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Fibrous Agroindustrial By-products in Pig Diets: Effects on Nutrient Balance and Gas Emission.

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POLITÉCNICA "Ingeniamos el futuro"

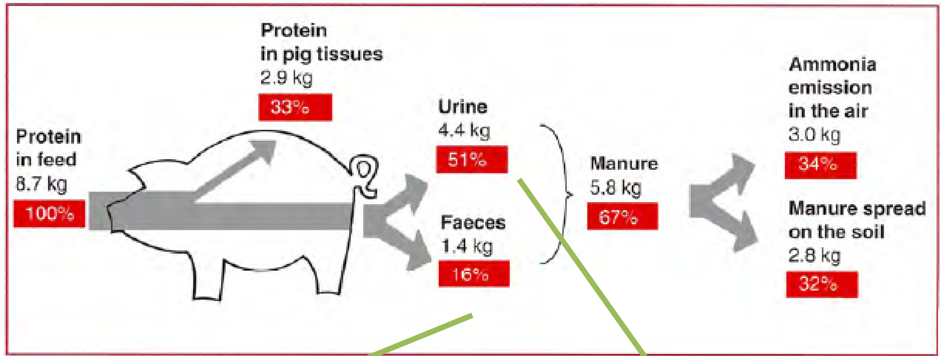
1. Importance of livestock farming on gas emission:

- **NH_3:** Livestock excreta **>** 80-90 % NH_3 emission from European agriculture (EEA, 2010).
- **Greenhouse gas emission** (**CH_4,** N_2O): Livestock 28% of the global emission (EPA, 2011).

NH_3 Emission from Pig Operations

NH_3 emission

- Result of N volatilization from manure (chemical process)
- The velocity and amount of volatilized N depend on Tª, surface area, air velocity, **pH** and **N amount and type** (organic vs inorganic) in the substrate.

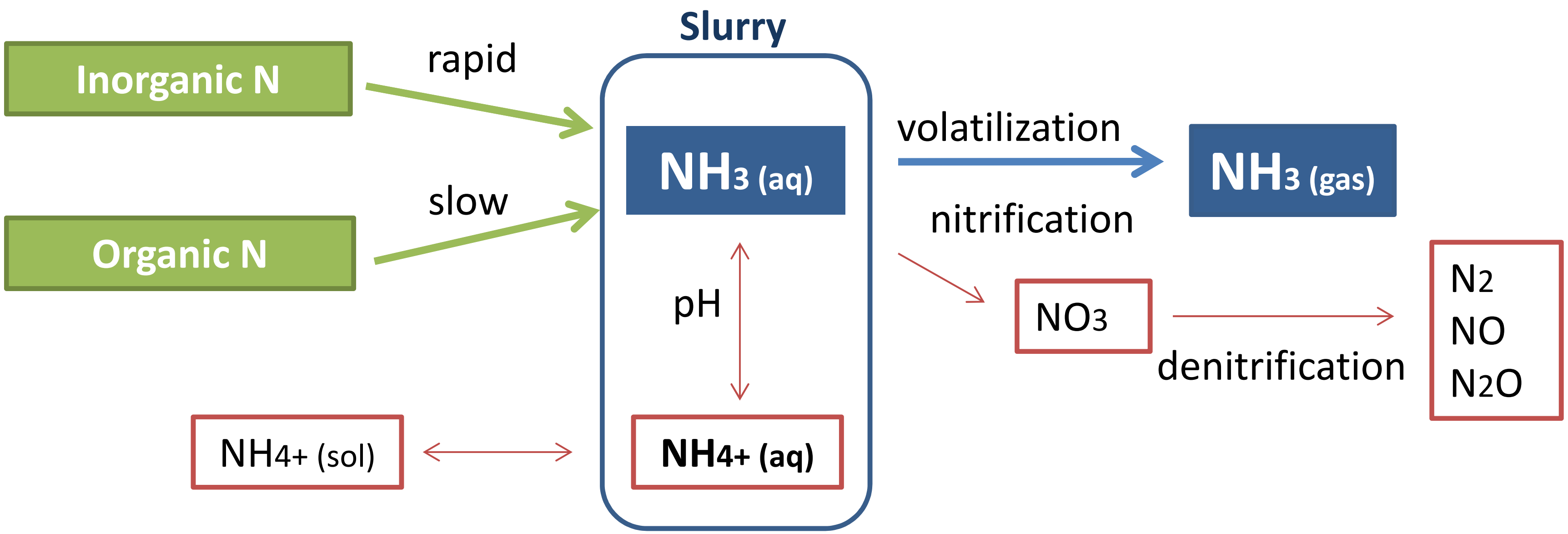


IPPC (2003)

Organic N
(Undigested N in feed, microbial protein, endogenous secretions)

Inorganic N
(Urea, Undigested N in feed)

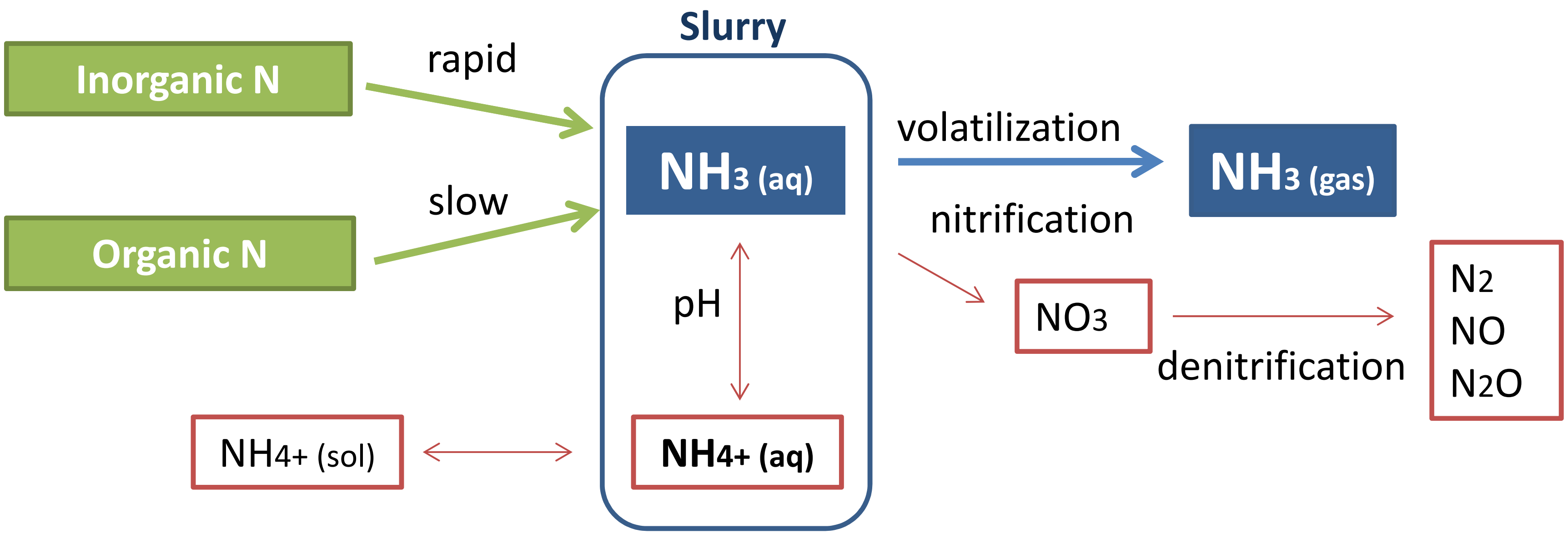
NH_3 Emission from Pig Operations



Feeding measures to reduce NH_3 loss from slurry:

- Adjust feed composition to animal requirements (CP and AA) **(IPPC, 2003)**
- Low CP level in feeds (increasing essential AA) **(IPPC, 2003)**
- **Inclusion of high fermentable fibre sources** (beet pulp and soybean hulls) (Canh et al., 1997; Heimendahl et al., 2010; Galassi et al., 2010; Jarret el al., 2012)
  - Increase the proportion of organic N (microbial N) and decease the proportion of inorganic N (urea) in slurry
  - Decreases faecal pH

NH_3 Emission from Pig Operations



Feeding measures to reduce NH_3 loss from slurry:

- Adjust feed composition to animal requirements (CP and AA) **(IPPC, 2003)**
- Low CP level in feeds (increasing essential AA) **(IPPC, 2003)**
- **Inclusion of high fermentable FIBRE sources** (beet pulp and soybean hulls) (Canh et al., 1997; Heimendahl et al., 2010; Galassi et al., 2010; Jarret el al., 2012)
- **High lignified fibre sources**?
  - No influence on N partitioning
  - Affects digestibility, N content in faeces and emissions?

