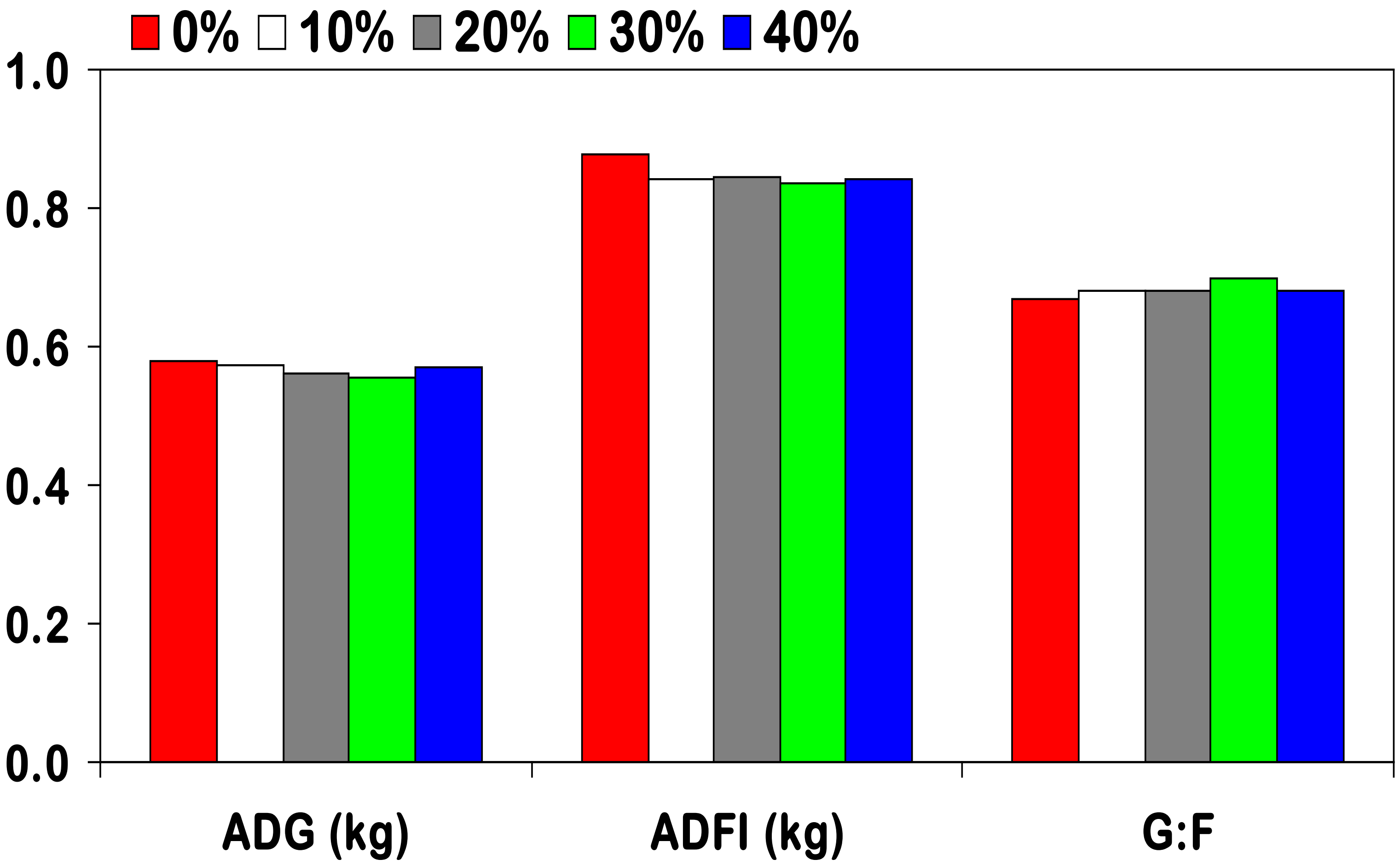
Pulse grains

- Chickpea
- Field pea
- Lentil
- Faba bean
- Lupin



Weaned Pigs

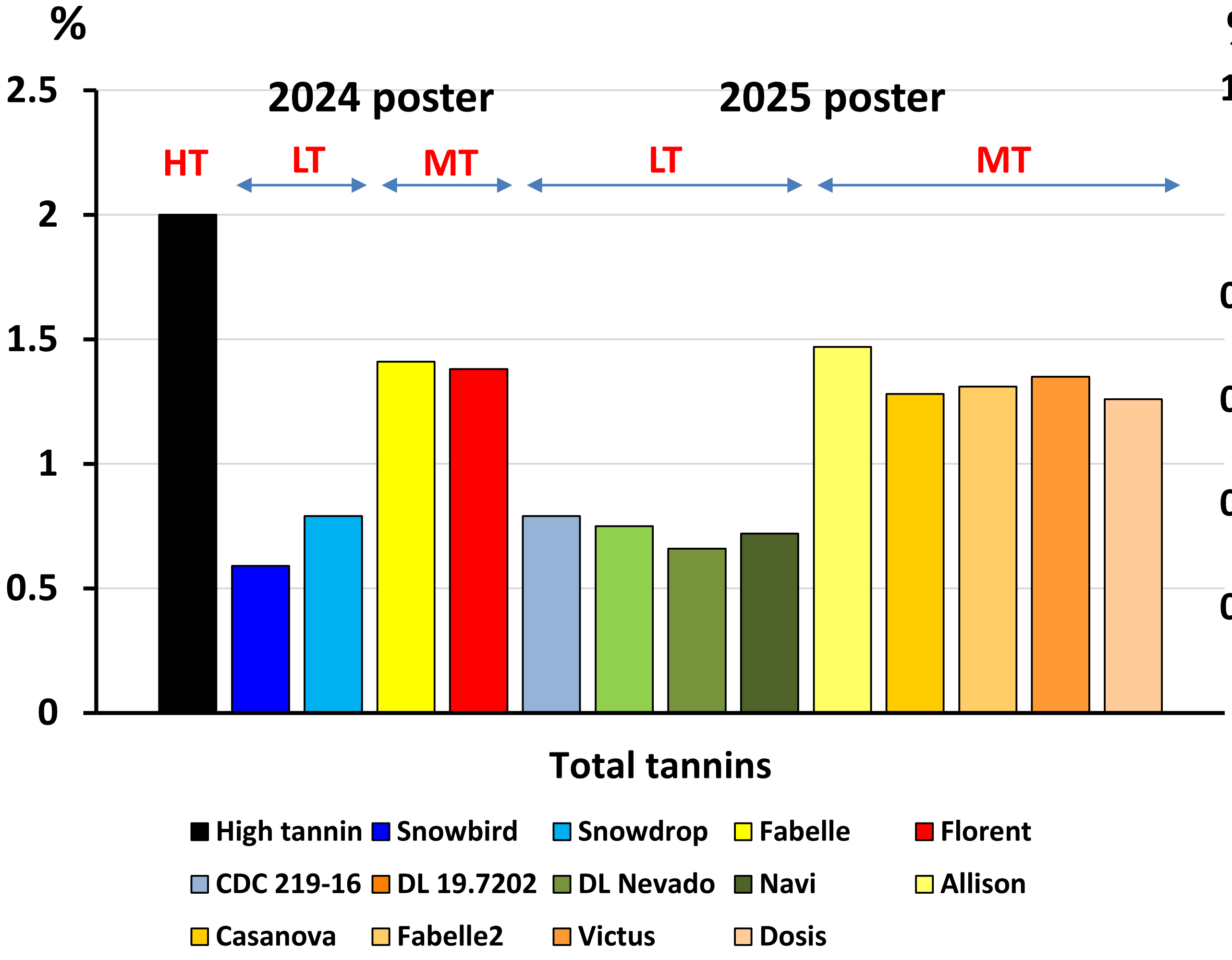
Faba bean

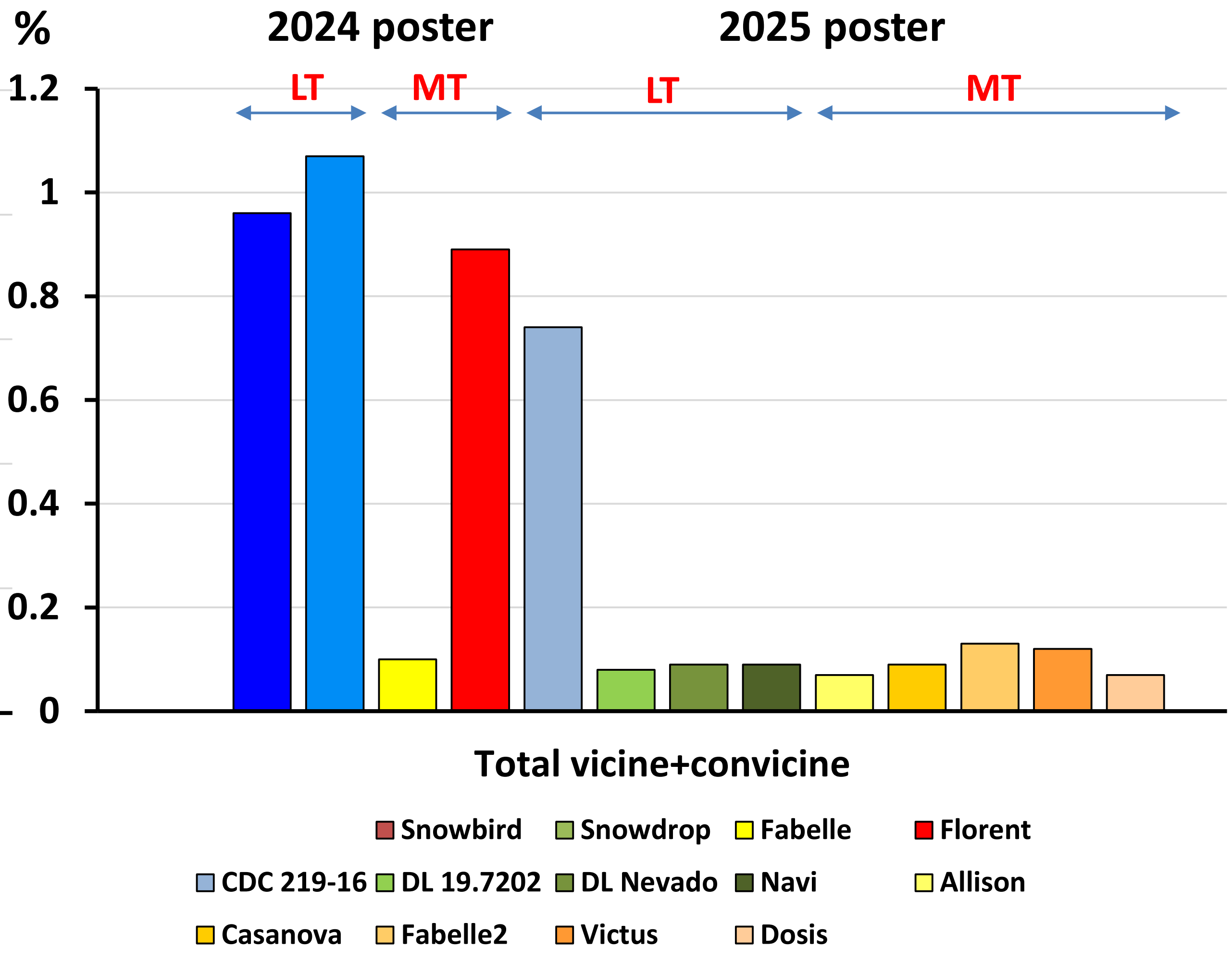


