



DIGESTIBILITY OF CA AND P BY PIGS

Hans H. Stein

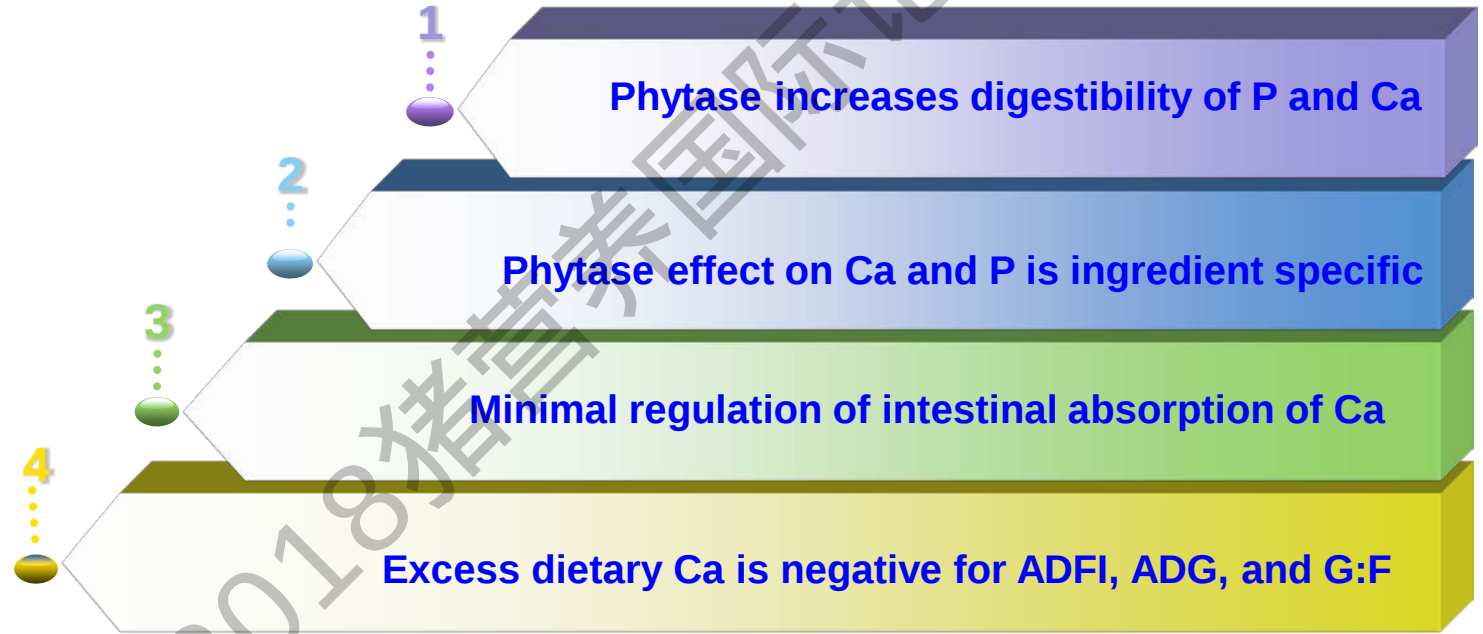
Division of Nutritional Sciences; Department of Animal Sciences