CH_4 Emission from Pig Operations

Proteins **Lipids**
Carbohydrates

↓ Hydrolisis

Sugars, AA, Alcohols, Fatty acids

↓ Acidogenesis

VFA

↓ Acetogenesis

Acetic acid

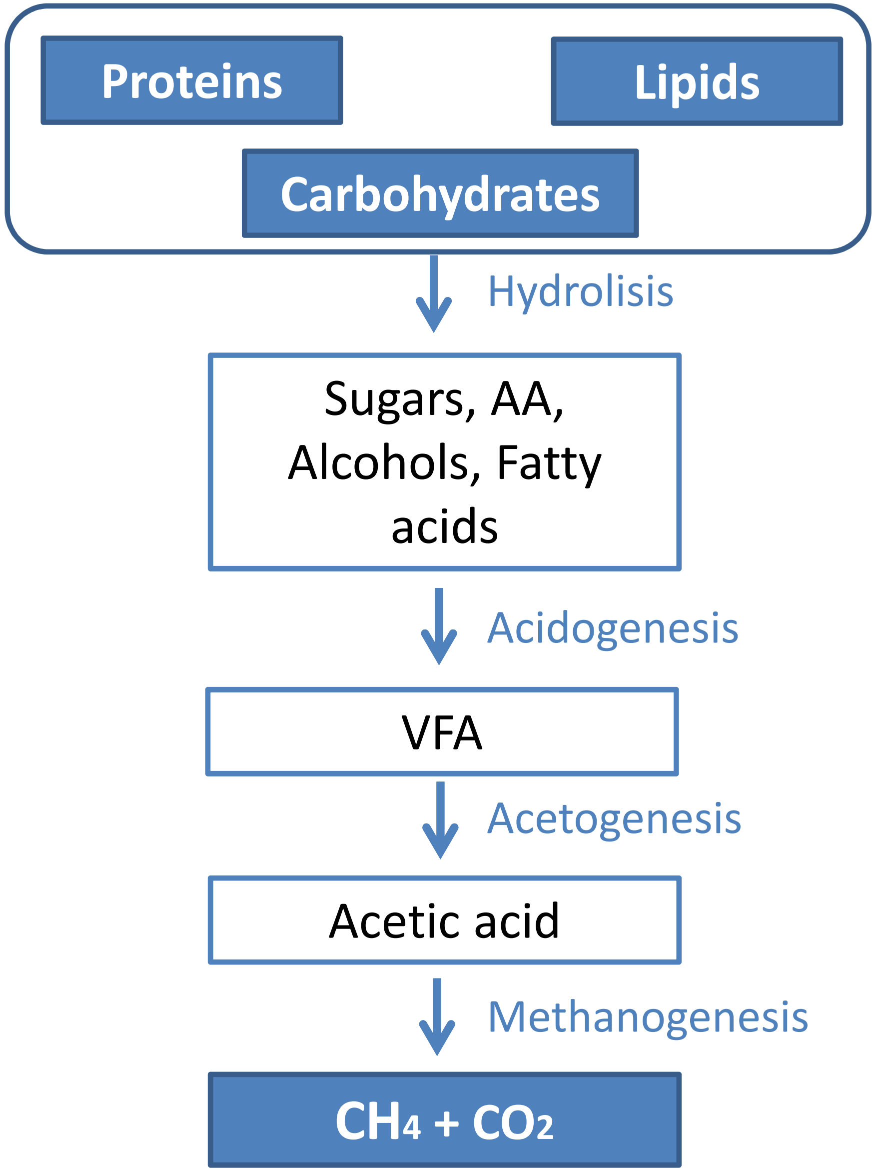
↓ Methanogenesis

CH_4 + CO_2

CH_4 emission

- Result of the natural digestive process of animals (enteric fermentation) and manure storage in livestock operations (biological process).
- The velocity and amount of CH_4 production from slurry depend on **amount and biodegradability** of nutrients (carbohidrates, protein and fat).

CH_4 Emission from Pig Operations



Feeding measures to reduce CH_4 emission from slurry:

- Less studied than NH_3.
- **Cellulose** and **lignin** have the lowest CH_4 potential emissions, whereas undigested **lipids** and **protein** have the highest.
- The addition of **FIBRE SOURCES** may affect nutrient digestibility, faeces composition and CH_4.
- The inclusion of different **fibrous by-products** (DDGS, SBP, RSM) led to variable effects on the potential for CH_4 production and the total CH_4 produced per pig (Jarret et al., 2010; Jarret et al., 2012).

ANIMAL NUTRITION and gas emission in pigs:

DIET COMPOSITION

Nutrient DIGESTIBILITY
Nutrient METABOLISM
Nutrient FERMENTATION

NUTRIENT UTILIZATION

SLURRY AMOUNT AND COMPOSITION

GAS EMISSION

2. The use of local agroindustrial by-products in pig diets:

Advantages:

- Decrease feed costs (not always)
- Use of local resources for animal feeding, support for local economy
-

Affect digestibility and nutrient output in excreta and gas emission??

Disadvantages: unusual feedstuffs

- High fibre content and variability in the type of fibre
- Lower knowledge on its nutritional value: difficult feed formulation
- High variability in composition
- Seasonality

OBJECTIVE

To investigate the effects of **two levels** (75 and 150 g/kg) of **two sources** of fibrous by-products highly available in the Mediterranean area (orange pulp and carob meal, with a low or high degree of lignification, respectively) in finishing pigs on:

- Nutrient balance
- Effluent (urine and faeces) composition
- Gas (NH_3 and CH_4) emission

Animals and feeds

- **30 male pigs** (Danish Duroc x (Landrace x Large White)) of 85.4±12.3 kg

- **Experimental period:** 21 days
  - 14 days adaptation (conventional pens)
  - 7 days of total collection of faeces and urine (metabolic pens)
    - Day 1 to 4: digestibility and N balance
    - Day 5 to 7: artificial slurry and emissions

- **5 experimental diets (160 g/kg DM NDF):**
  - **CONTROL:** barley, wheat, soybean meal, lard
  - **OP7.5**: 75 g/kg DM orange pulp
  - **OP150**: 150 g/kg DM orange pulp
  - **CB7.5**: 75 g/kg DM carob meal
  - **CB150**: 150 g/kg DM carob meal

Animals and feeds

By-products in diets, g/kg DM

	Orange pulp	Carob meal
Dry matter	907	867
Ash	60.9	31.7
Crude protein	52.6	42.5
Ether extract	16	7
NDF	274	356
ADF	185	317
ADL	24.7	173
Sugars	228	350
Soluble fibre	275	80
Gross energy (MJ/kg)	15.8	16.6

Animals and feeds

Ingredient composition of the experimental diets (g/kg, as fed basis)