Importance of cultivar: here zero-tannin (high v + cv) Snowbird

(Beltranena et al., 2009)

Faba bean cultivars

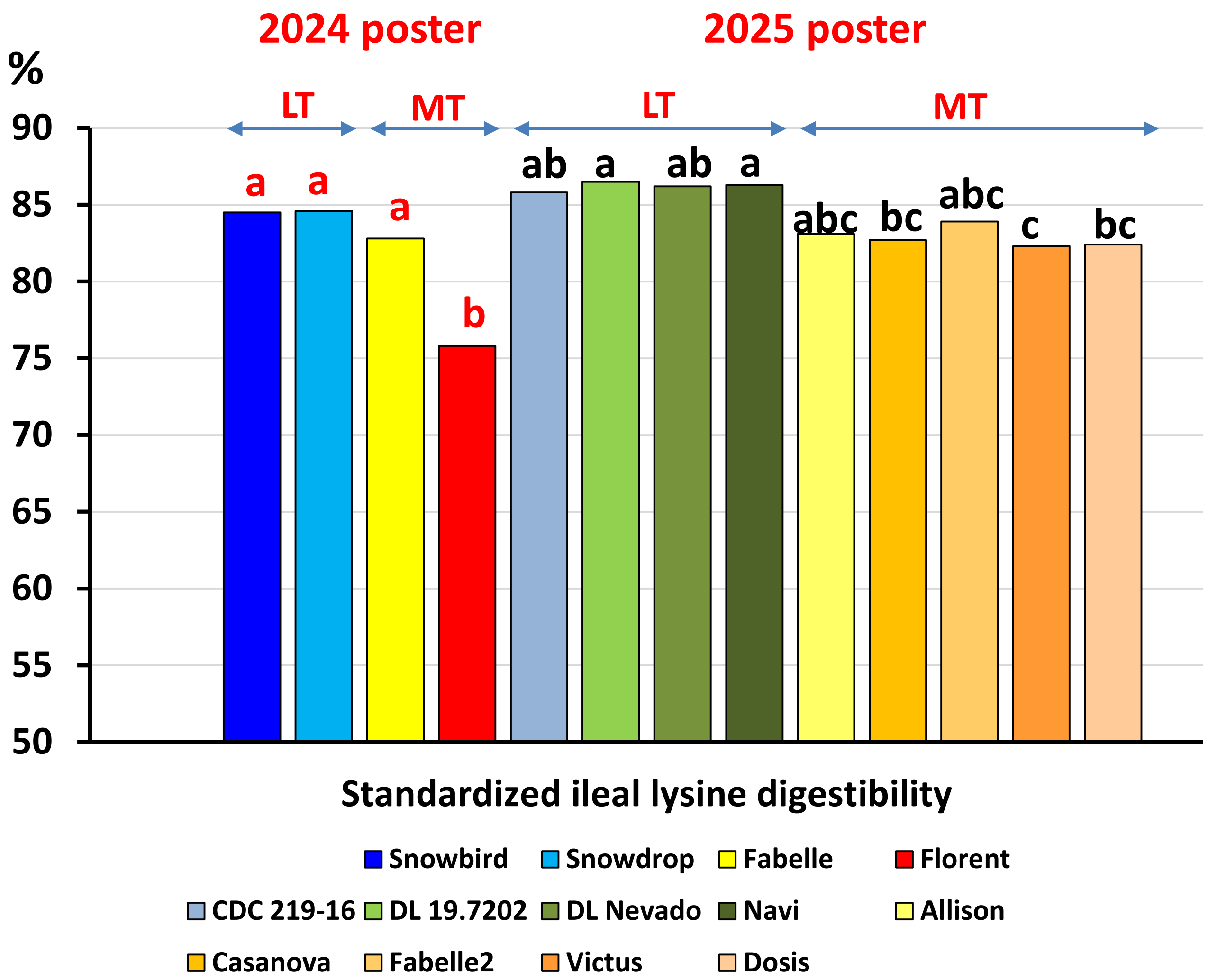


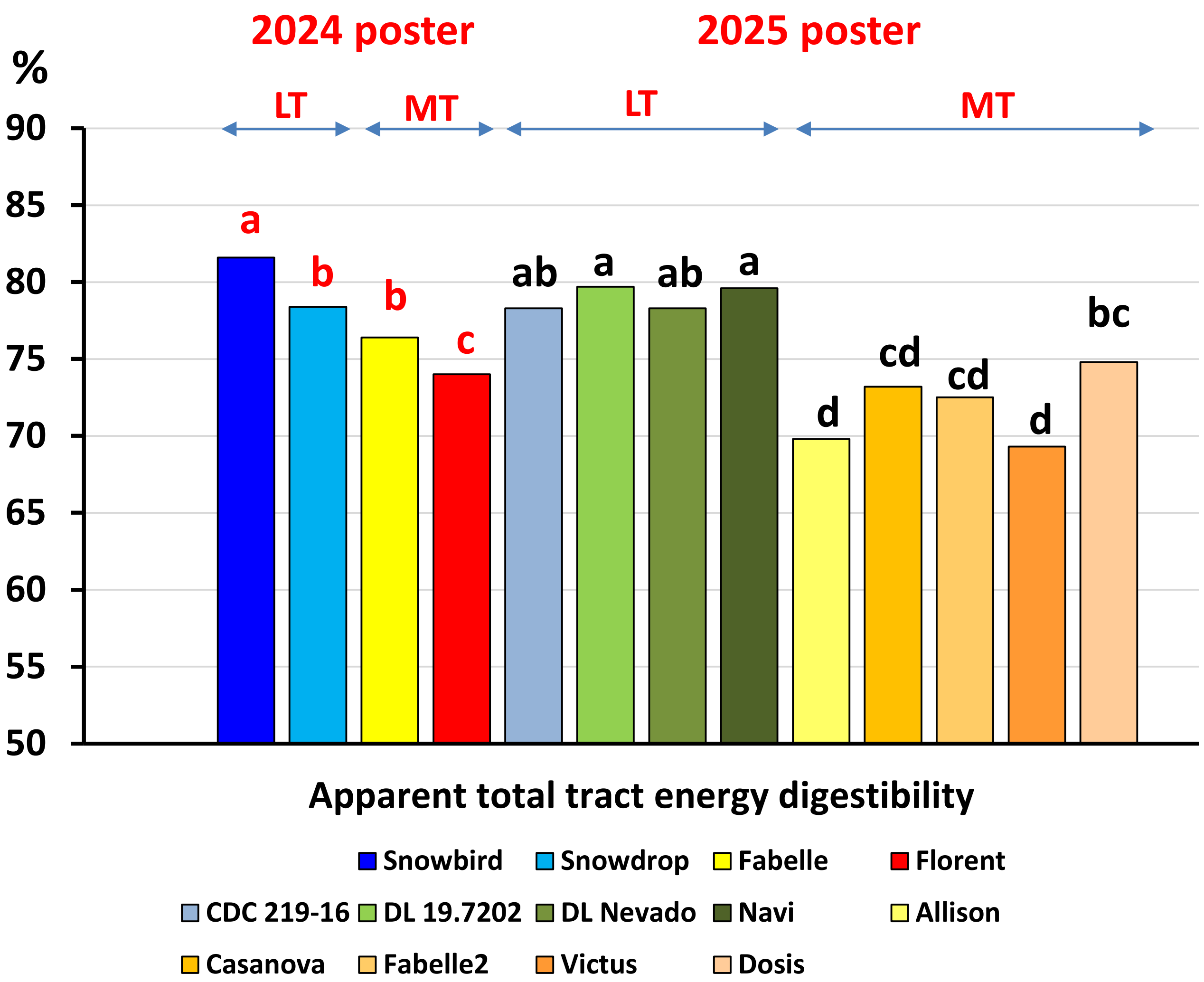


- Taste and digestibility (pig)
+ Frost tolerance (crop)