University of Illinois

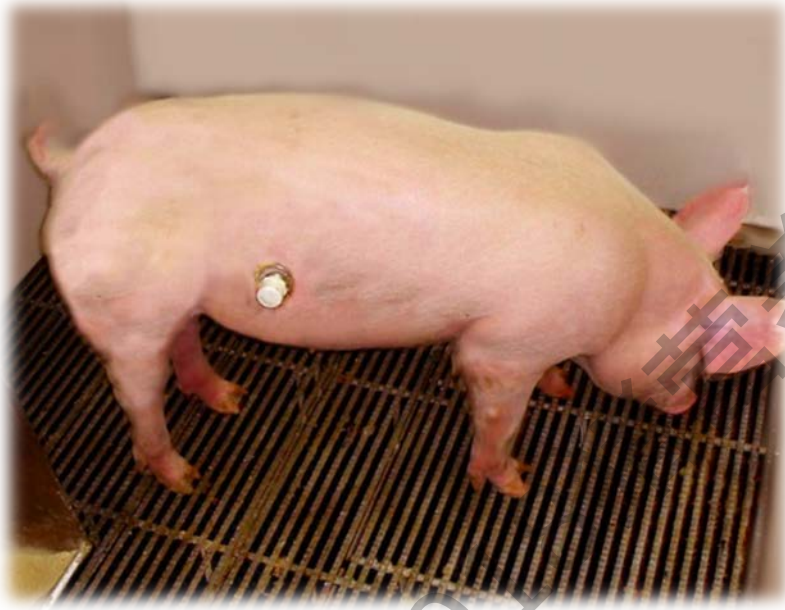
<http://nutrition.ansci.illinois.edu>



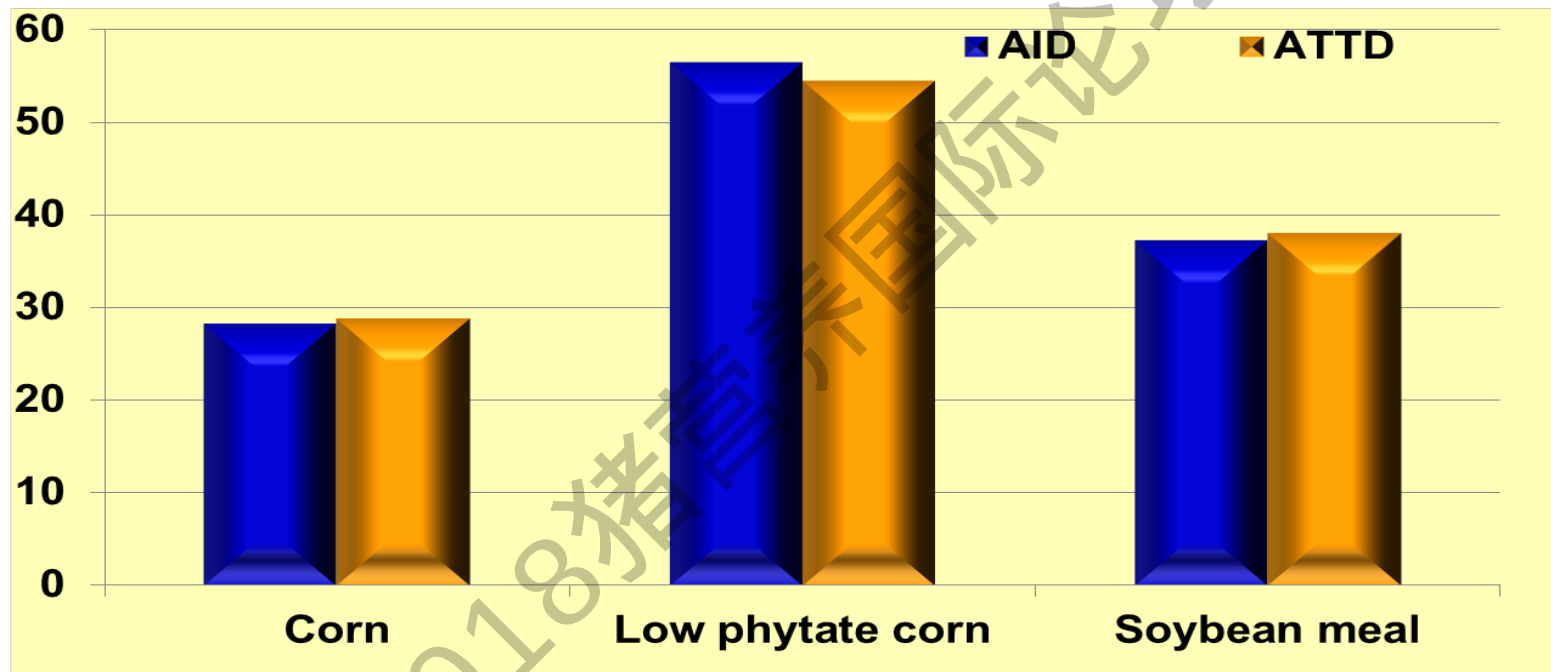
Take Home Messages



Questions on P-Digestibility

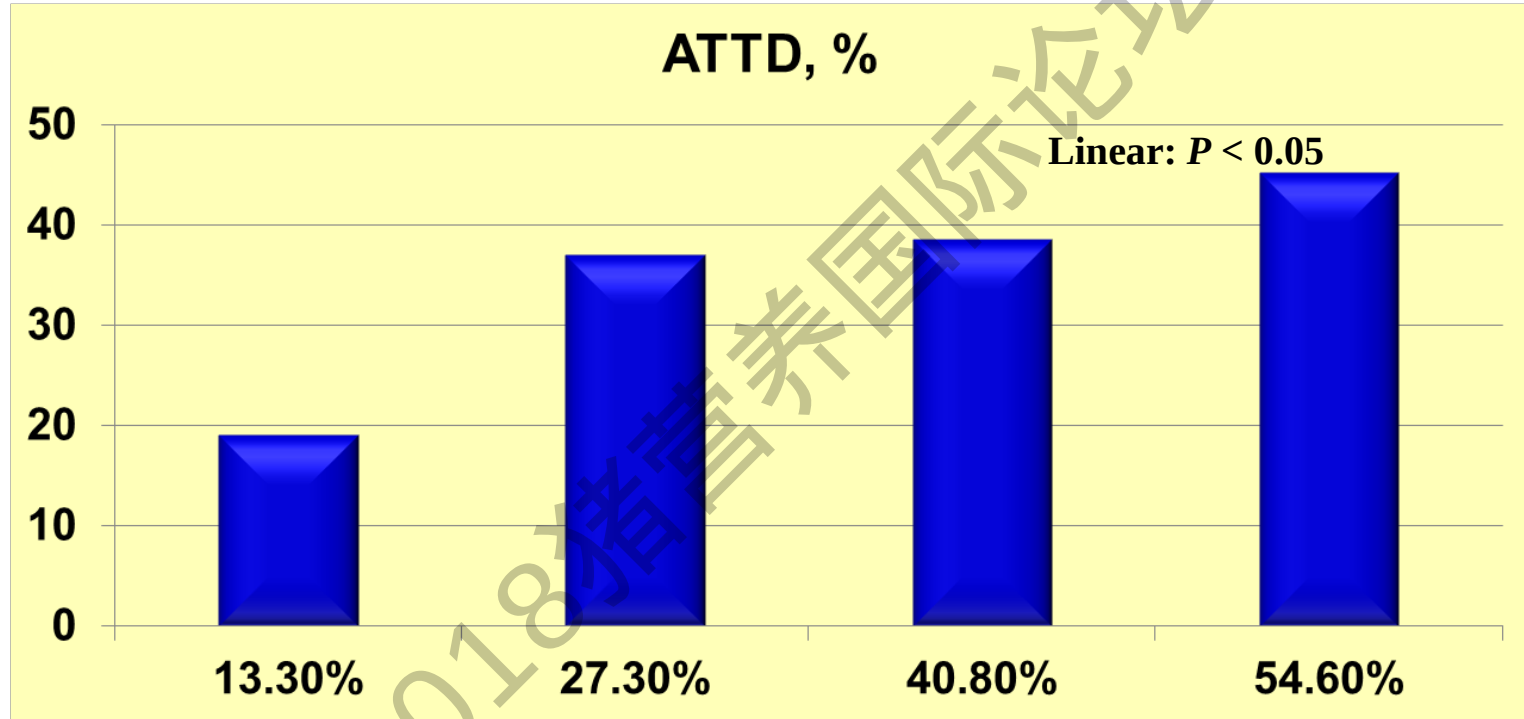


AID vs. ATTD for P



Bohlke et al., 2005

Challenges with ATTD values



Fan et al., 2001

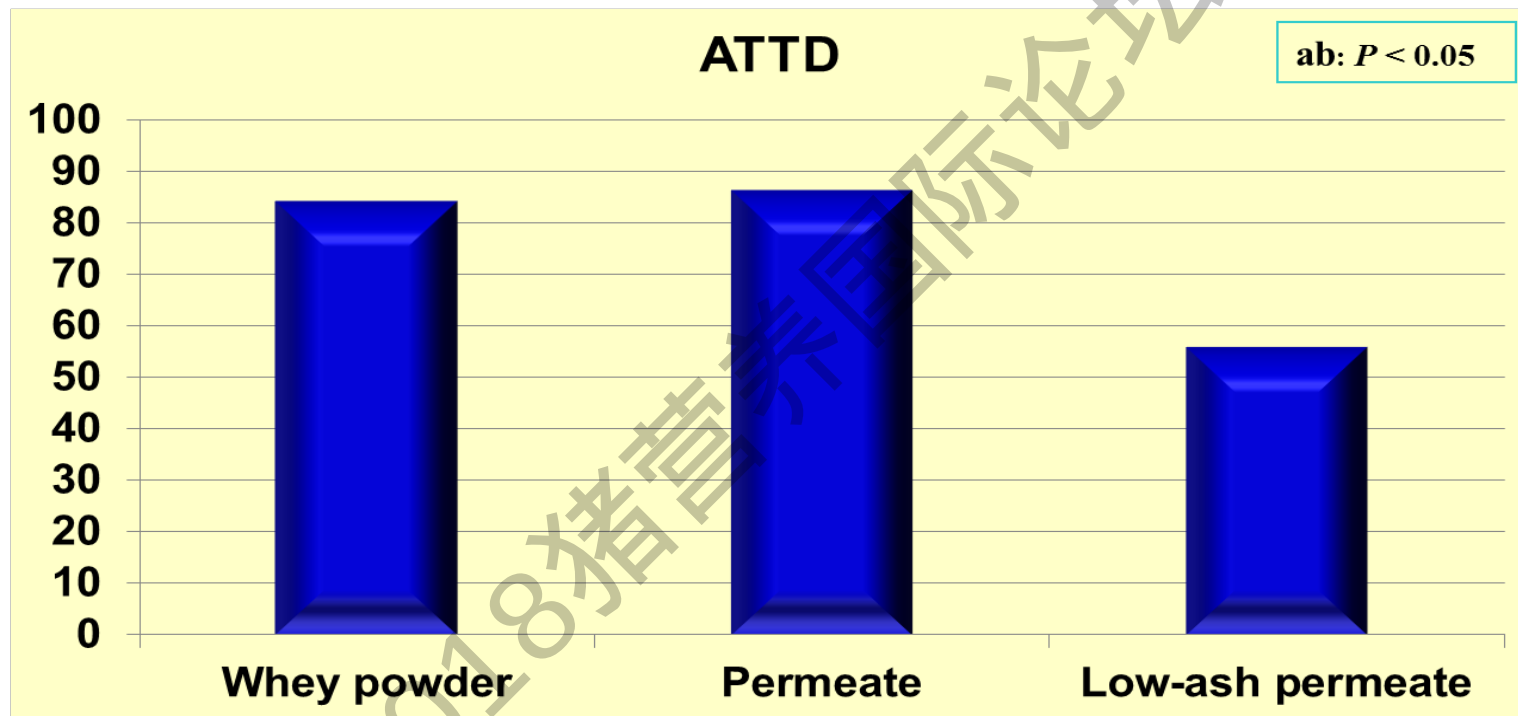


Whey Powder and Permeate

Item	Whey powder	Permeate	Low-ash permeate
DM	95.8	97.7	98.4
P, %	0.63	0.57	0.10

Kim et al., 2012

ATTD of P (%)