	Control	OP75	OP150	CM75	CM150
Barley grain	400	301	202	282	163
Wheat grain	450	450	450	450	450
Soybean meal	103	122	141	132	161
Orange pulp	0	75.0	150	0	0
Carob meal	0	0	0	75.0	150
Lard	11.9	20.5	29.0	27.5	43.0
Calcium carbonate	11.6	8.0	4.4	10.1	8.6
Sodium chloride	3.9	3.8	3.7	3.8	3.8
Monocalcium phosphate	8.8	9.4	10.1	9.4	10.0
L-lysine HCL	4.1	3.9	3.7	3.7	3.3
DL-methionine	0.6	0.6	0.6	0.6	0.6
L-threonine	1.1	1.1	1.1	1.1	1.1
Premix[b]	5.0	5.0	5.0	5.0	5.0

Animals and feeds

Chemical composition of the experimental diets (g/kg DM)

	Control	OP75	OP150	CM75	CM150
Net energy (MJ/kg DM)	10.8	10.8	10.8	10.8	10.8
Crude protein	173	173	171	171	175
Ether extract	43.0	53.3	62.9	59.2	72.1
NDF	154	165	158	164	161
ADF	45.6	52.3	56.3	61.0	75.4
ADL	8.0	9.0	10.7	18.9	33.9
Soluble fibre	39.4	48.4	71.7	36.0	48.5
Starch	457	408	359	398	339
Sugars	18.8	36.0	53.2	51.6	84.5
Ileal digestible lysine	8.2	8.2	8.2	8.1	8.1

Measurements

- **Apparent faecal digestibility** (nutrient balance)
  - **OM**: organic matter (AOAC, 2000)
  - **CP**: crude protein (AOAC, 2000)
  - **EE**: ether extract (AOAC, 2000)
  - **FND, FAD, ADL**: Fibre fractions (Van Soest et al., 1991)
  - **GE:** gross energy (AOAC, 2000)

- **Faeces and urine amount and composition** (OM, CP, EE, FND, ADF, ADL, GE, pH)
- **Slurry characteristics** (pH, DM, OM, VFA (volatile fatty acids), TKN (total Kjeldahl nitrogen)
- **NH_3 and CH_4 emission from slurry**

Measurements

- **NH_3 emission (11 days):** dynamic chamber methodology and acid trap system (Ndegwa et al., 2009). Slurry samples of 0.5 L from each animal.

Measurements

- **CH_4 emission (100 days):** Biochemical methane potential (B_0) is the CH_4 produced per gram of OM in a batch assay (Angelidaki et al., 2009).

Biogas monitorization and sampling

Methane concentration analysis (Chromatograph)

STATISTICS: Factorial arrangement with two sources (S) and two levels (L) of fibre inclusion using PROC GLM and PROC MIXED of SAS (2008). Also contrasts with C diet.

Intake and volume of excreta

Treatments	Control	OP75	OP150	CM75	CM150	SEM	Significance		
							S	L	S x L
n	6	6	6	6	6	-	-	-	-
Intake, kg/d	2.67	2.63	2.52	2.55	2.99	0.143	0.134	0.207	0.045
Faeces excretion, kg/d	1.04	1.17	1.04	1.25	1.40	0.092	0.018	0.863	0.115
Urine excretion, Kg/d	2.10	3.03	2.86	2.88	2.96	0.496	0.982	0.906	0.826
Slurry, kg/d	3.16	4.19	3.43	4.05	4.36	0.494	0.435	0.656	0.307

Intake and volume of excreta

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Faeces excretion, kg/d	1.04	1.17	1.04	1.25	1.40	0.092	0.018	0.863	0.115
Urine excretion, Kg/d	2.10	3.03	2.86	2.88	2.96	0.496	0.982	0.906	0.826
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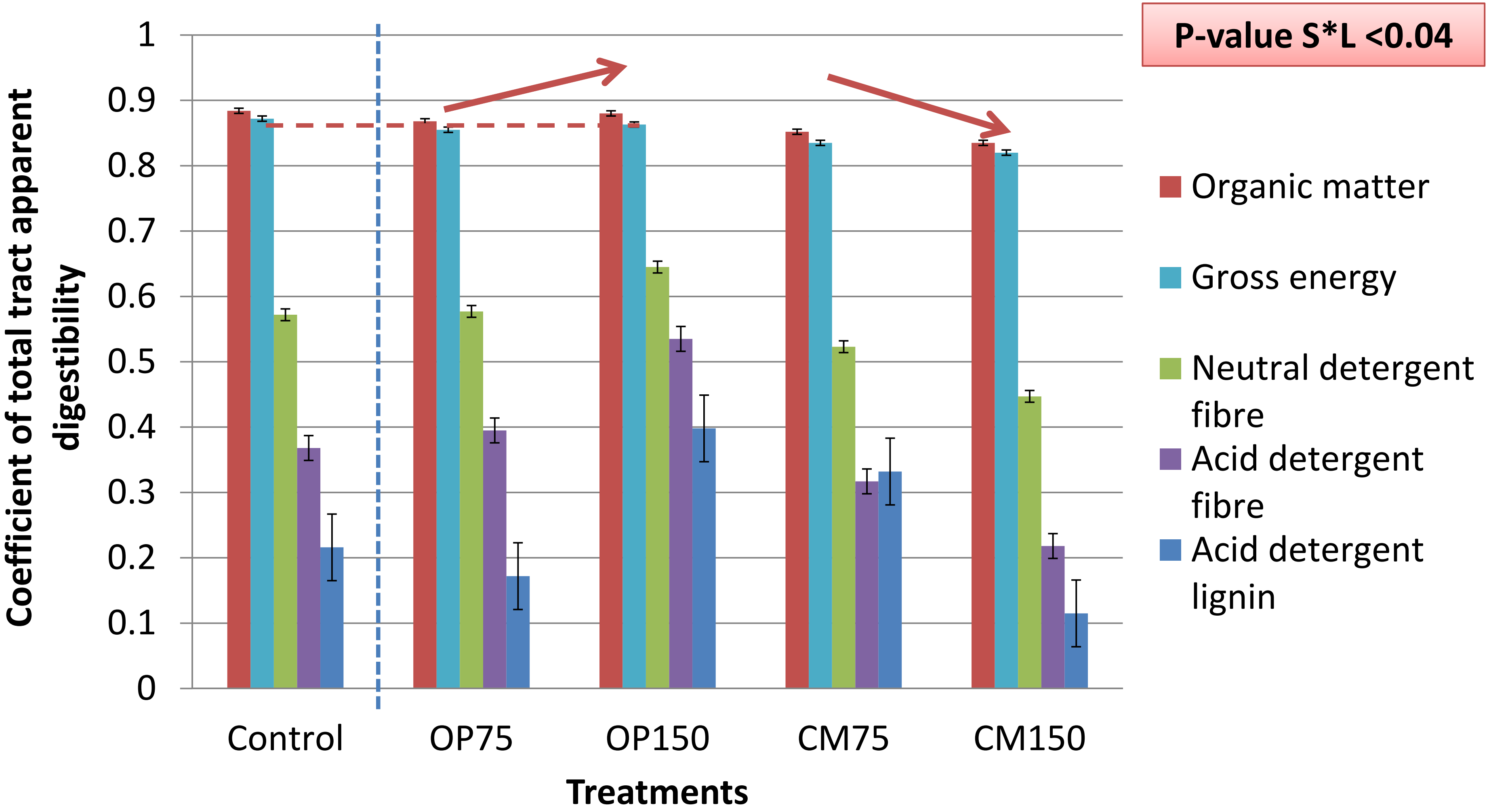
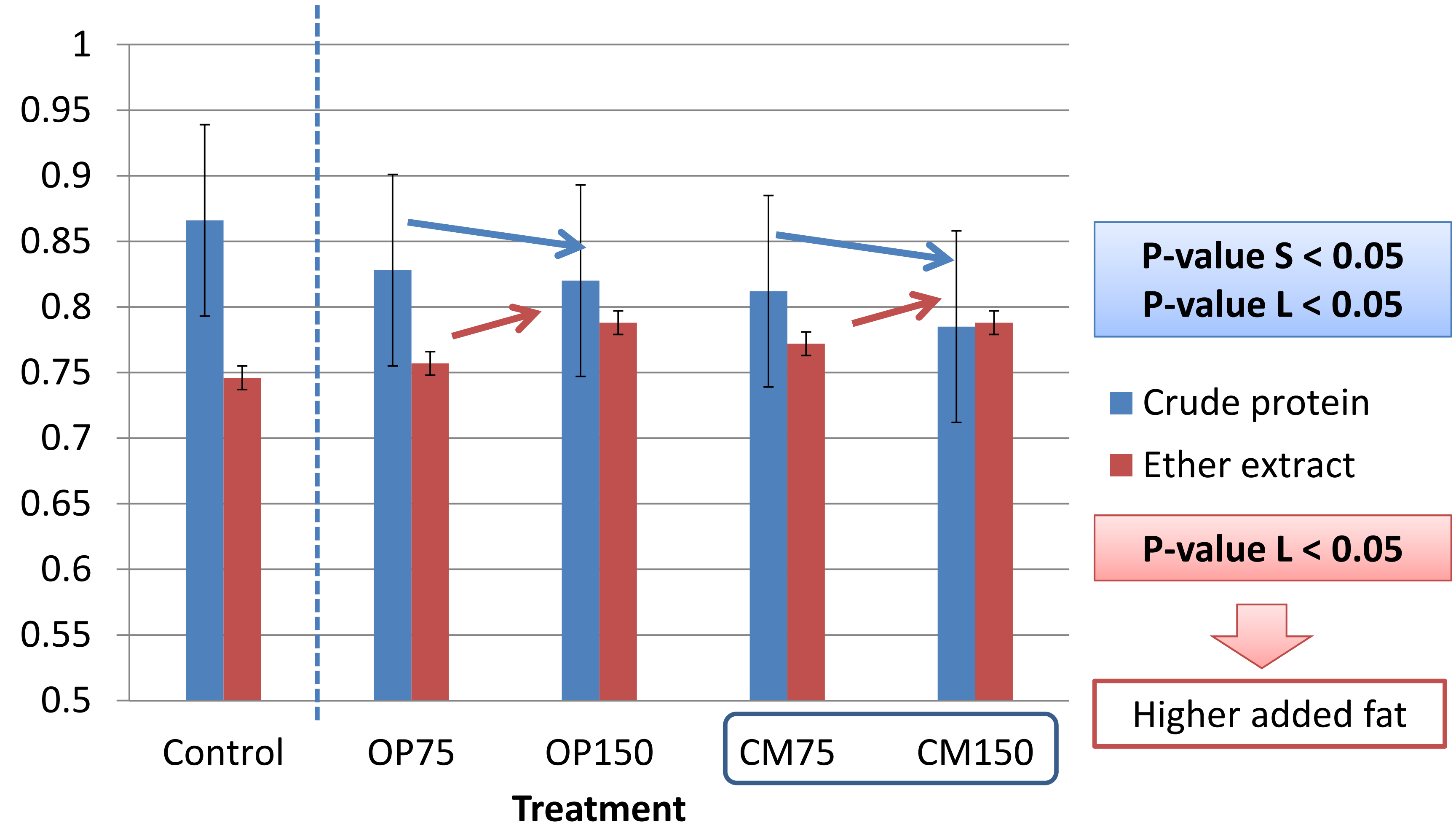
Nutrient balance