+ Unknown (pig)
- Favism risk (people w/o specific enzyme)

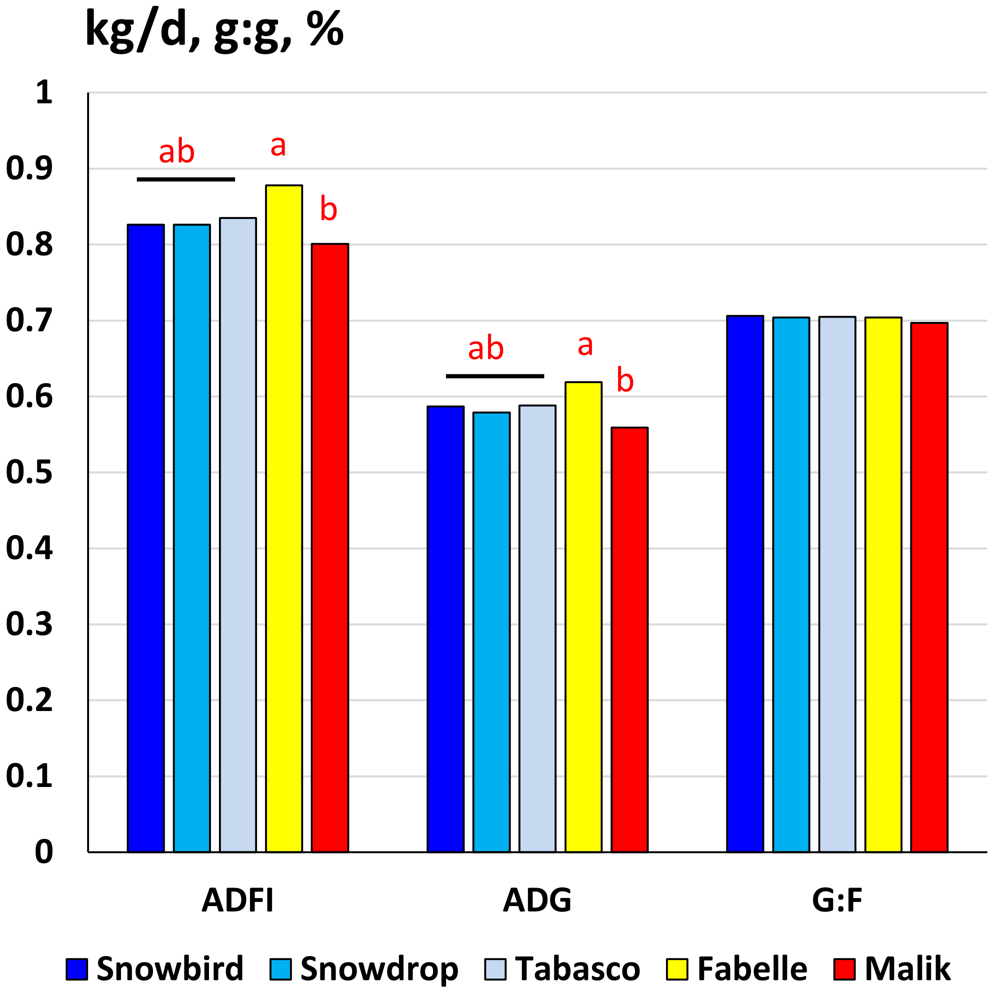
Faba bean digestibility

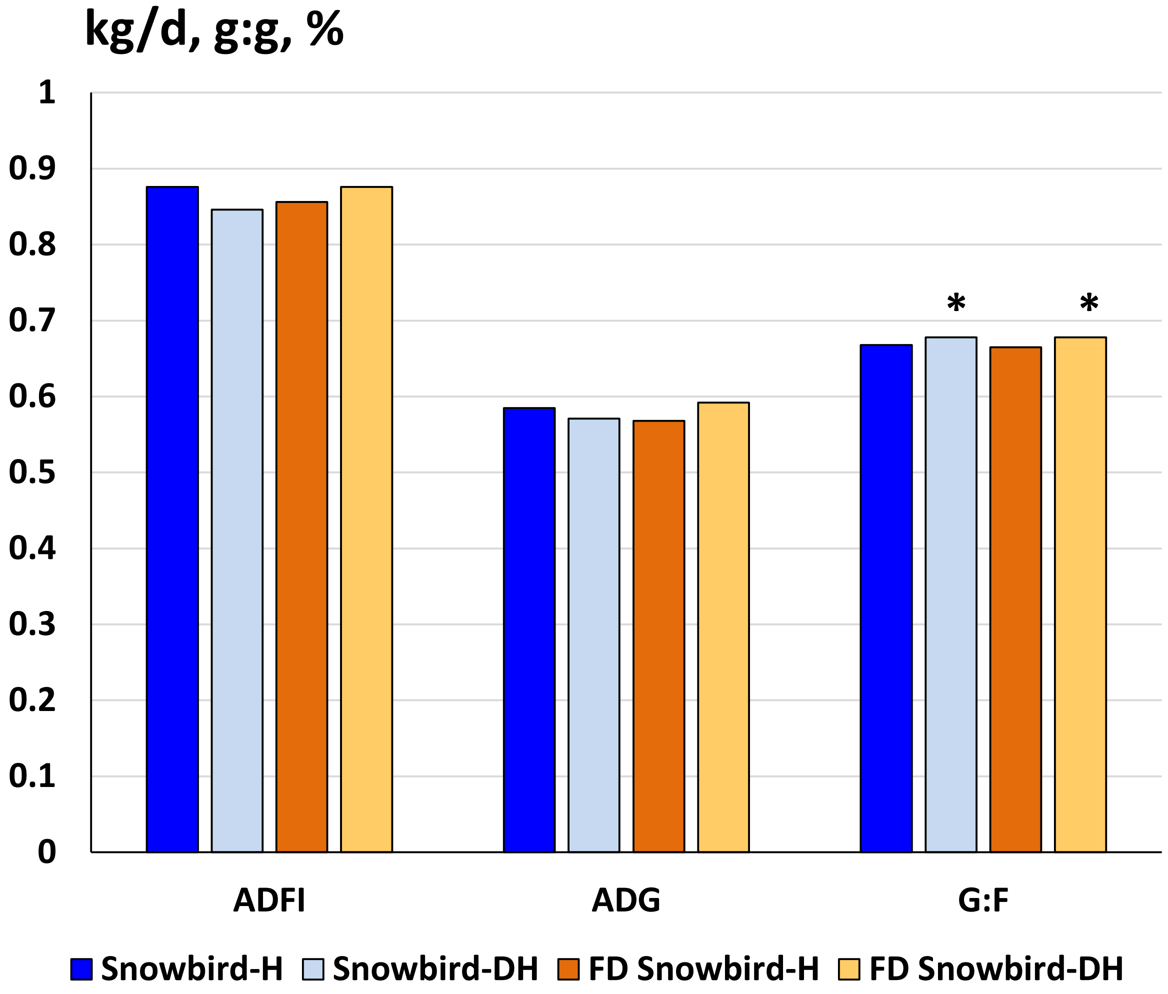




More tannin did reduce amino acid and energy digestibility

Faba bean – nursery growth trial





20% phase-2, 30% phase 3
Positive role of reduced vicine+convicine in mid-tannin cultivar (Fabelle)