Kim et al., 2012

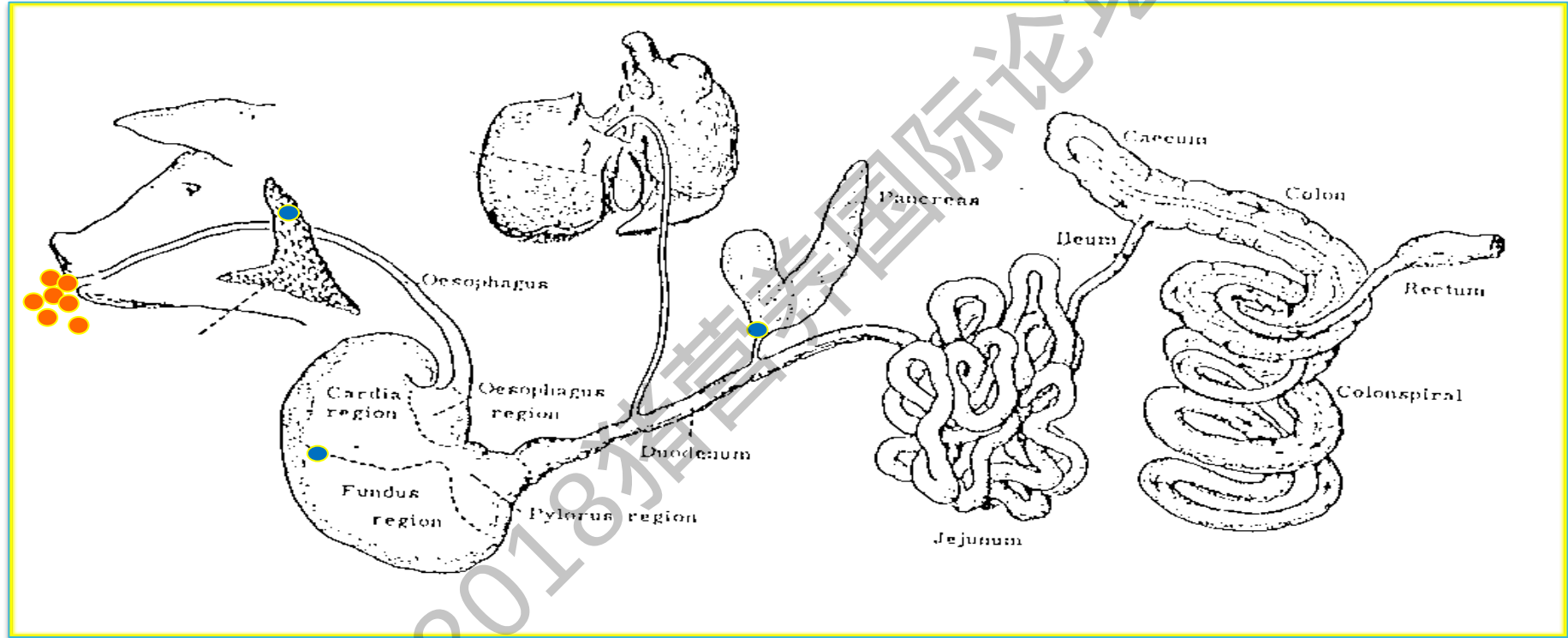
Endogenous losses



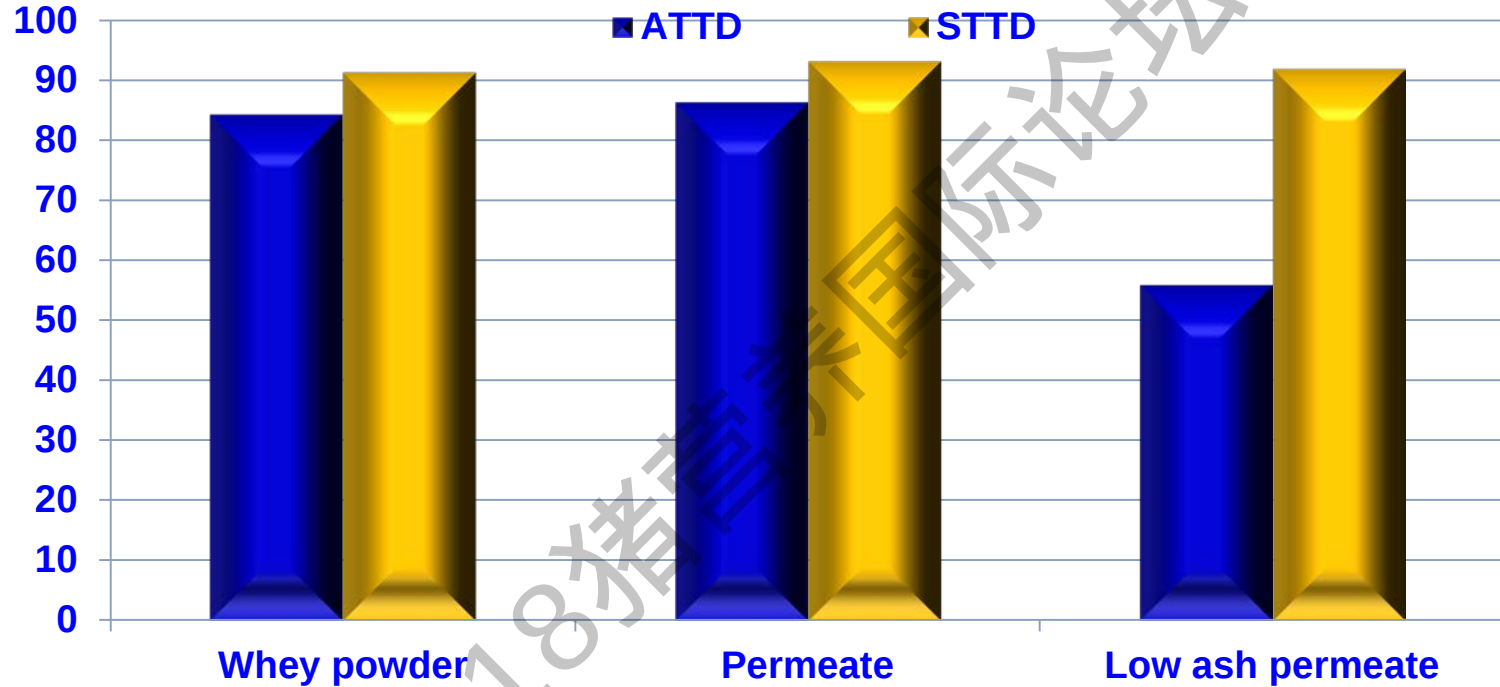
Nutrient from diet



Nutrient of endogenous origin

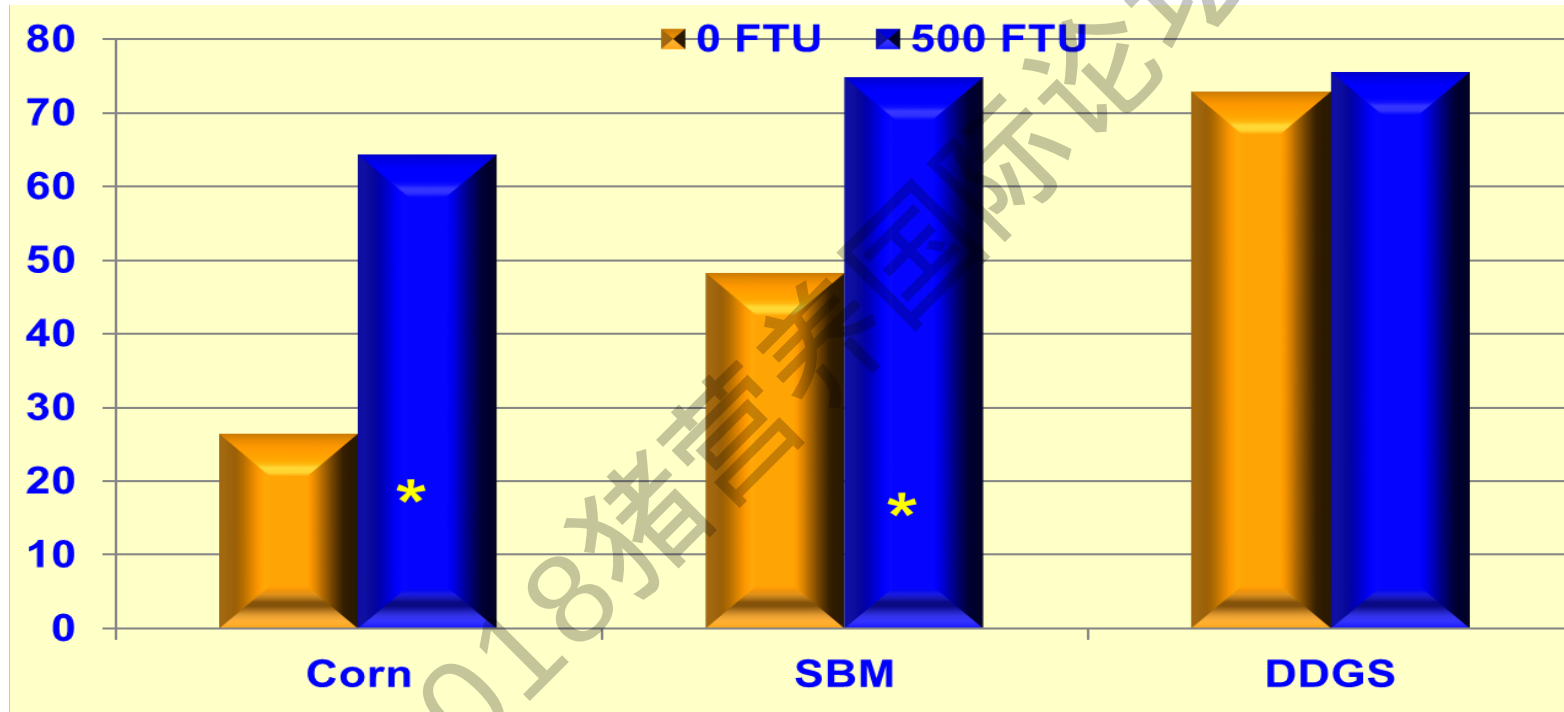


ATTD and STTD of P



Kim et al., 2012

Effect of Phytase (STTD, %)



Almeida and Stein, 2010

Digestibility of Calcium

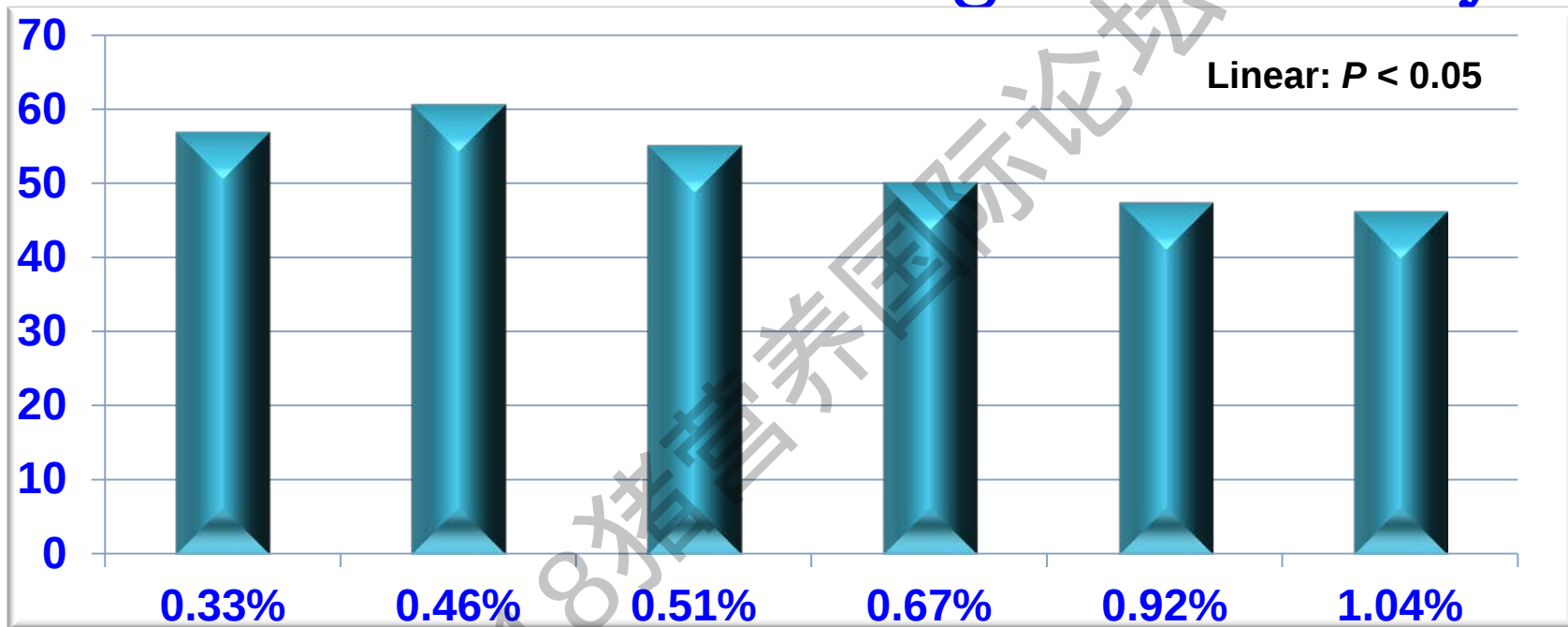
0.01–0.69% Ca



18.5–38.5% Ca



Effect of Ca on Digestibility



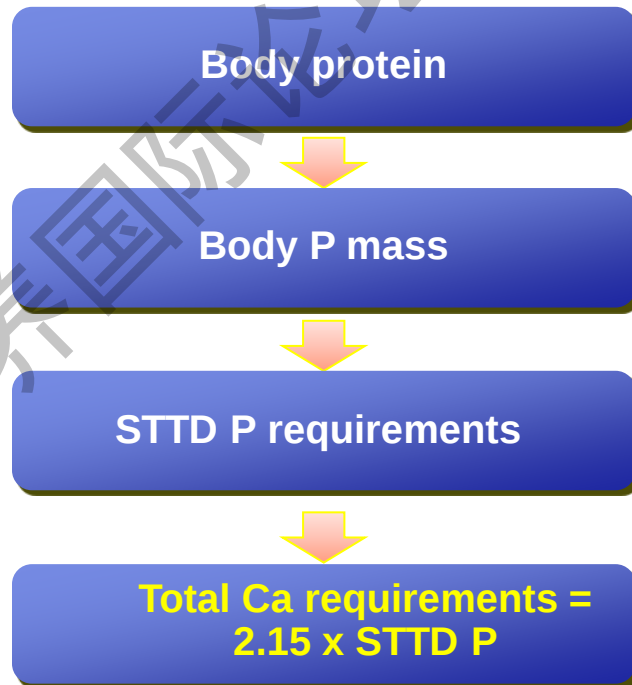
Stein et al., 2011

Requirements for Ca

Item	100 - 125 kg
Total Ca, %	0.46
STTD P, %	0.21



(NRC, 2012)