In respect to **Control:**

- Diets with **CM** showed lower (P<0.05) OM, GE, NDF, ADL and ADL digestibility
- Diets with **OP** showed **similar GE digestibility** and higher (P<0.05) NDF and ADF

Nutrient balance



In respect to **Control** , diets with **BY-PRODUCTS** showed lower (P<0.05) CP digestibility

Nutrient balance

	Treatments						Significance		
	Control	**OP75**	**OP150**	**CM75**	**CM150**	**SEM**	**S**	**L**	**S x L**
Dry matter	0.868	0.852	0.868	0.835	0.820	0.005	<0.001	0.860	0.004
Organic matter	0.884	0.868	0.880	0.852	0.835	0.004	<0.001	0.402	0.002
Crude protein	0.866	0.828	0.820	0.812	0.785	0.073	0.003	0.031	0.230
Ether extract	0.746	0.757	0.788	0.772	0.788	0.009	0.448	0.025	0.447
NDF	0.572	0.577	0.645	0.523	0.447	0.009	<0.001	0.654	<0.001
ADF	0.368	0.395	0.535	0.317	0.218	0.019	<0.001	0.297	<0.001
ADL	0.216	0.172	0.398	0.332	0.115	0.051	<0.007	0.060	0.032
Gross energy	0.872	0.855	0.863	0.835	0.820	0.004	<0.001	0.451	0.016

Faeces composition

In respect to Control:

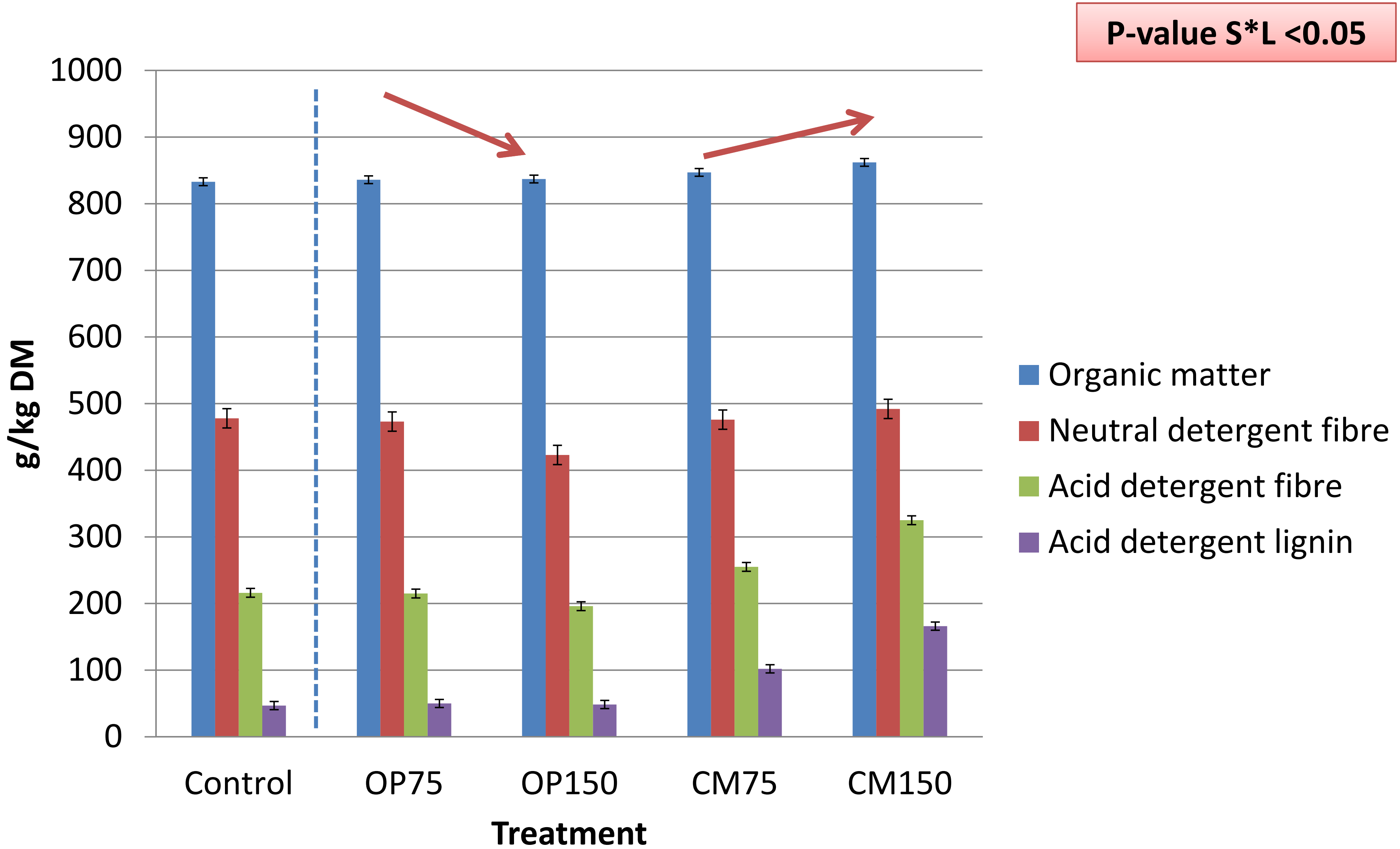
- Diets with **CM** showed higher ($P<0.05$) OM and NDF, A
  concentration.
- All diets with **BY-PRODUCTS** showed higher ($P<0.05$) CP (**organic N**)