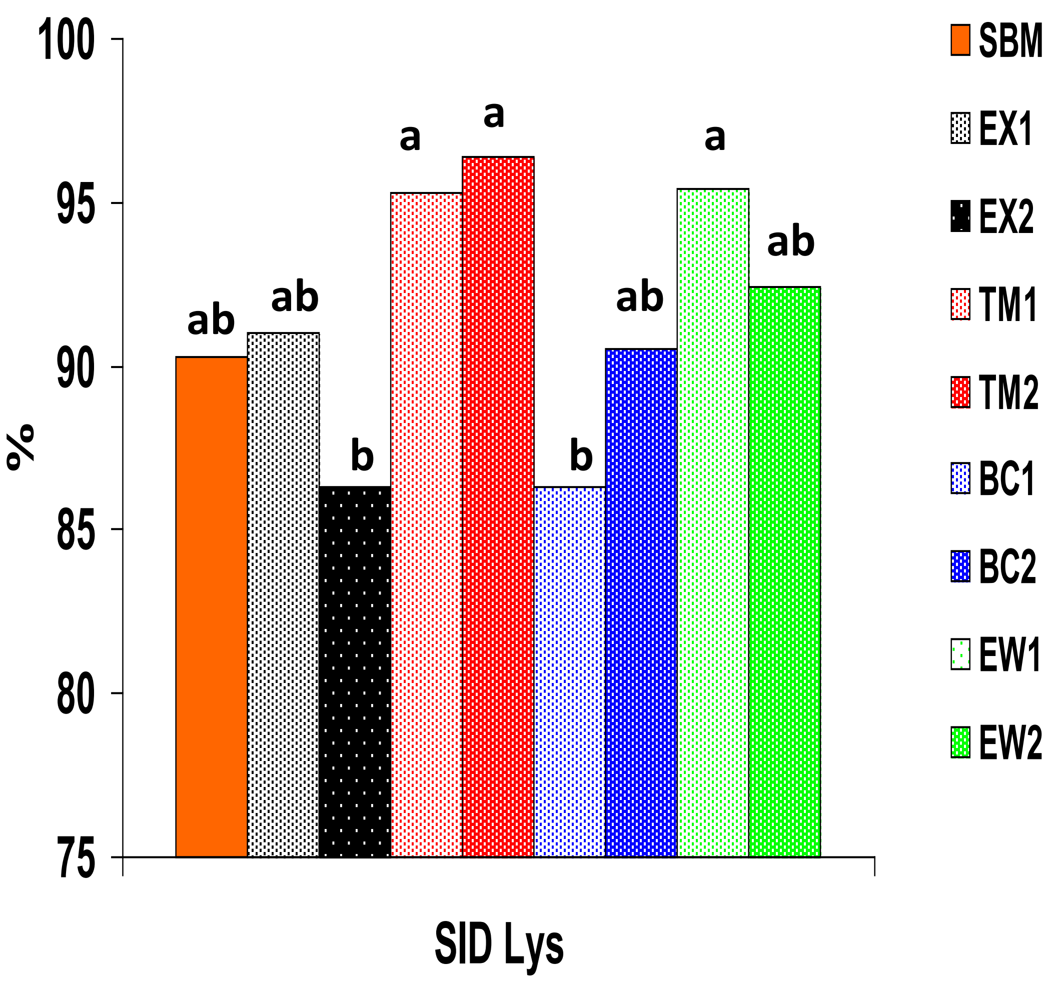
20% phase-2, 30% phase 3
No changes ADFI and ADG
Greater G:F with dehulling

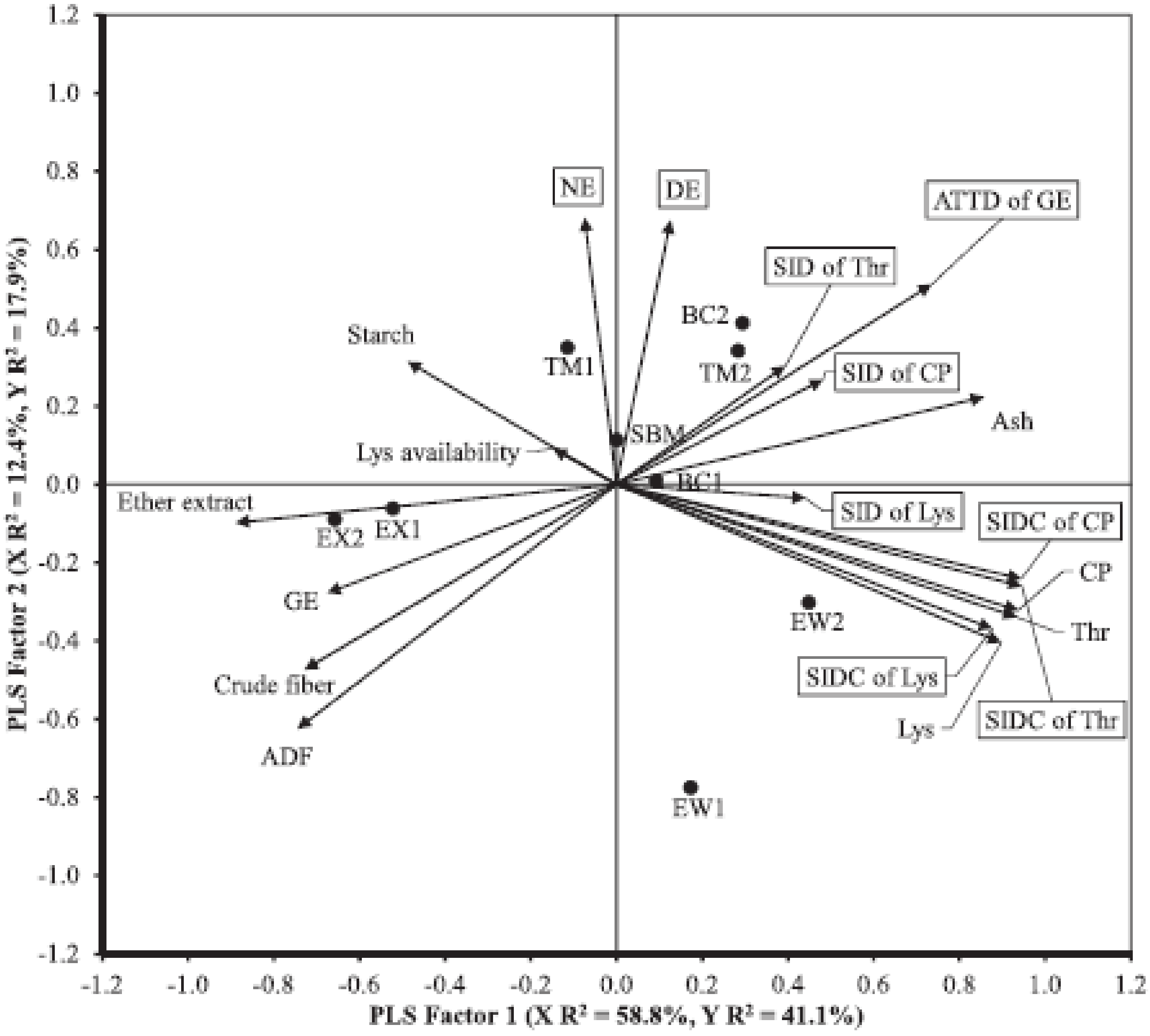
Soybean meal fractions

- **Large investments have been made**
  - **An array of companies & products (Hamlet, Agilia, Protekta)**
  - **Basically, remove fiber and ANF**
    - **Thereby increasing CP content & AA digestibility**
  - **Now also removing minerals**
  - **Targeted for feeding pigs immediately after weaning**