**Endogenous
losses**

**Phytate
Phytase
Fiber
Fat**

**Duodenal
Ileal
Total tract**



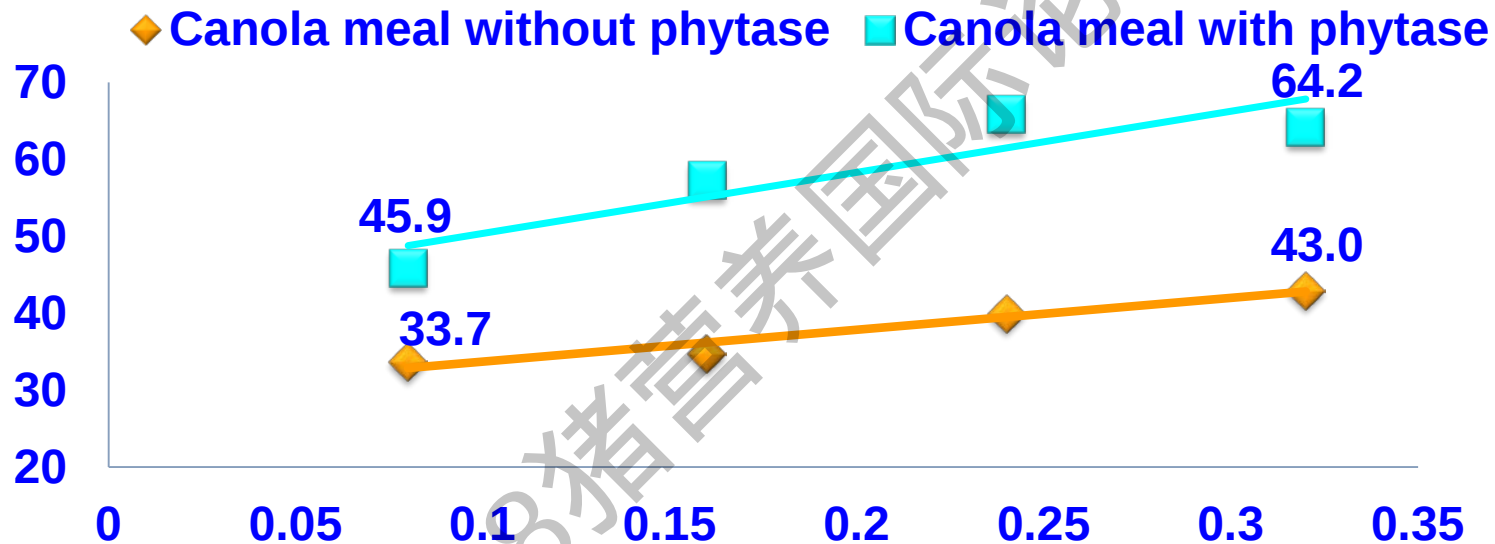
Duodenal, ileal, or total tract digestibility



Gonzalez-Vega et al., 2014

ATTD of Ca, %

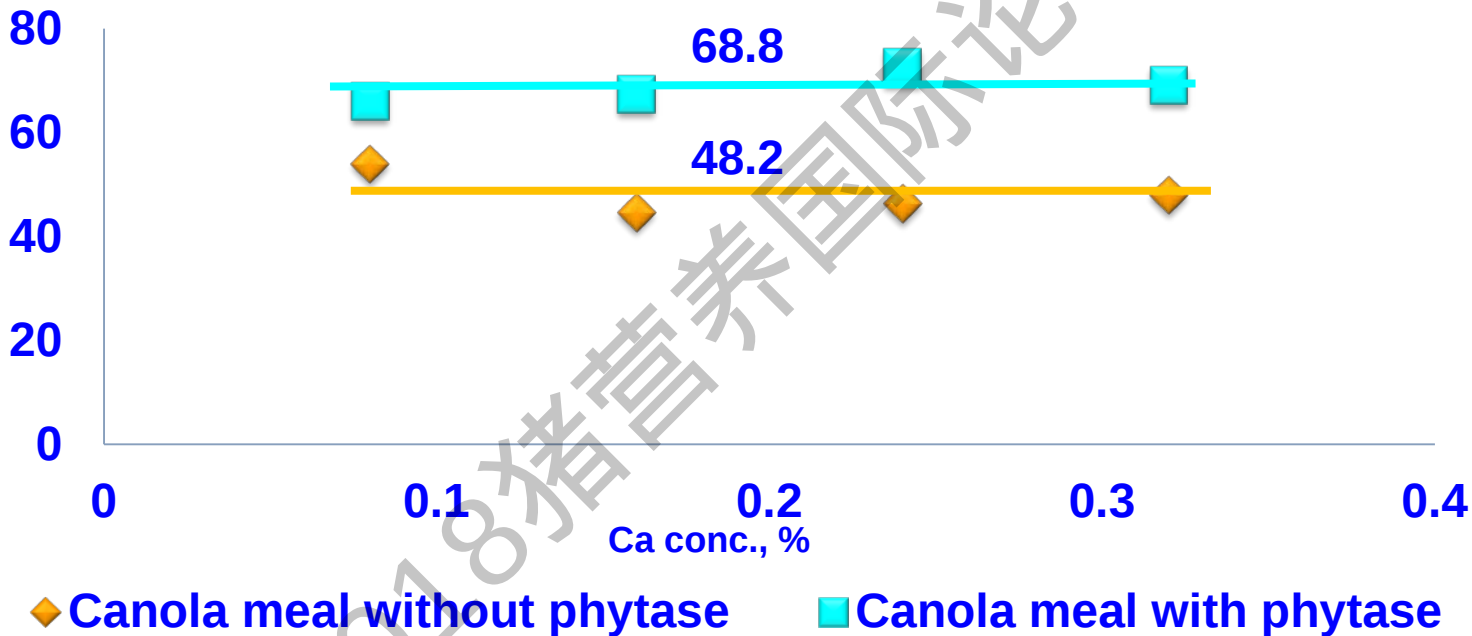
Ca level: $P = 0.03$; Phytase: $P < 0.01$; Ca $\times$ phytase: $P = 0.56$