By-products increase organic N concentration

Among the diets including by-products:

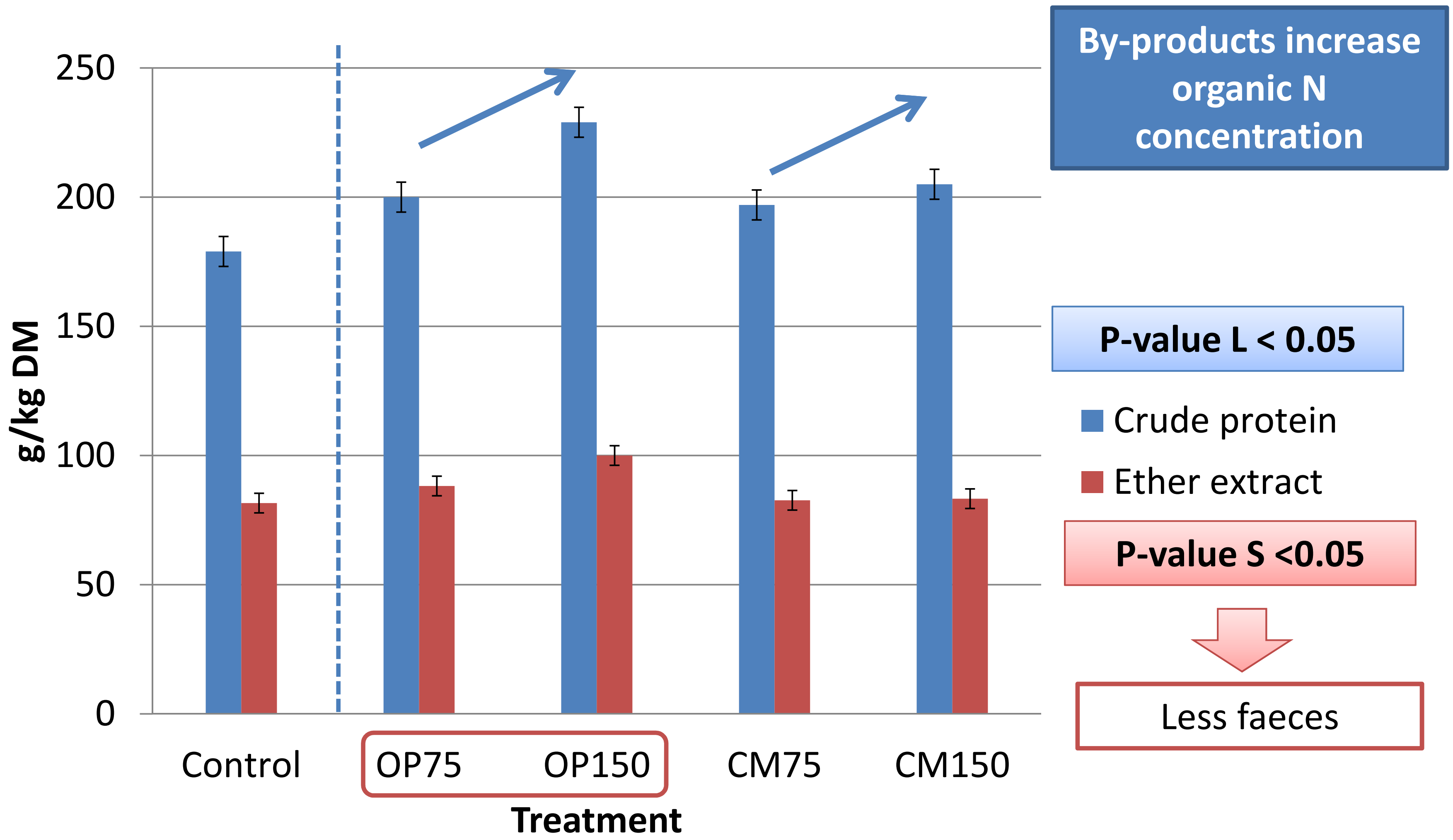
- **OM and NDF, ADF and ADL** concentration **depend on the source of fibre**, decreased with the level in OP diets but increased with the level in CM diets ($P_{(SxL)}<0.05$).
- **CP** content increase with the **inclusion level** ($P_{(L)}<0.05$), independently of the by-product.
- **Fat** content was higher in diets with **OP** ($P_{(S)}<0.05$) due to less faeces?
- In combination,

Faeces composition



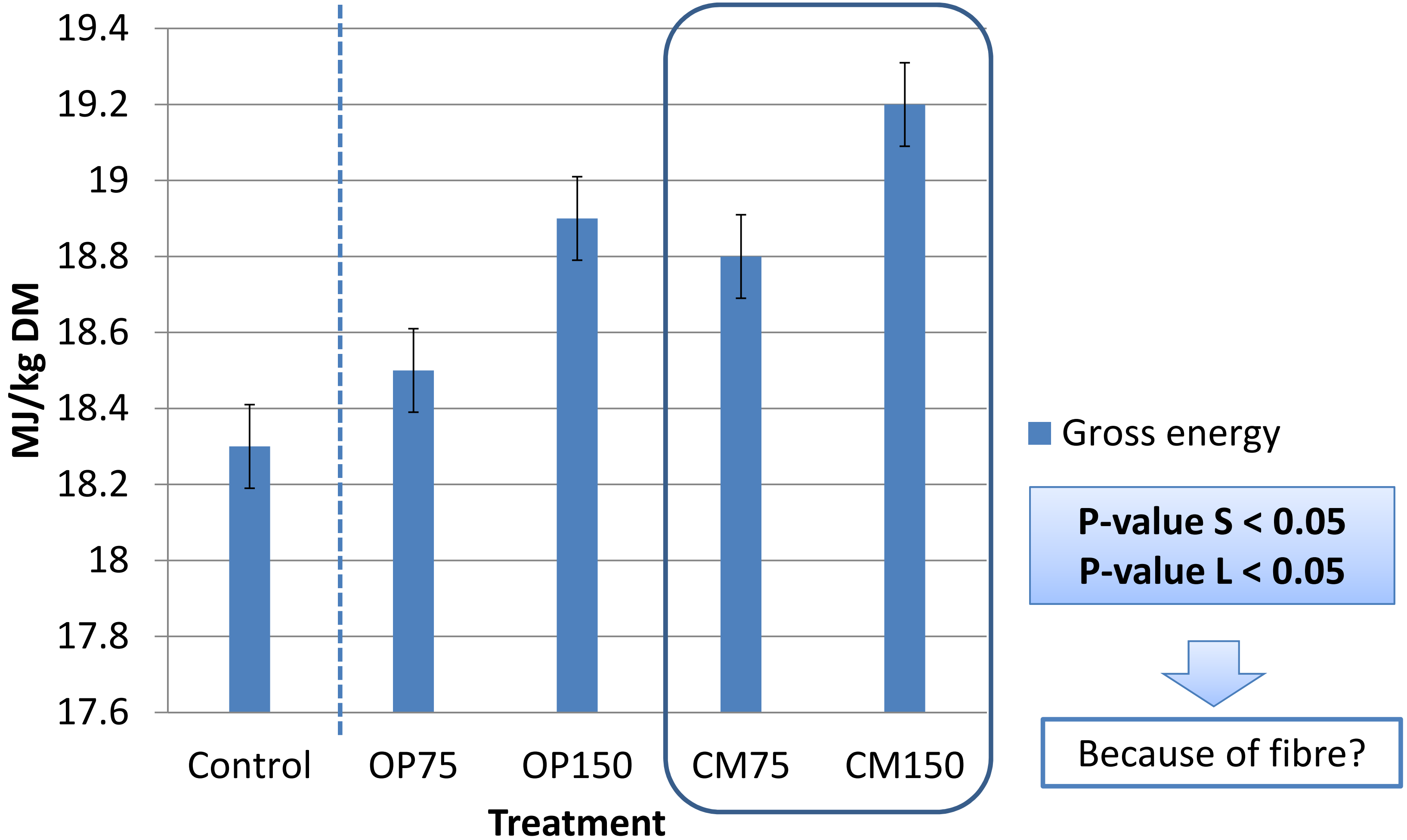
In respect to **Control**, diets with **CM** showed higher (P<0.05) OM and NDF, ADL and ADL