- **Associated with (fermentation of) undigested protein residue**

Soybean meal fractions

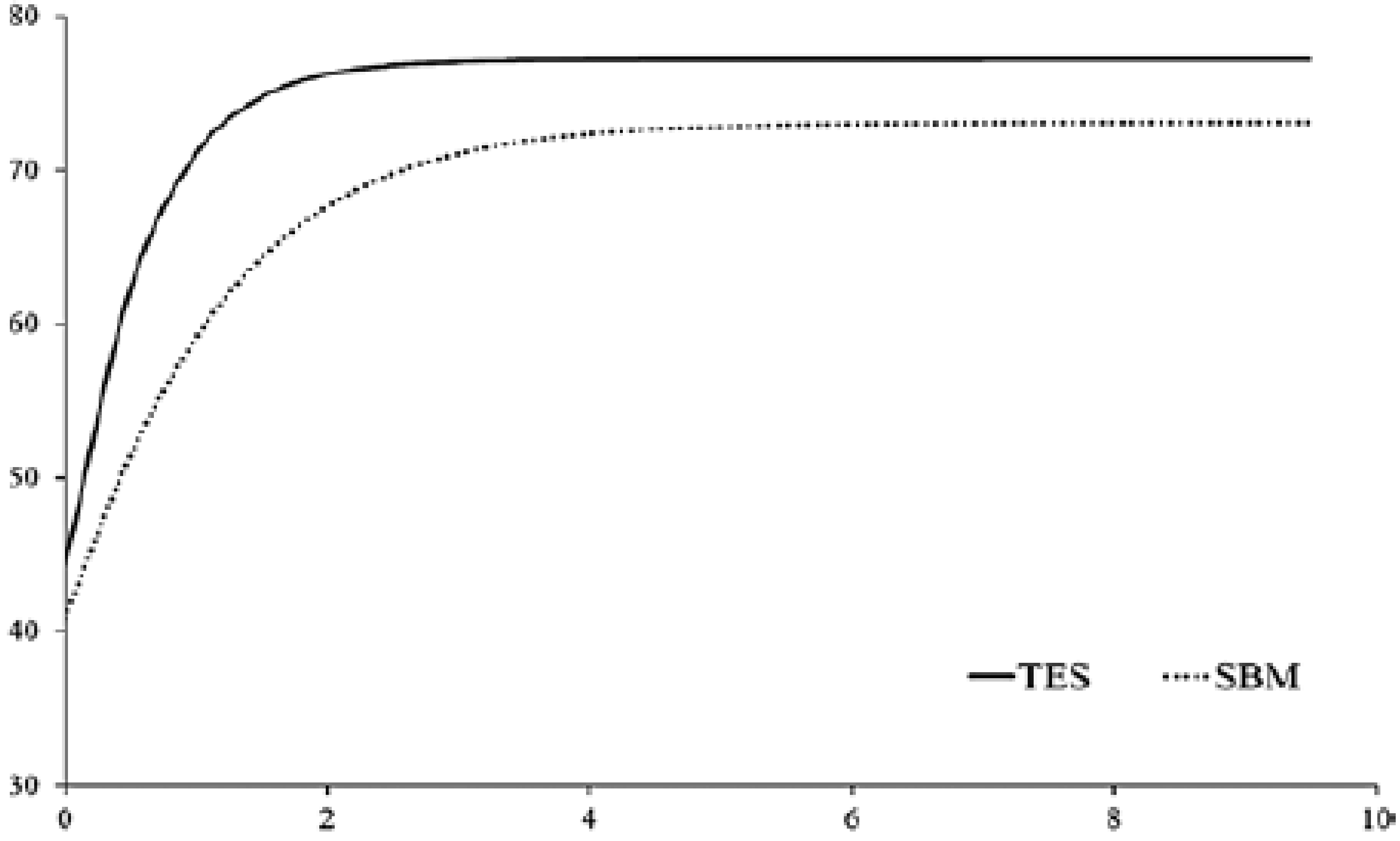




Reducing fiber increases CP digestibility

(Yanez et al. 2004)

Soybean meal fractions



Digested CP of total CP, %

Time$_{intestine}$ hour

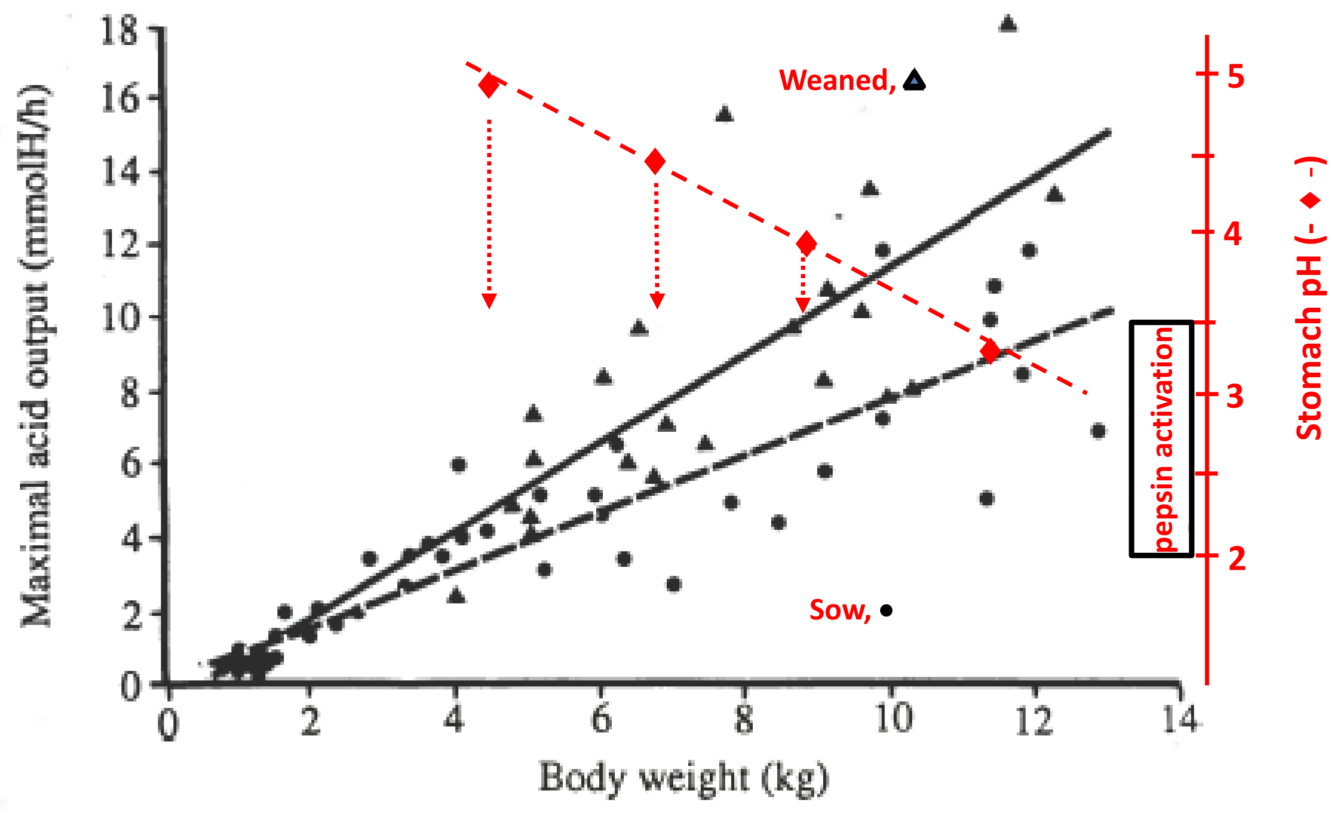
SBM = soybean meal

TES = thermomechanical and enzyme-facilitated processed soybean meal

Fractionation increases total extent and rate of protein digestion
Excellent opportunity for ingredient development (reduce PWD)

(Ton Nu et al. 2020)

Development of Stomach pH



How can the diet be reformulated to reduce stomach pH immediately after weaning?

(recreated from Cranwell and Moughan, 1989)

Acid Binding Capacity

Acid binding capacity (ABC) of feed(stuffs):
the amount of acid required to reduce the pH of feed to a particular pH, either 3 or 4 (Gilani et al., 2013)

Some excellent recent research on the topic has been conducted at Kansas State University (Stas et al., 2022, 2023, etc.).

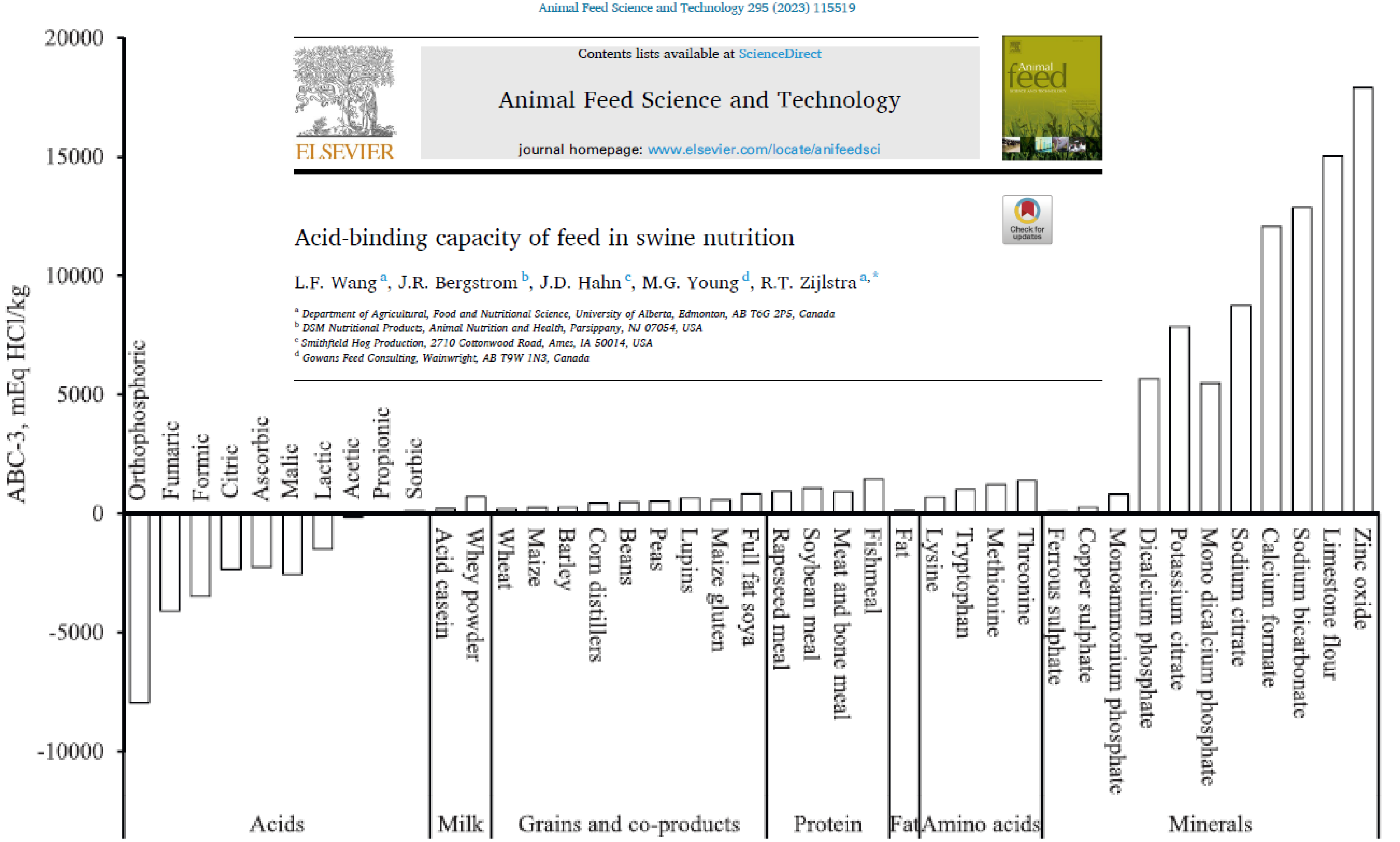


Fig. 6. Acid-binding capacity (ABC-3, mEq HCl/kg) of 41 common feedstuffs[1]. [1] ABC-3, acid-binding capacity with titration end pH at 3. Generated from published data (Lawlor et al., 2005b).