González-Vega et al., 2013

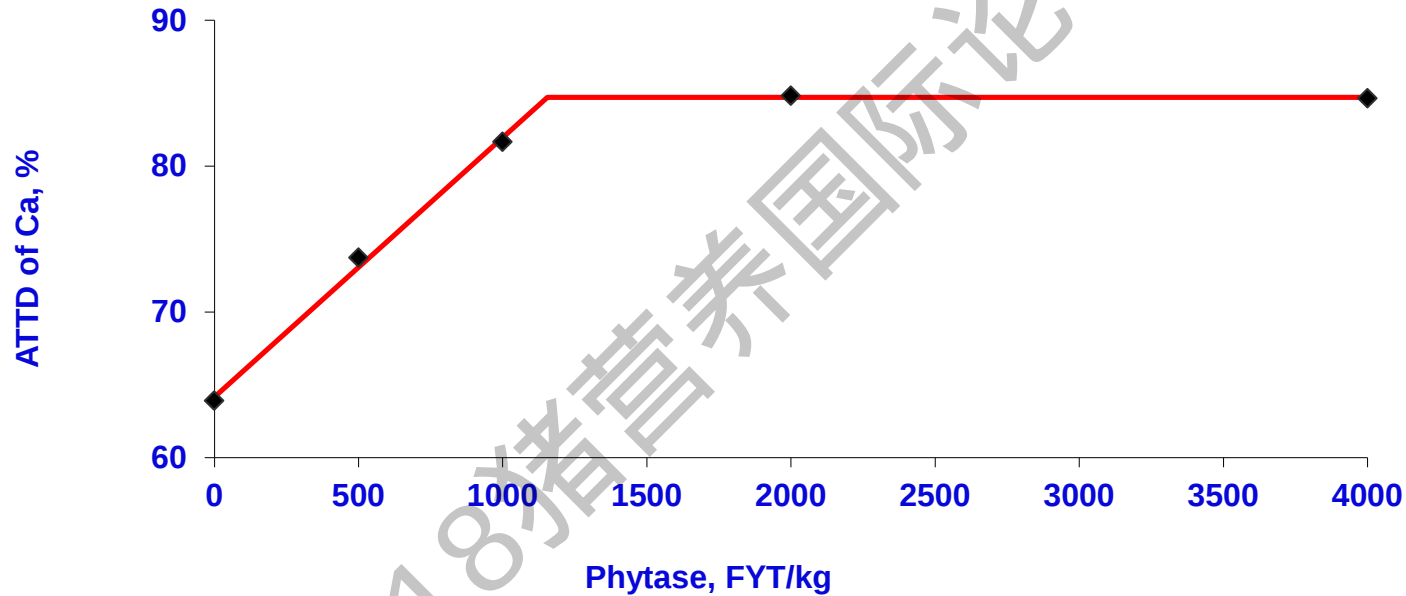
STTD of Ca, %

Ca level: $P = 0.86$; **Phytase: $P < 0.01$** ; Ca $\times$ phytase: $P = 0.55$



González-Vega et al., 2013

Phytase for Weanling Pigs



Almeida and Stein, 2013

Phytate

Phytate



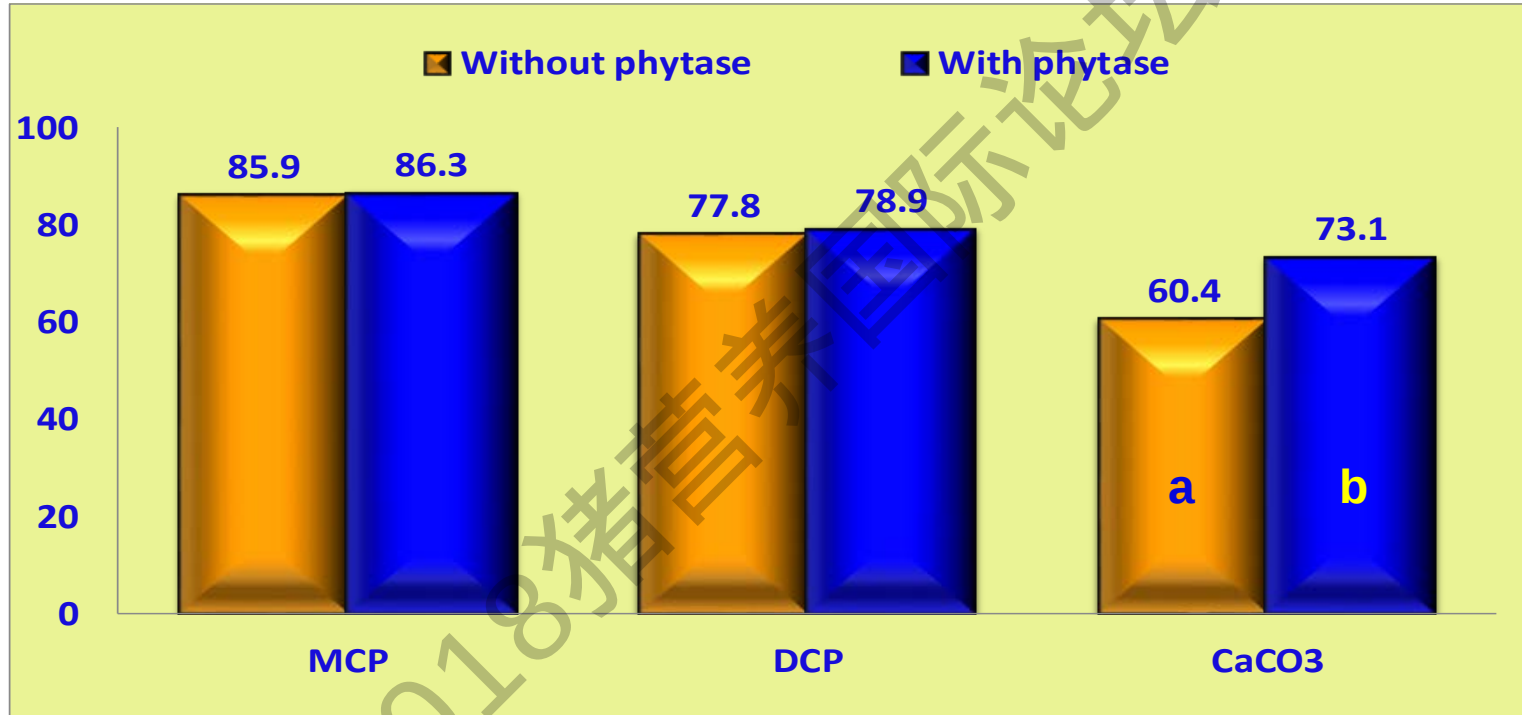
Phytate

Ca

Ca

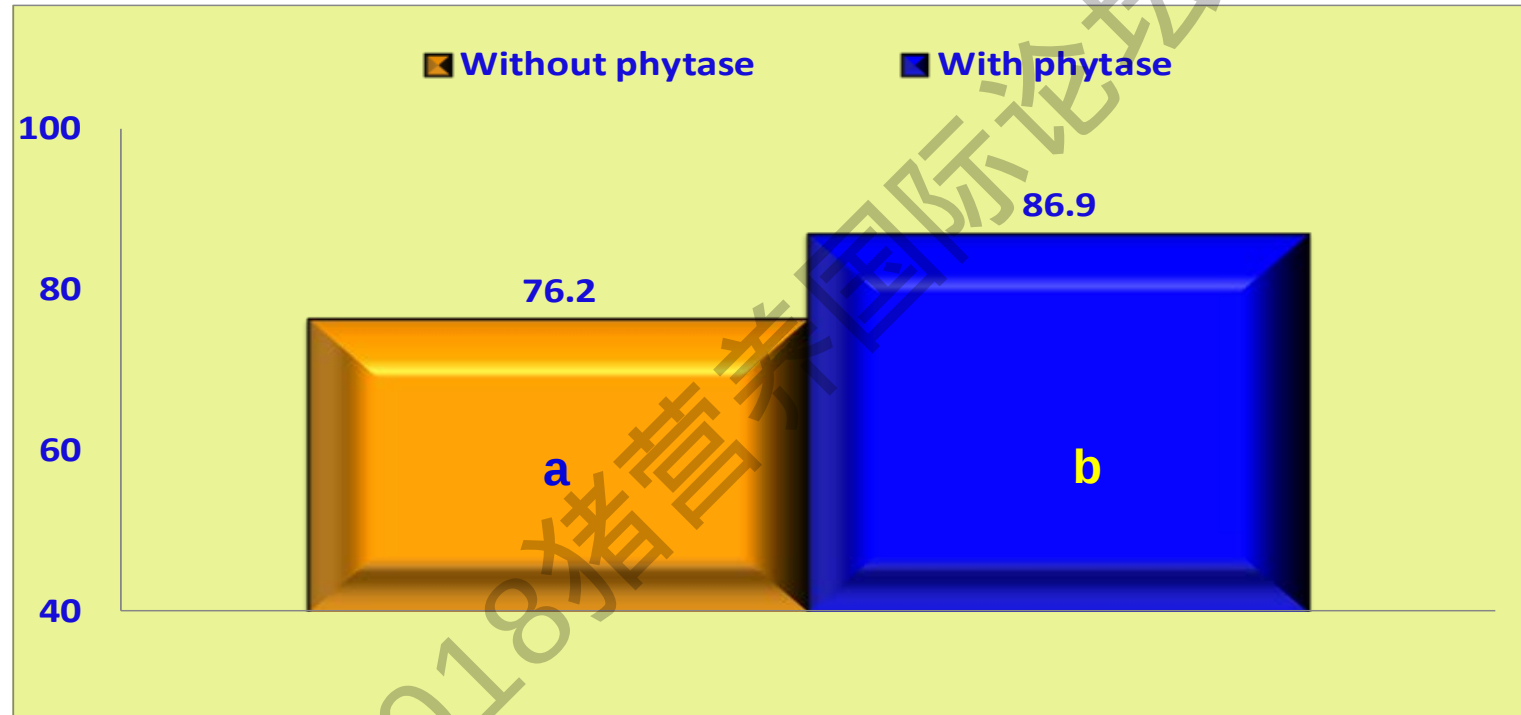
Ca

STTD of Ca (%) in Ca supplements



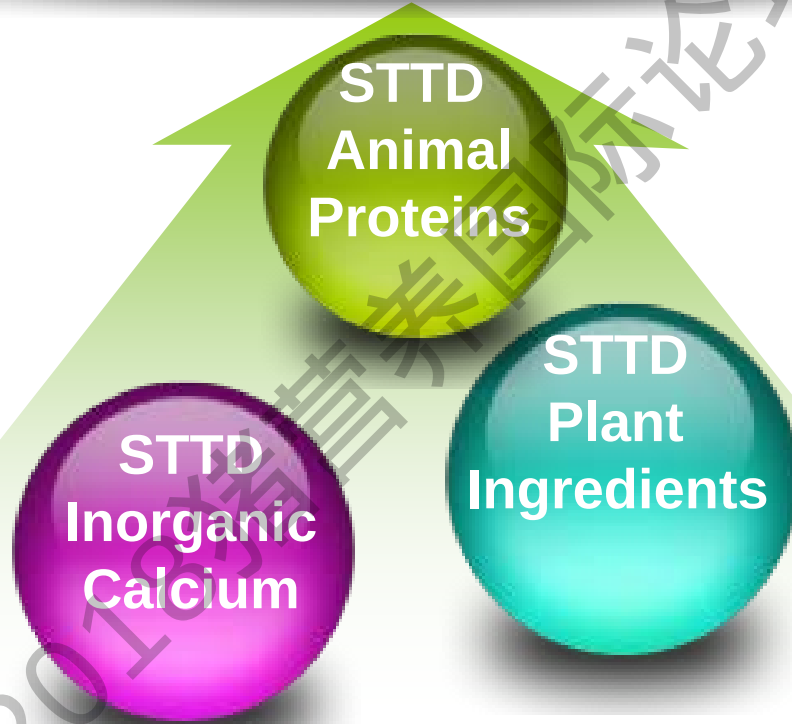
Gonzalez-Vega et al., 2015a

STTD of Ca (%) in Fish Meal



Gonzalez-Vega et al., 2015b

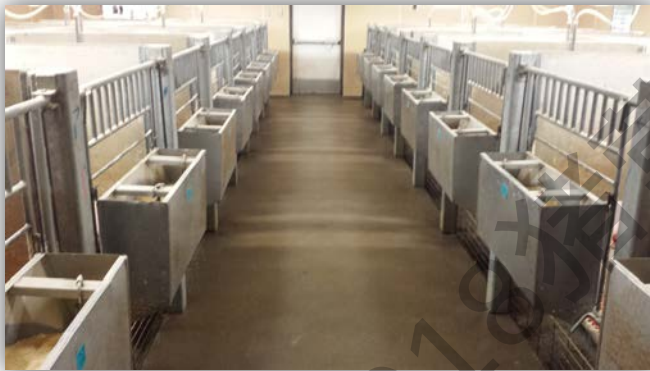
Diet Formulation



Requirement for Ca (11-25 kg)