Faeces composition



In respect to **Control**, diets with **BY-PRODUCTS** showed higher (P<0.05) CP (**organic N**)

Faeces composition

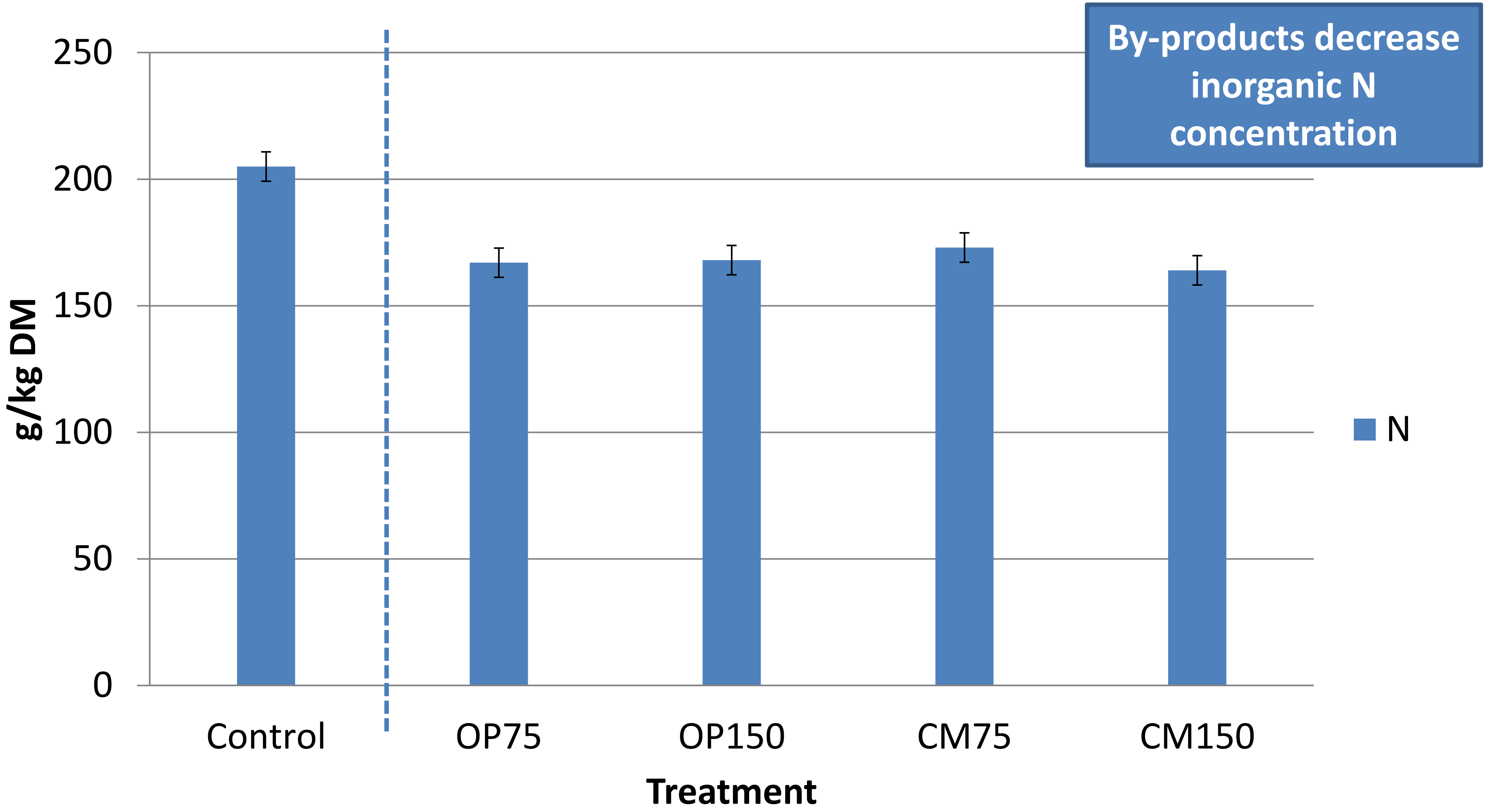


In respect to **Control**, diets with **BY-PRODUCTS** showed higher (P<0.05) GE (except OP75)

Faeces composition (g/kg DM)