Diets – Phase 1

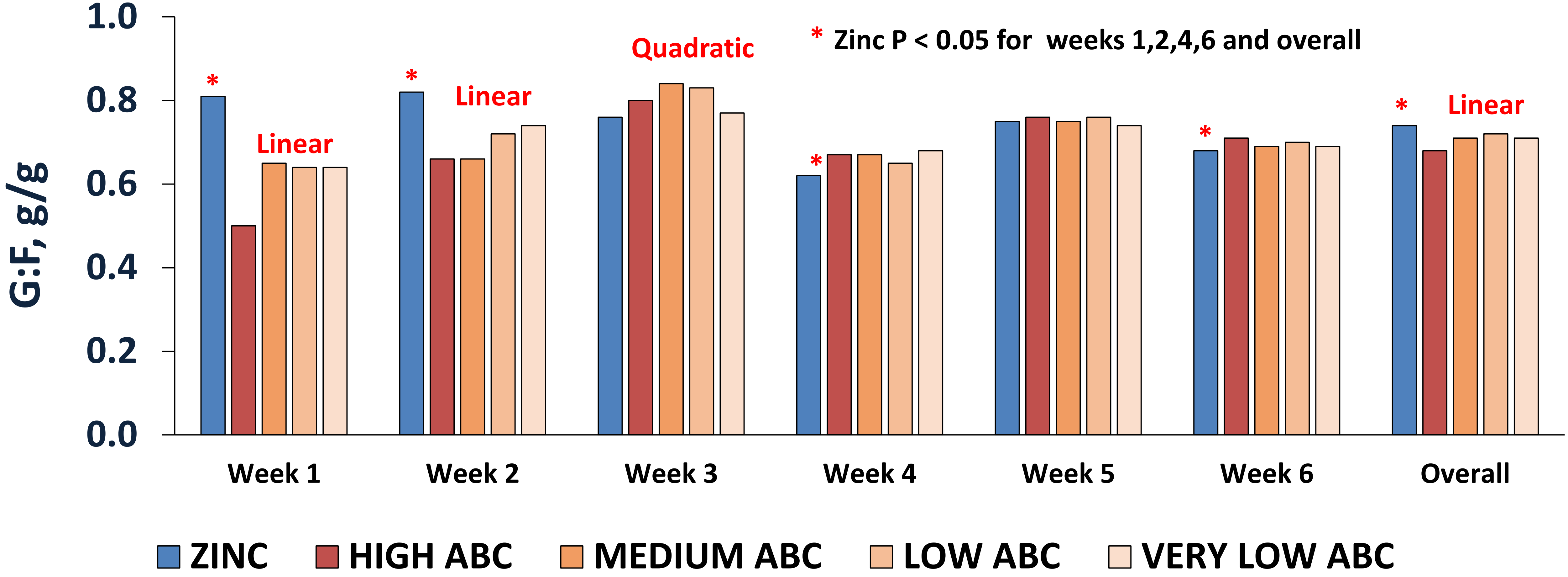
Ingredient, %	Zinc	High ABC	Medium ABC	Low ABC	Very low ABC
Equal	Wheat, 32%; Barley, 20%; Soybean expeller, 10%, Lactose, 12.6%				
Soy protein concentrate	11.1	11.0	7.4	3.7	–
Low ABC-4 soy pr. conc.	–	–	2.8	5.6	8.4
Equal	Faba bean, 5%, potato protein concentrate 3.3%, Lysine HCl, 0.6%; Others, 1.08%				
Canola oil	2.1	1.9	2.1	2.3	2.5
Mono-calcium P	0.89	0.88	0.92	0.95	0.98
Salt	0.80	0.80	0.77	0.74	0.71
Limestone	0.82	0.83	0.62	0.42	0.22
Zinc oxide	0.40	–	–	–	–
Formic	–	–	0.25	0.50	0.75
Ca formate	–	–	0.25	0.50	0.75
Benzoic	–	–	0.25	0.50	0.75
ABC-4, mEq/kg	412	326	267	209	150

Equal: NE, 2.50 Mcal/kg; SID Lys/NE, 5.70 g/Mcal; SID Lys, 1.43%; CP, 21.5%; Ca, 0.55, STTD P, 0.46

Not equal: Zn, 3,000 ppm vs. 150 ppm

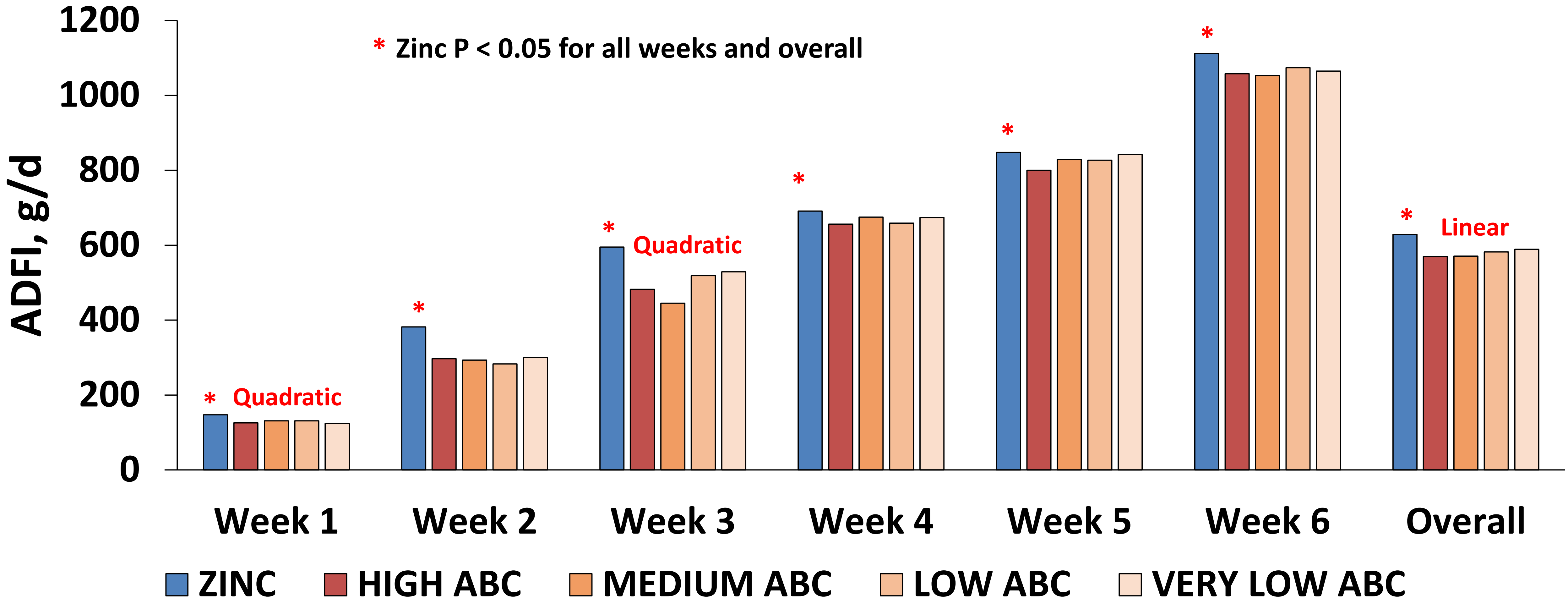
Gain:Feed (G:F)

2025 poster



Removing high ZnO for first 3 wk: strong reduction G:F for 2 wk that subsides by wk 3
Within low ZnO diets, reducing ABC linearly increased G:F, but insufficient to restore G:F completely