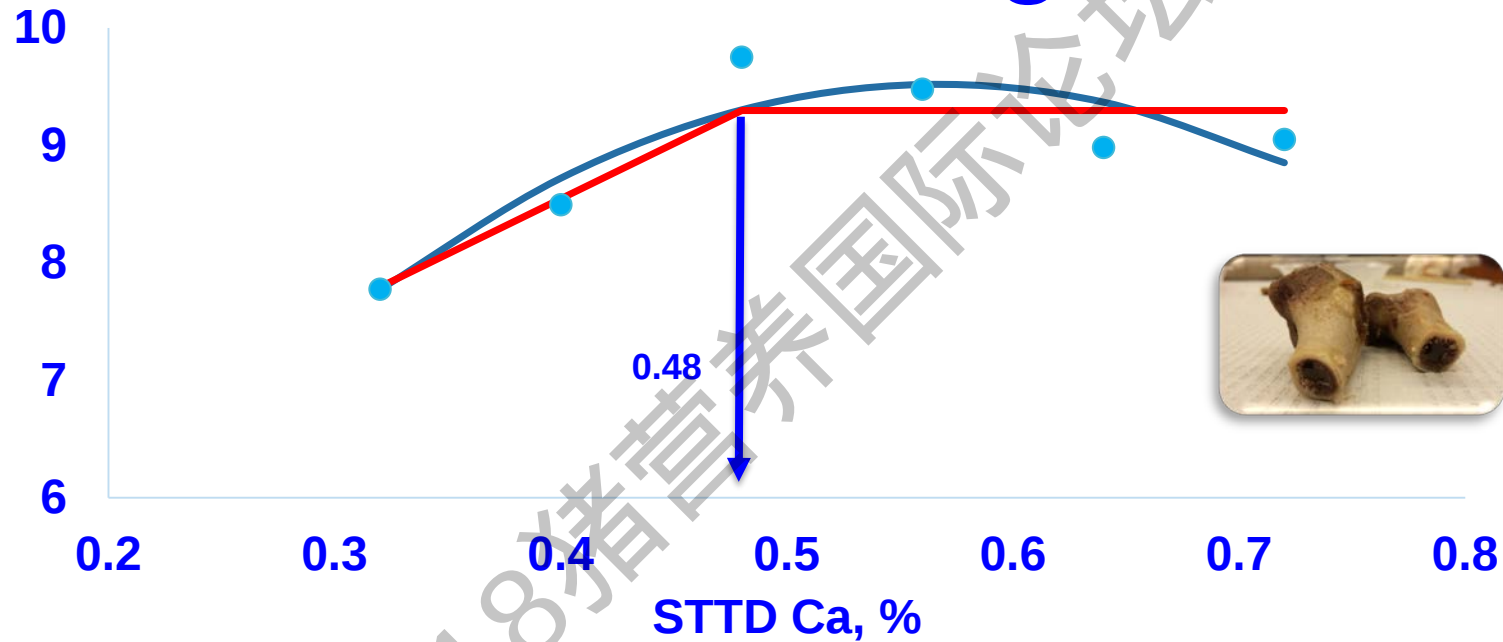
STTD Ca, %	0.32	0.40	0.48	0.56	0.64	0.72
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Total Ca, %	0.40	0.54	0.67	0.80	0.93	1.07
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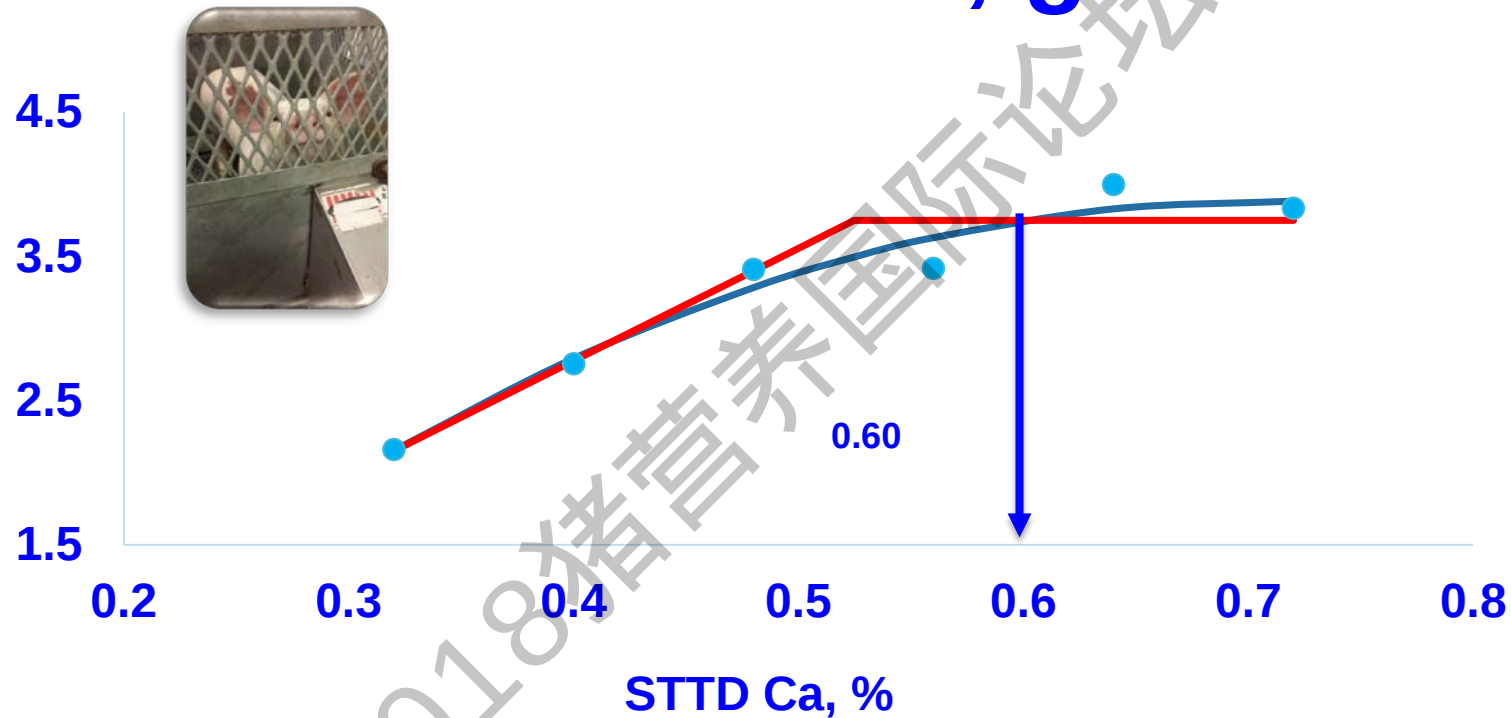
Gonzalez-Vega et al., 2016a