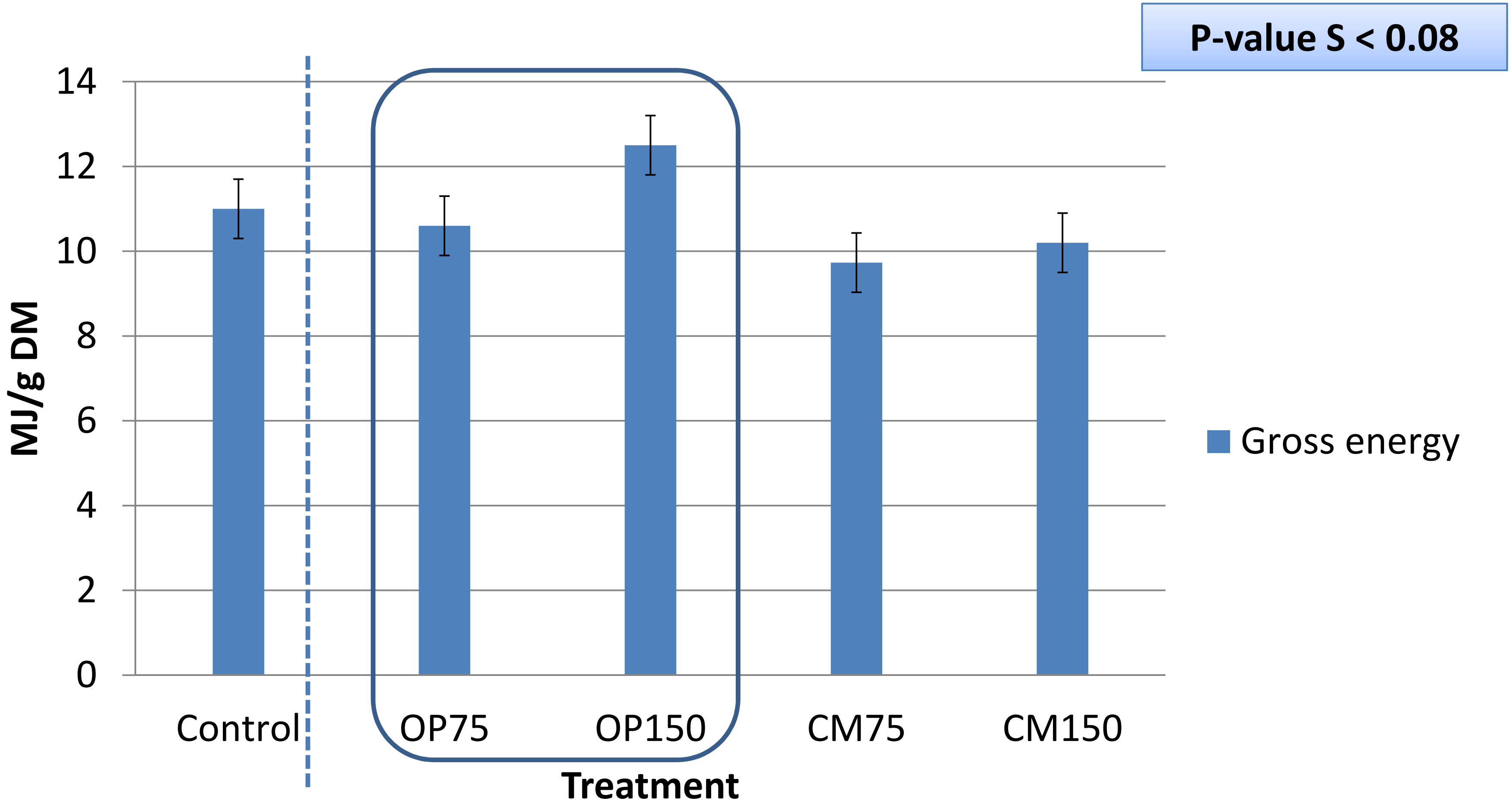
	Treatments						Significance		
	Control	OP75	OP150	CM75	CM150	SEM	S	L	S x L
Faeces									
Organic matter	833	836	837	847	862	3.0	<0.001	0.022	0.034
Crude protein	179	200	229	197	205	5.8	0.065	0.014	0.131
Ether extract	81.6	88.2	100	82.7	83.3	3.8	0.007	0.108	0.147
NDF	478	473	423	476	492	14.5	0.003	0.120	0.005
ADF	216	215	196	255	325	6.6	<0.001	0.002	<0.001
ADL	46.8	50.0	48.4	102	166	6.1	<0.001	0.001	0.001
Gross energy (MJ/kg DM)	18.3	18.5	18.9	18.8	19.2	0.11	0.016	0.002	0.997
pH	6.60	6.70	6.55	6.62	6.59	0.092	0.796	0.294	0.450

Urine composition



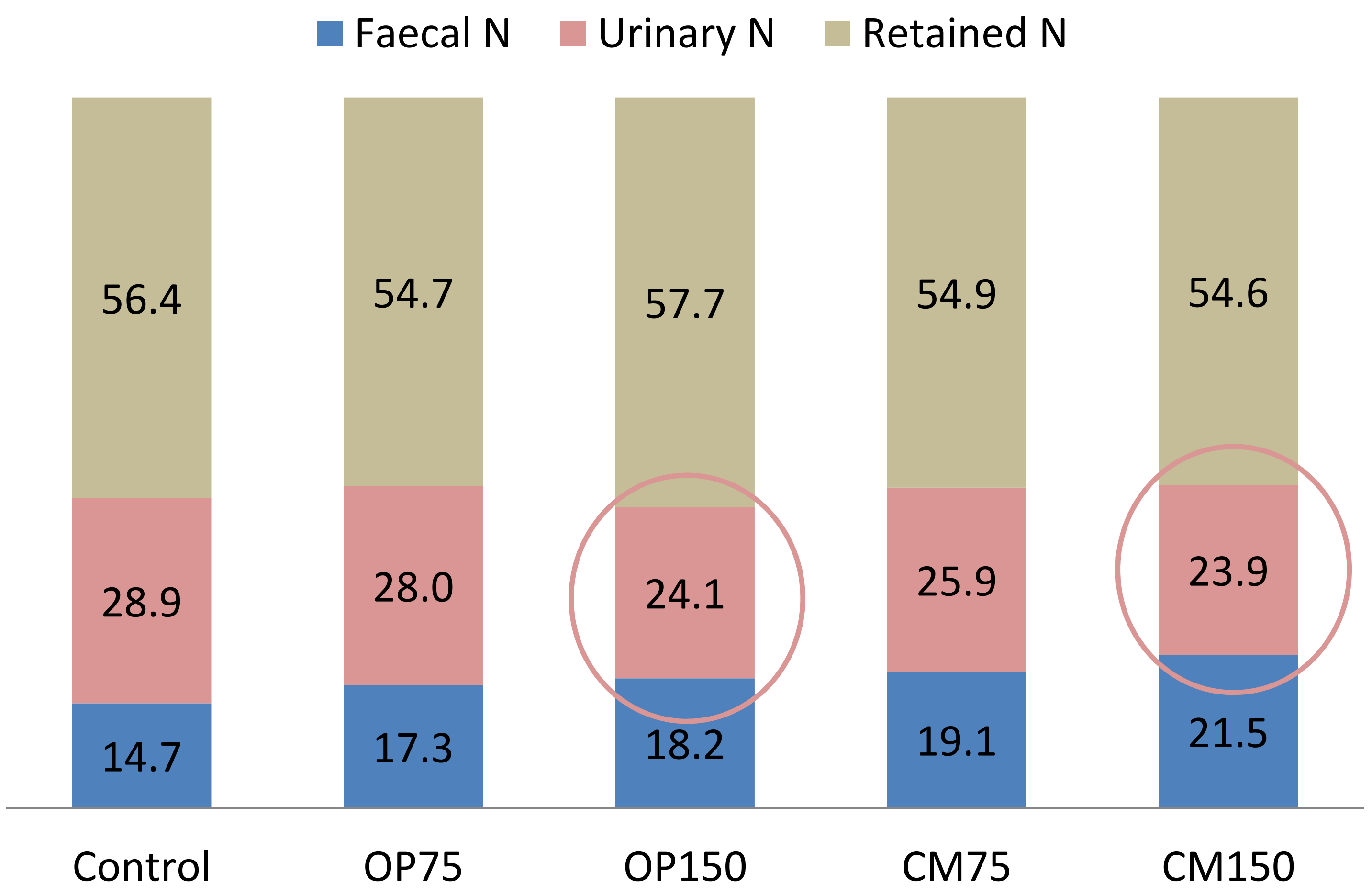
In respect to **Control**, diets with **BY-PRODUCTS** showed lower (P<0.05) CP (**inorganic N**)

Urine composition



	Control	OP75	OP150	CM75	CM150	SEM	S	L	S x L
(DE-UE)/DE	0.975	0.972	0.969	0.973	0.973	0.002	0.093	0.558	0.250

N balance (% of ingested)



Slurry characteristics

Treatments	Control	OP75	OP150	CM75	CM150	SEM	Significance		
							S	L	S x L
DM (g/kg)	136.8	109.2	114.5	100.6	121.7	13.43	0.958	0.324	0.554
OM (g/kg)	108.7	87.3	91.9	82.0	99.9	10.97	0.899	0.305	0.541
Total Kjeldahl N (TKN, g/L)	9.89	8.27	7.73	7.26	8.70	1.04	0.980	0.620	0.282
pH[a,b]	6.86	8.00	7.41	8.17	7.49	0.232	0.601	0.011	0.844
Total volatile fatty acids (mmol/kg)	68.13	84.8	78.1	67.1	73.8	9.20	0.242	0.989	0.459