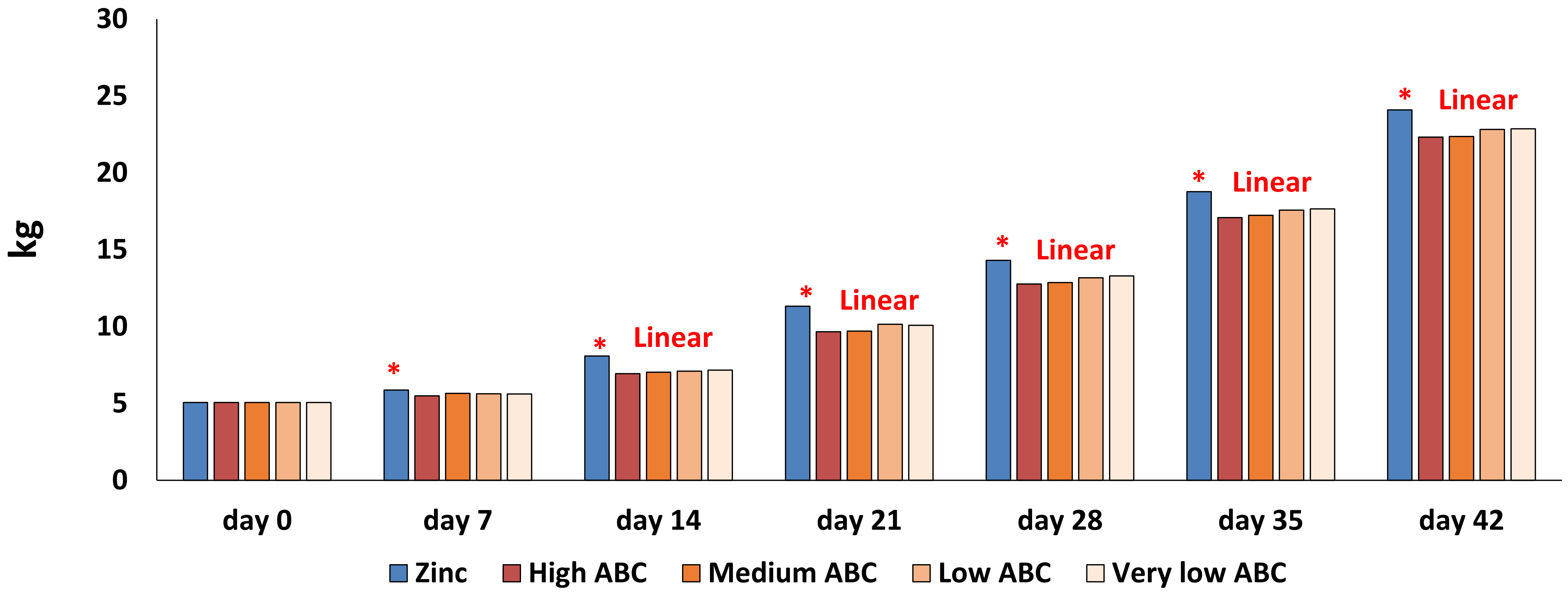
Average Daily Feed Intake (ADFI)



Removing high ZnO for first 3 wk: strong reduction ADFI that does not subside by wk 6

Within low ZnO diets, reducing ABC linearly increased ADFI, but insufficient to restore ADFI completely

Body Weight



At day 21, pigs fed high Zn were 1.6 kg heavier ($P < 0.01$) than pigs fed low Zn

Within low Zn diets, reducing ABC-4 linearly increased body weight (9.7 vs. 10.1 kg)

At day 42: pigs fed high Zn were 1.8 kg heavier ($P < 0.01$) than pigs fed low Zn

Within low Zn diets, reducing ABC-4 for the first 3 weeks linearly increased body weight (22.9 vs. 22.3 kg)

BLOGS | ANIMAL NUTRITION VIEWS

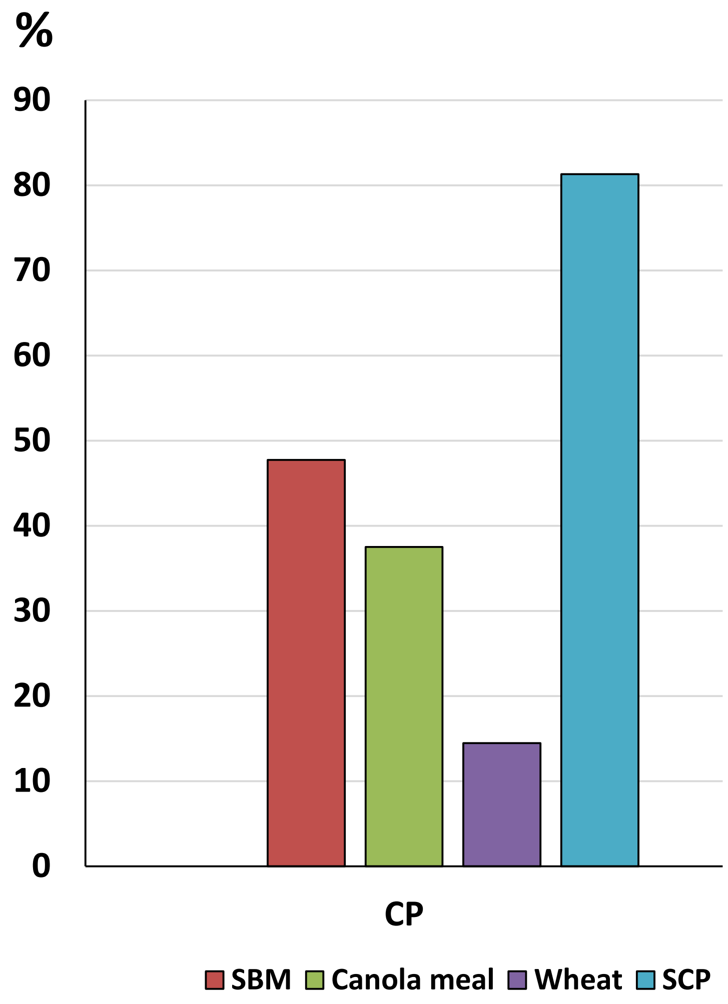
Sustainable alternative protein sources in piglet feeds

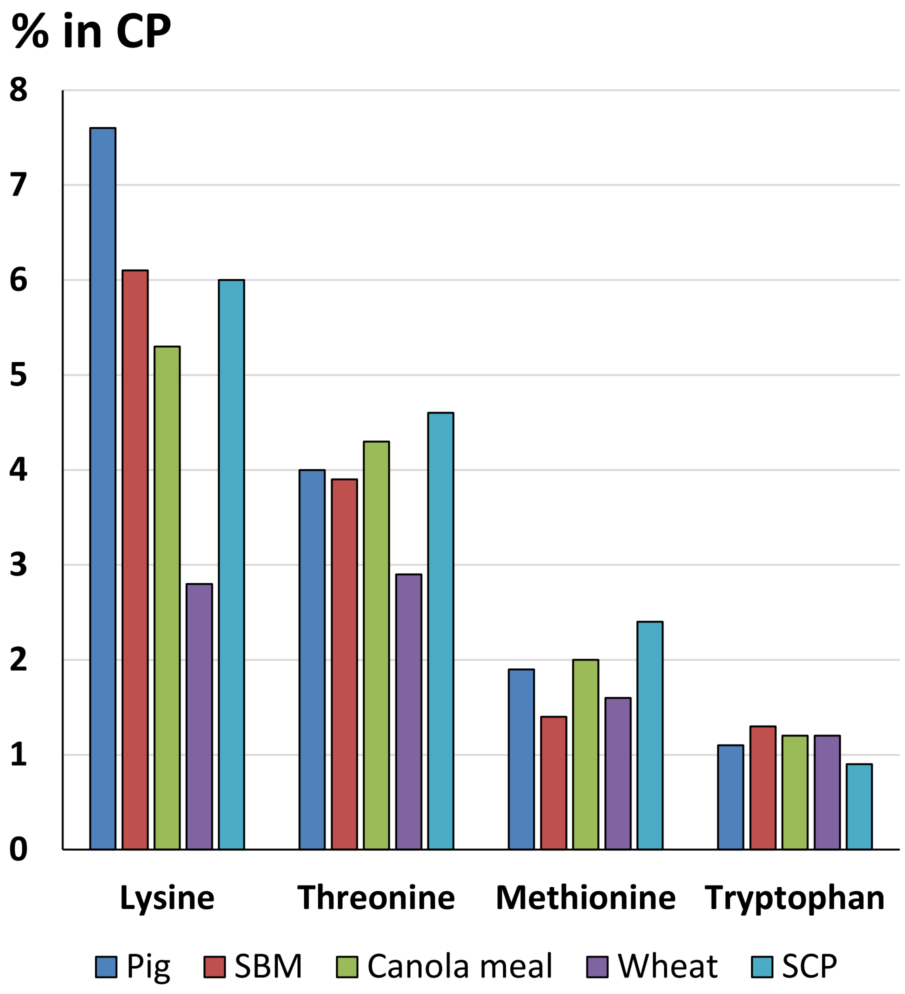
One critical aspect of sustainable pig farming is optimizing nutrition, particularly in piglet diets.