Bone ash, g



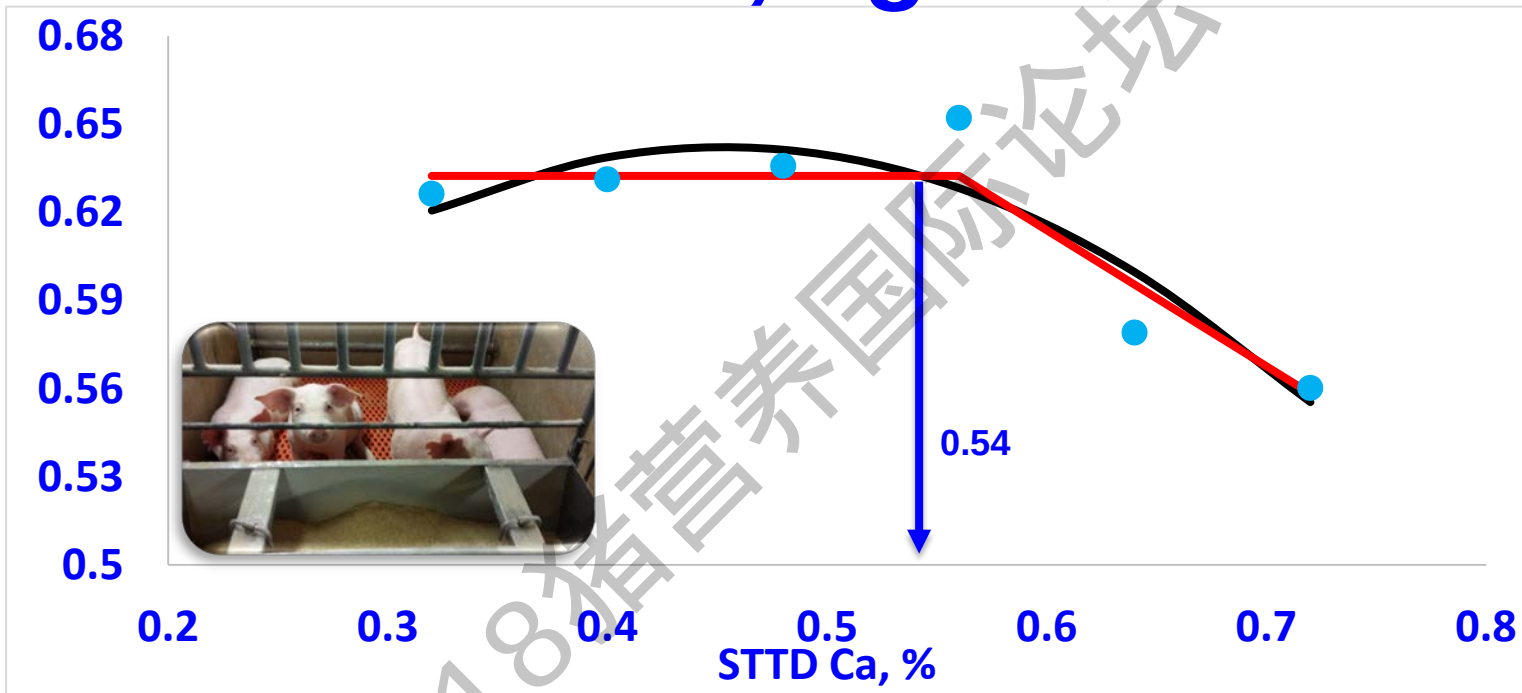
Gonzalez-Vega et al., 2016a

Ca retention, g/d



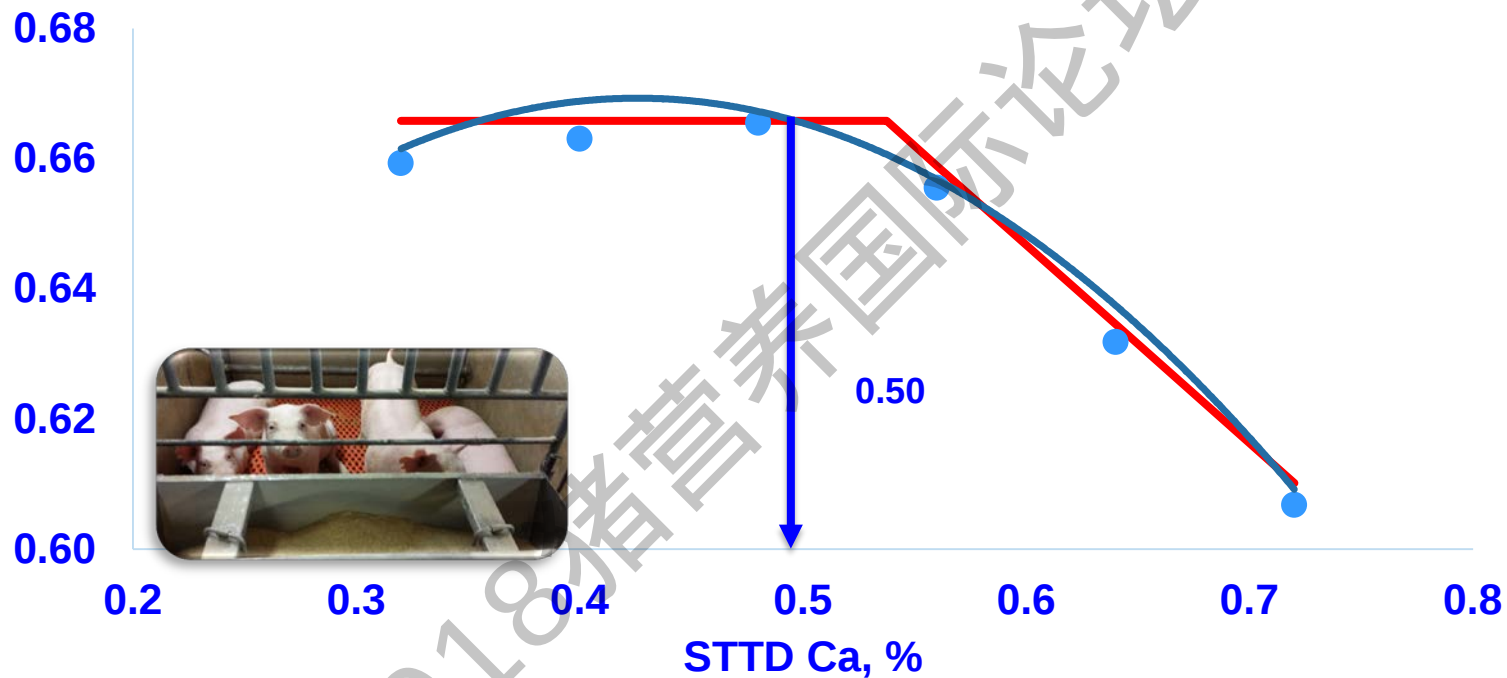
Gonzalez-Vega et al., 2016a

ADG, kg/d



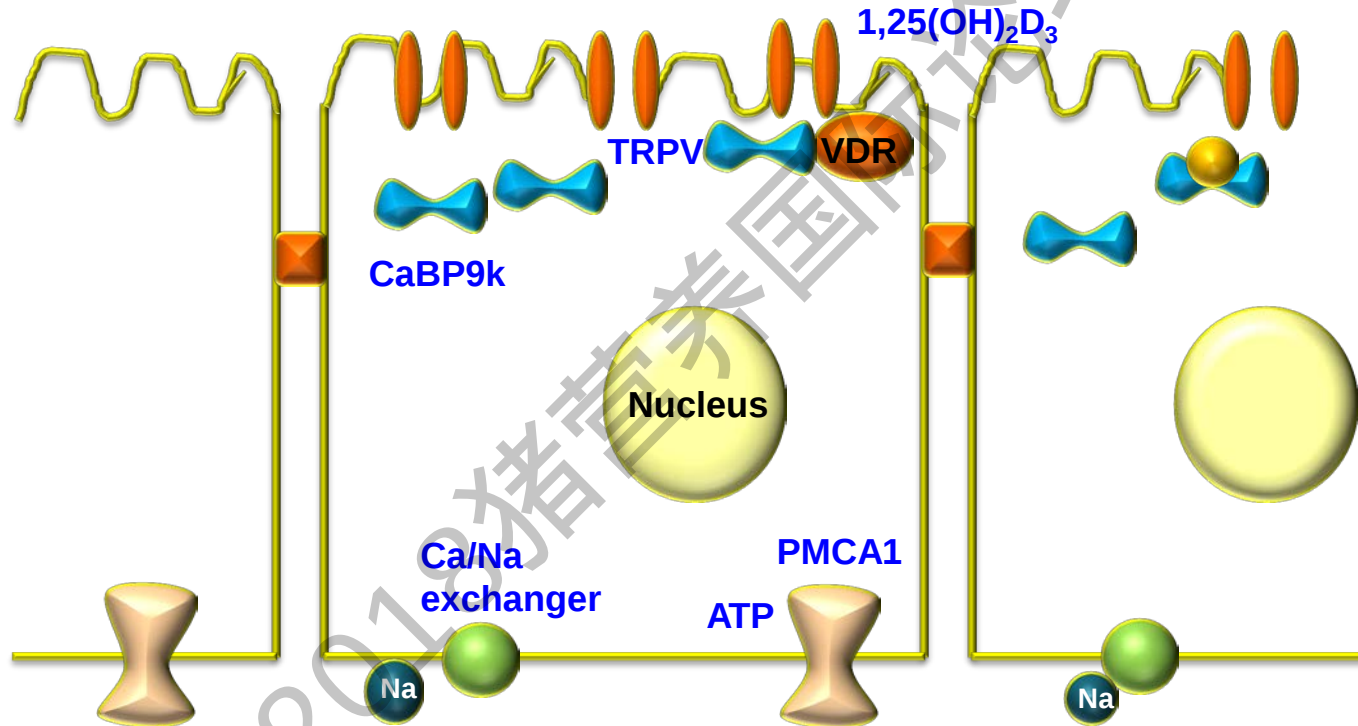
Gonzalez-Vega et al., 2016a

G:F, kg/kg



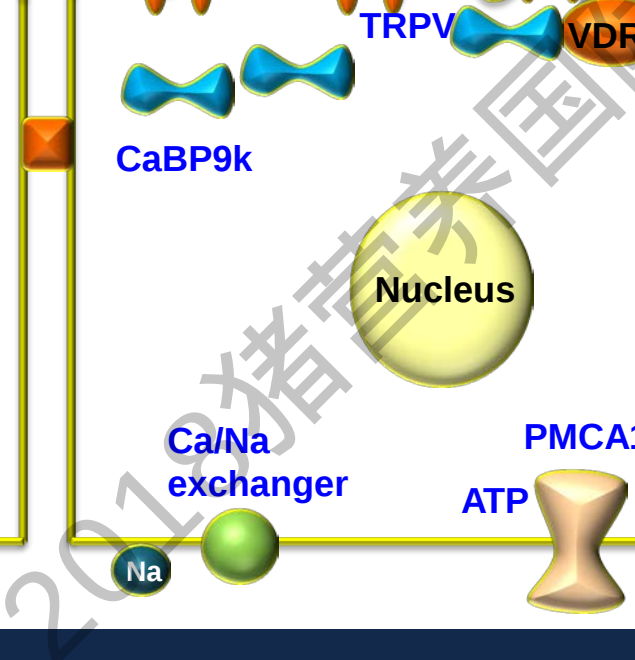
Gonzalez-Vega et al., 2016a

Low Diet Ca



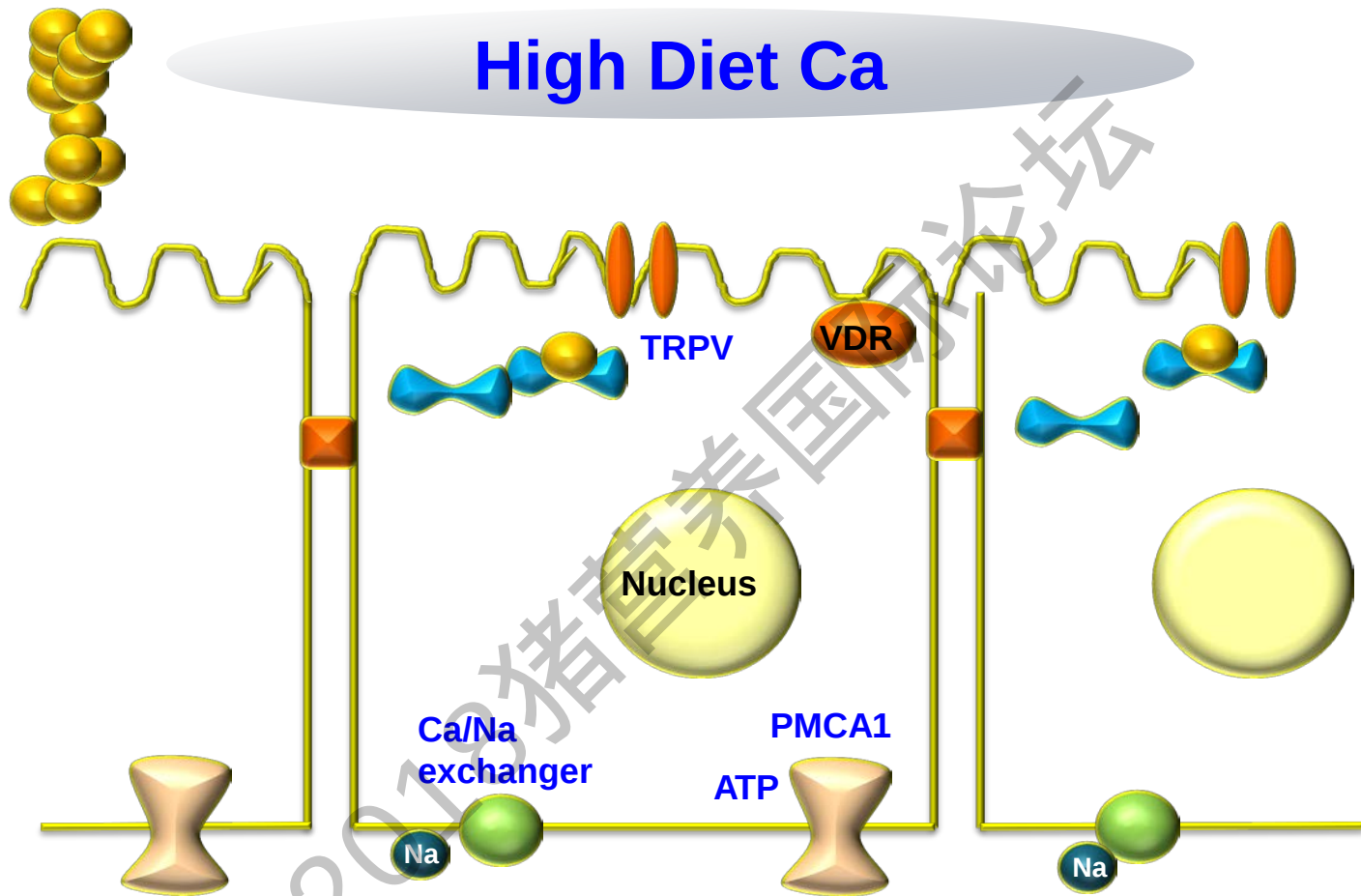