[a] Contrast C vs OP75 P<0.05

[b] Contrast C vs CM75 P<0.05

Slurry characteristics

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[a] Contrast C vs OP75 $P<0.05$

[b] Contrast C vs CM75 $P<0.05$

- **OP150 and CM150 should emit less NH_3 (combination of less N and lower pH)**
- **pH is not related with VFA in this case**

NH_3 and CH_4 emission

Treatments	Control	OP75	OP150	CM75	CM150	SEM	Significance		
							S	L	S x L
NH_3									
g NH_3/ L slurry[1]	2.44	1.84	1.64	1.76	1.99	0.205	0.409	0.973	0.135
g N-NH_3/ kg initial TKN	207	209	169	205	186	16.0	0.694	0.059	0.495
g NH_3/animal and day	8.57	8.29	6.09	7.98	8.57	0.838	0.222	0.358	0.123
CH_4									
B_0, ml methane /g OM	353.0	392.5	332.1	360.6	325.6	26.44	0.412	0.052	0.586
L methane /animal and day	117.8	133.9	115.7	129.1	143.7	10.30	0.257	0.855	0.117

[1] Contrast C vs OP150 $P<0.05$

NH_3 and CH_4 emission

Treatments	Control	OP75	OP150	CM75	CM150				
NH_3									
g NH_3/ L slurry[1]	2.44	1.84	1.64	1.76	1.99	[illegible]	[illegible]	[illegible]	[illegible]
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[1] Contrast C vs OP150 P<0.05

Lower proportion of volatilizable N (urinary N) + lower pH = lower NH_3 emission

NH_3 and CH_4 emission

Treatments	Control	OP75	OP150	CM75	CM150				
NH_3									
g NH_3/ L slurry[1]	2.44	1.84	1.64	1.76	1.99	[illegible]	[illegible]	[illegible]	[illegible]
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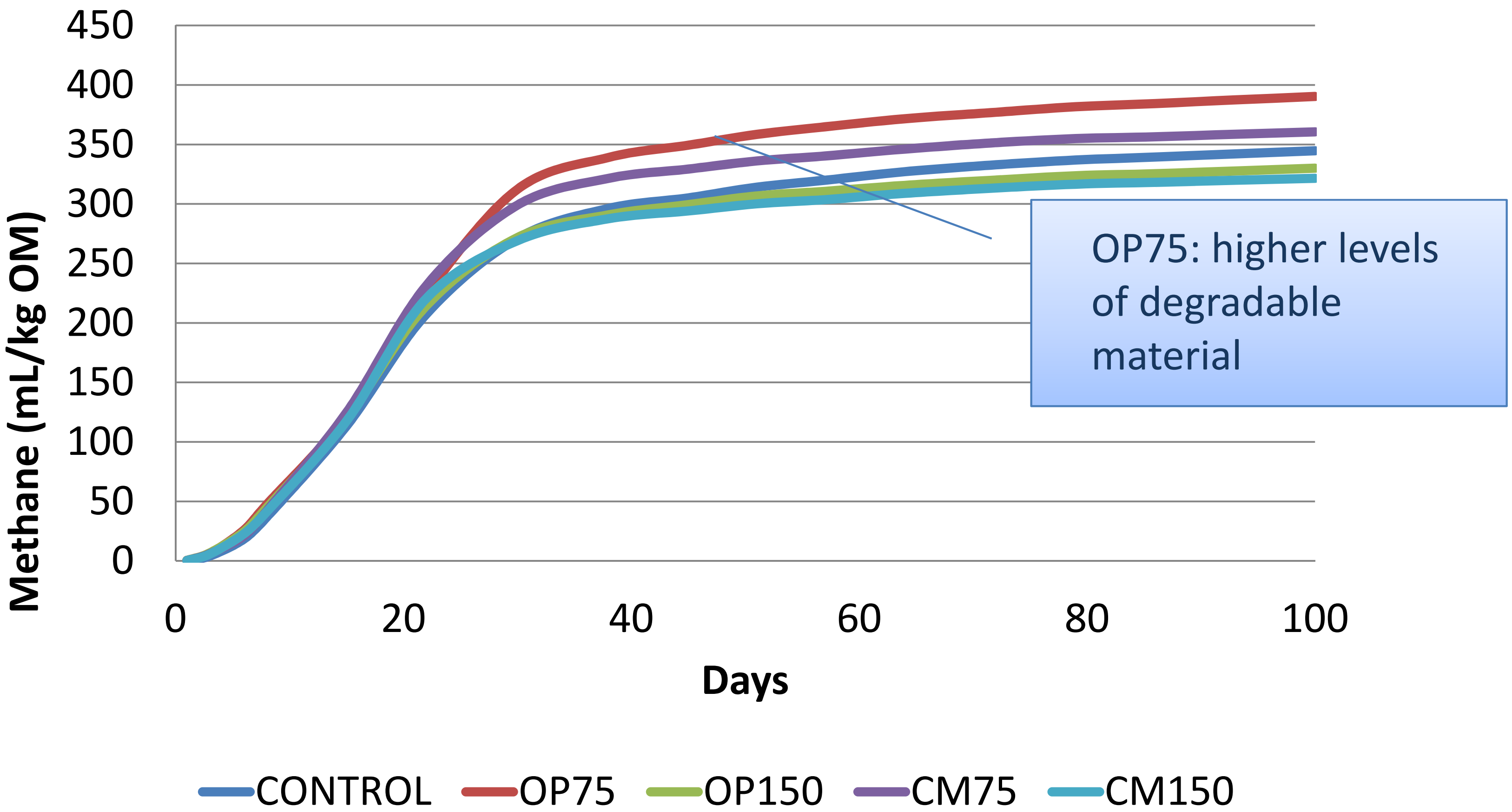
[1] Contrast C vs OP150 P<0.05

Lower proportion of volatilizable N (urinary N) + lower pH = lower NH_3 emission

No linear relationship between nutrient/GE concentration and CH_4. OM biodegradability? Other aspects such as pH?

Accumulated CH4 emission



Summary

- The inclusion of OP increases fibre digestibility and decreases CP digestibility not affecting energy digestibility compared to Control.
- As expected, CB reduced nutrient and energy digestibility and increase OM output.
- The inclusion of by-products increase the N concentration in faeces (organic N), especially the highest level of inclusion and decrease the N concentration in urine (inorganic N) compared to Control diet.
- In slurry, diets with by-products showed a lower N content and the diets with the highest fibre inclusion levels showed the lowest pH values (not related with VFA).
- The proportion of $N\text{-}NH_3$ emitted from the initial $N\text{-}NH_3$ is lower in diets OP150 and CB150 probably due to a combination of lower N and lower pH.
- The diets with the highest levels of by-products showed the lowest B0 showing no clear relationship between OM concentration and CH_4. Biodegradability or conditions (pH, N,…).

Conclusions

- There is a shift of N from urine to faeces with the inclusion of by-products which is **independent from the degree of lignification**. Different mechanisms? Microbial N vs undigested N?
- The amount of N-NH_3 finally emitted from slurry decreased with the inclusion of by-products **independently of the degree of lignification** (combination of pH and N concentration).
- Nutrient digestibility behave as expected and was not directly related with CH_4 potential, but affected the amount of CH_4 excreted by pig/day.

Future:

- N fractionation from faeces (dietary N, microbial N, soluble N)
- Improving the understanding of the complex relationship between nutrients in slurry and CH_4.
- Information to dictate BATs in Animal Nutrition.

Thank you for your attention!!

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