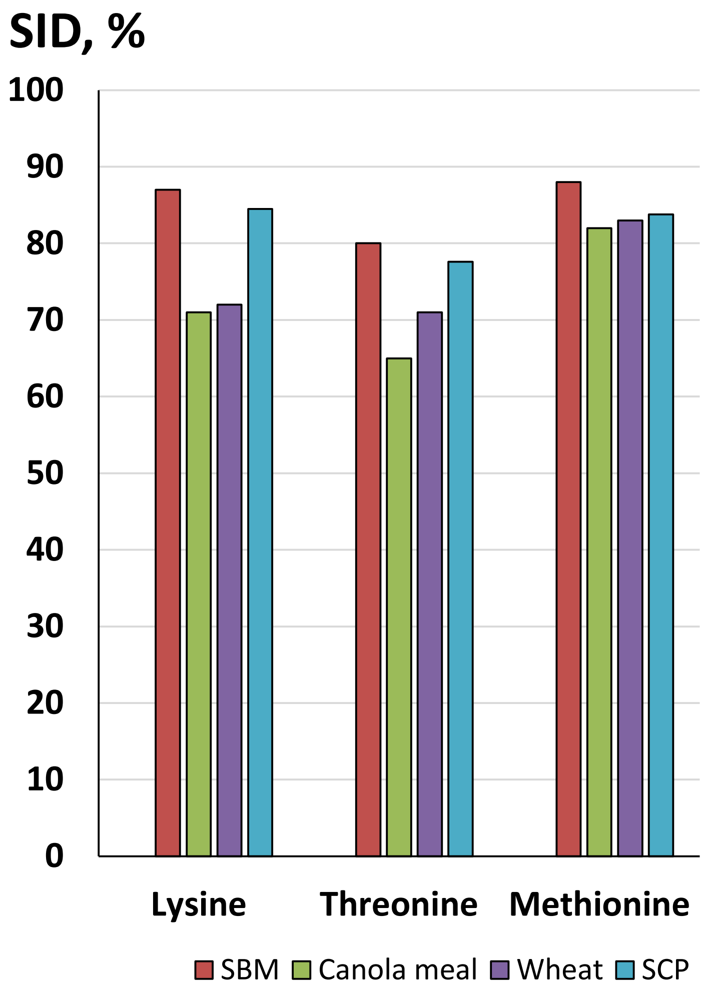
Ioannis Mavromichalis
July 1, 2024

- **Co-products food industry** → **e.g., canola meal, expeller, cake**
- **Microbial fermentation** → **Next, single cell protein**
- **Hydrolyzed proteins** → **Novel canola meal hydrolyzation**

Single Cell Protein (from bacteria)

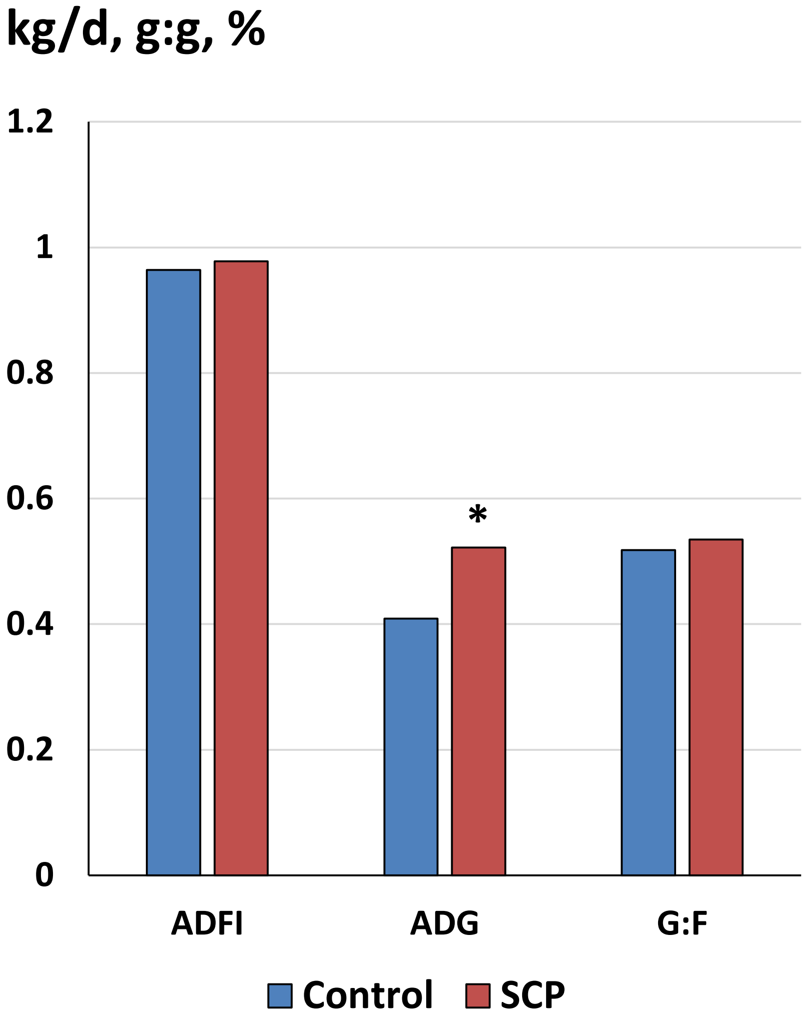






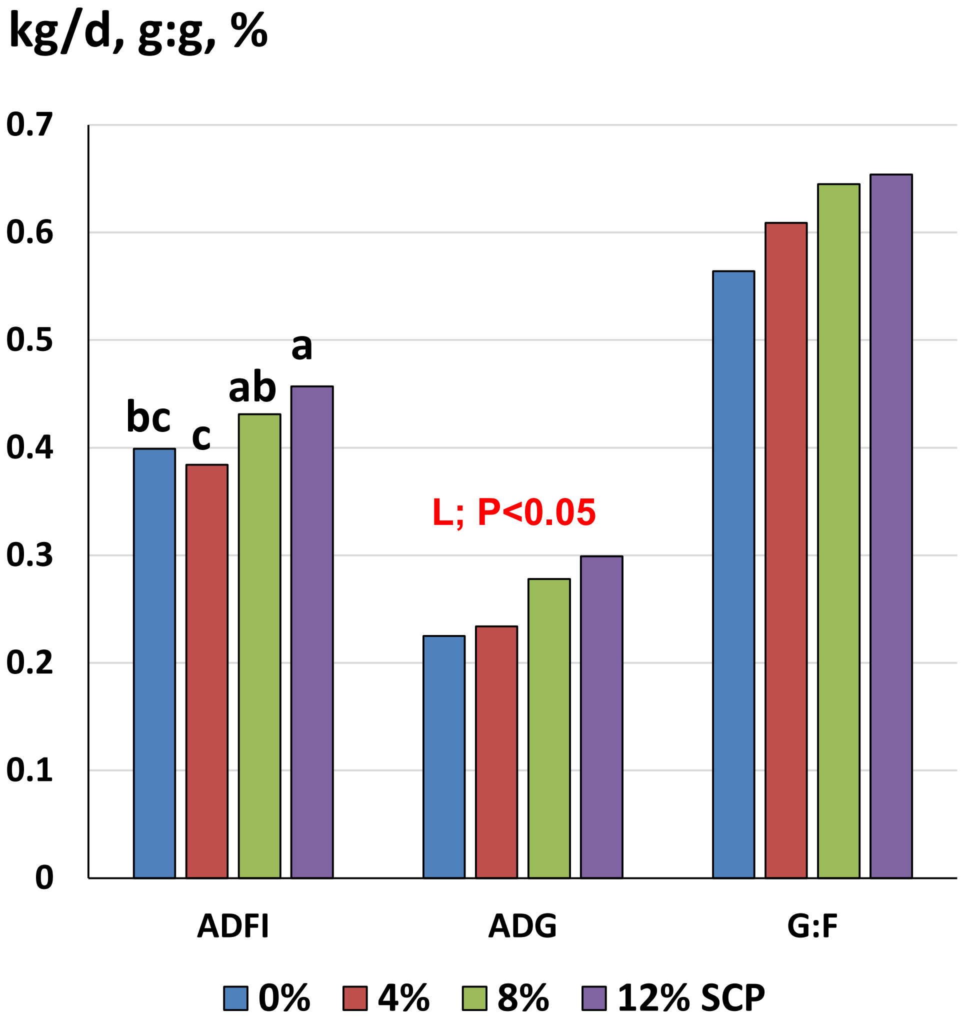
The CP in SCP is mostly AA, but also ~10%-unit nucleotides (might be useful for young pigs)

SCP in Starter Diets



SCP replaced fish meal in starter diets

(Waterworth. 1992)



SCP replaced fish meal, MBM, and SBM
From d 35, data initial 2 weeks

(Øverland et al. 2001)

Summary and Conclusions

- **Protein Feedstuffs**
    - Continue to evolve
- **Local Protein Feedstuffs in Growing-Finishing Pigs**
    - Canola co-products continue to expand
        - Need novel, stable technology to increase protein content and AA digestibility
    - Pulse grains esp. faba bean continue to provide opportunities
- **In nursery pigs**
    - Watch acid-binding capacity: undigested protein
    - Ingredient with high protein digestibility are a tool for when PWD is a concern
    - Apart from dietary ingredients, should also look at weaning age
- **Implications**
    - Optimize the use of local protein feedstuffs
        - Stay up-to-date for cost effective opportunities
        - Carefully look at increasing maximum inclusion levels while controlling risk

Opportunities & Challenges for Novel Protein Feedstuffs in Swine Diets

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