Bronner, 1987

Low Diet Ca



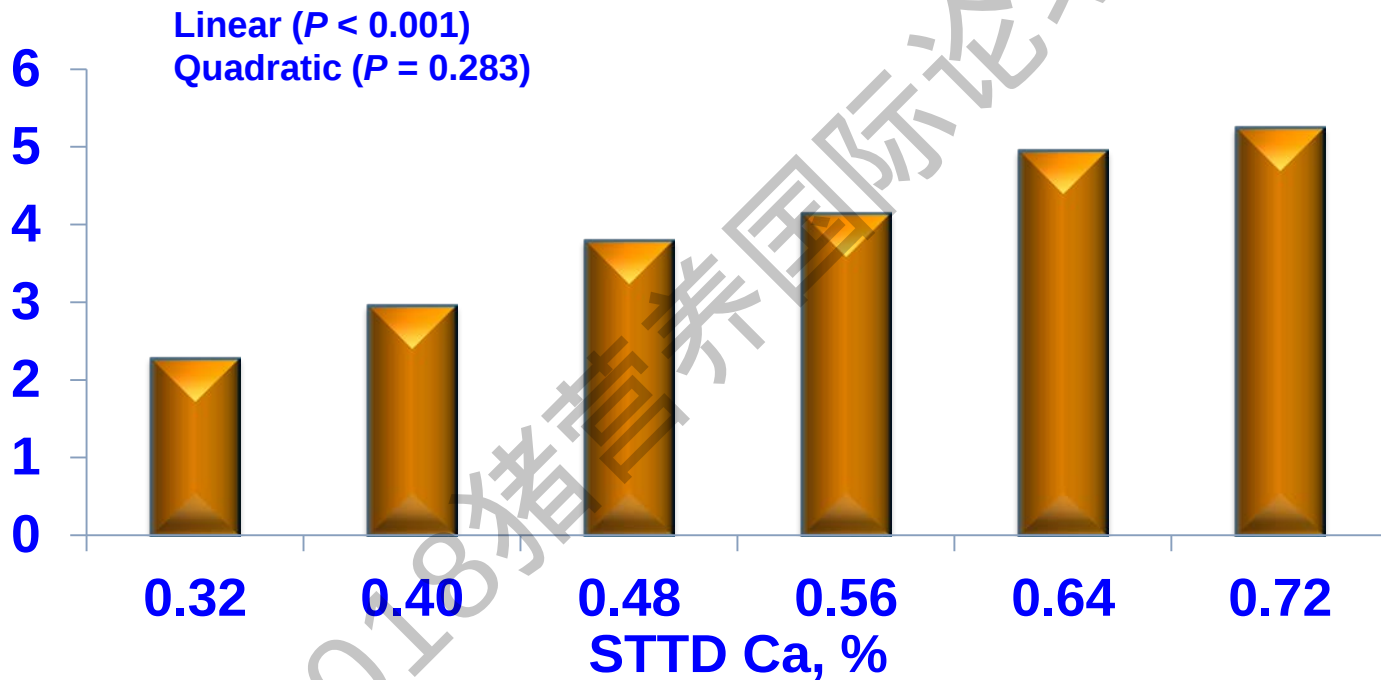
Bronner, 1987

High Diet Ca



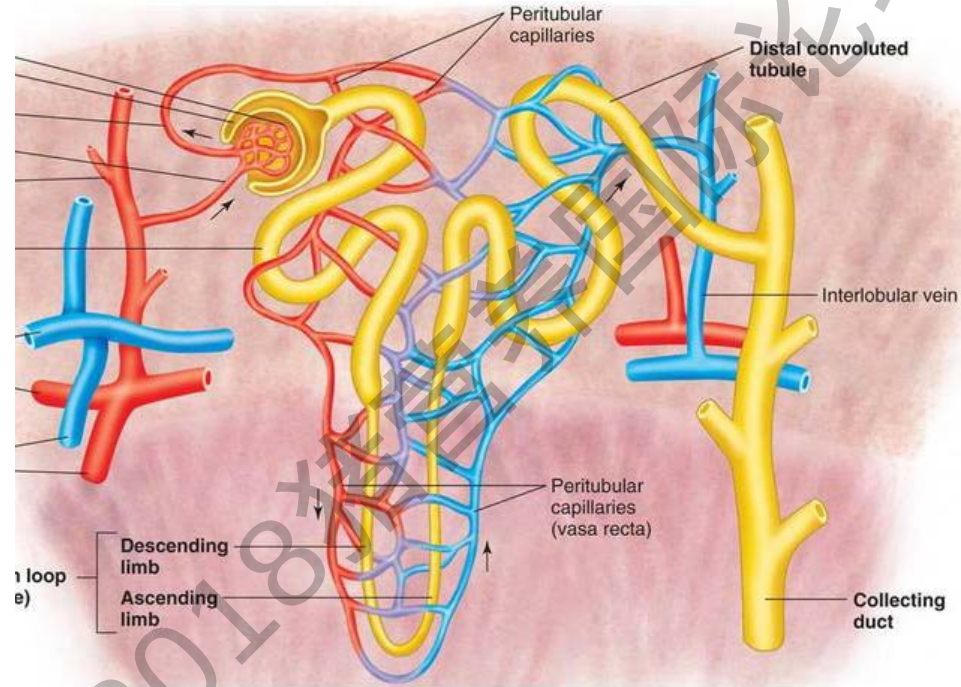
Bronner, 1987

Absorbed Ca, g/d

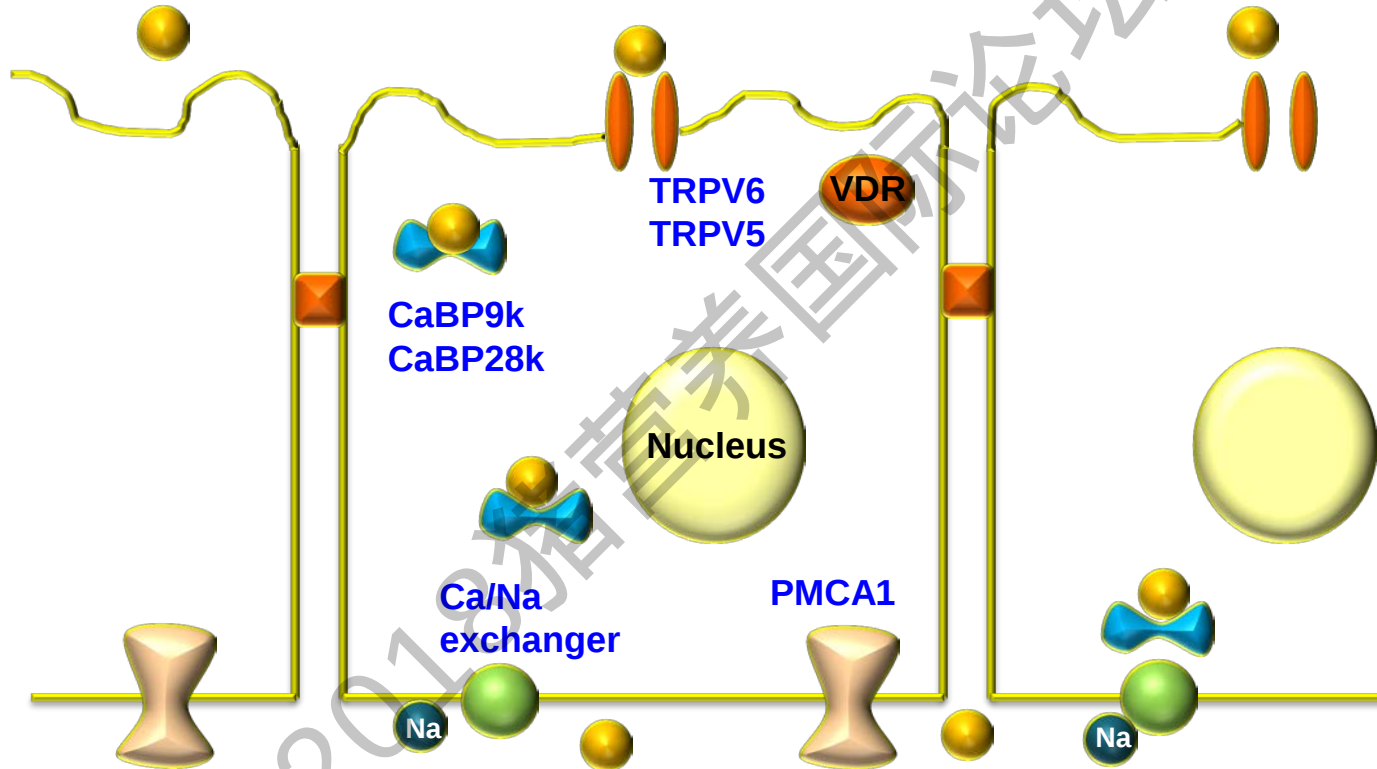


Gonzalez-Vega et al., 2016a

Reabsorption of Ca in kidney

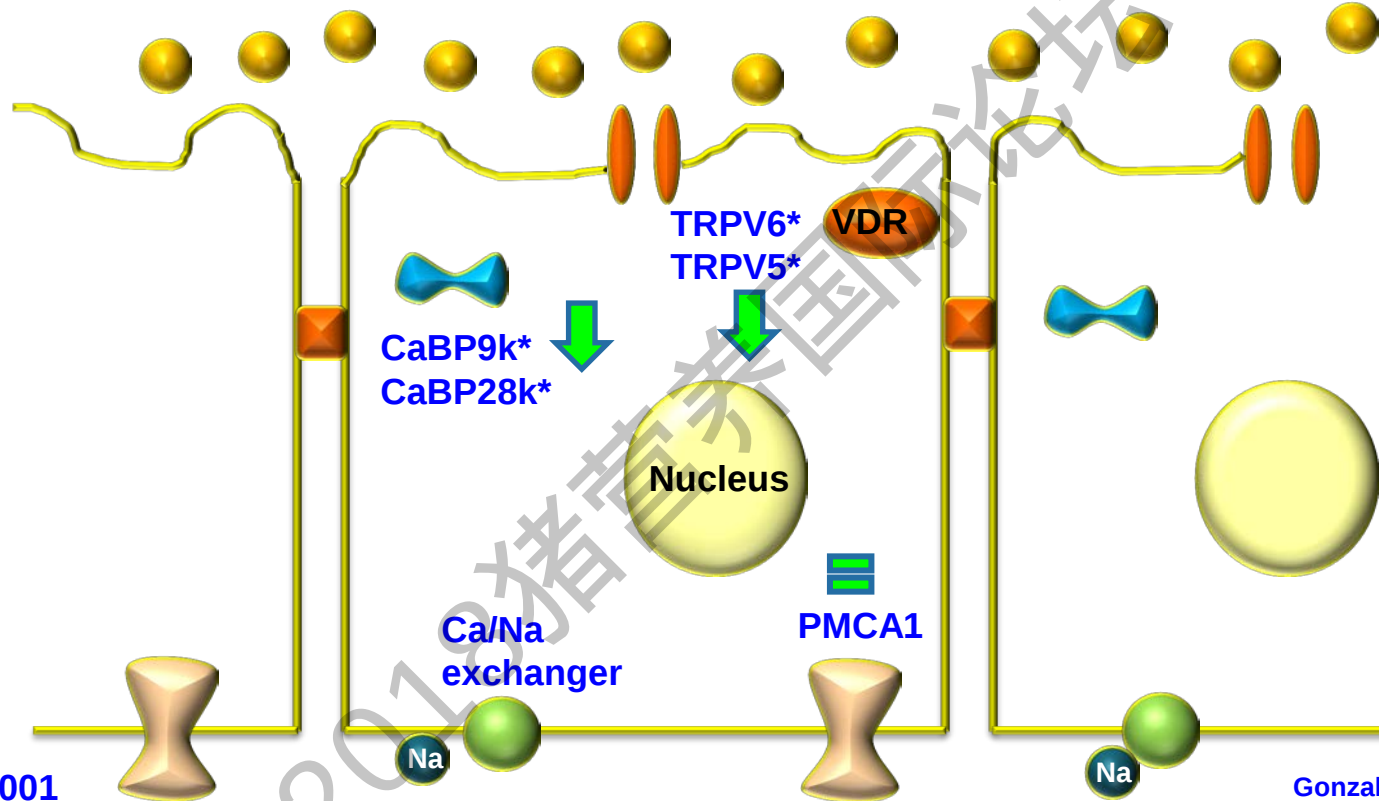


Kidney-Distal tubules



Bronner, 1987

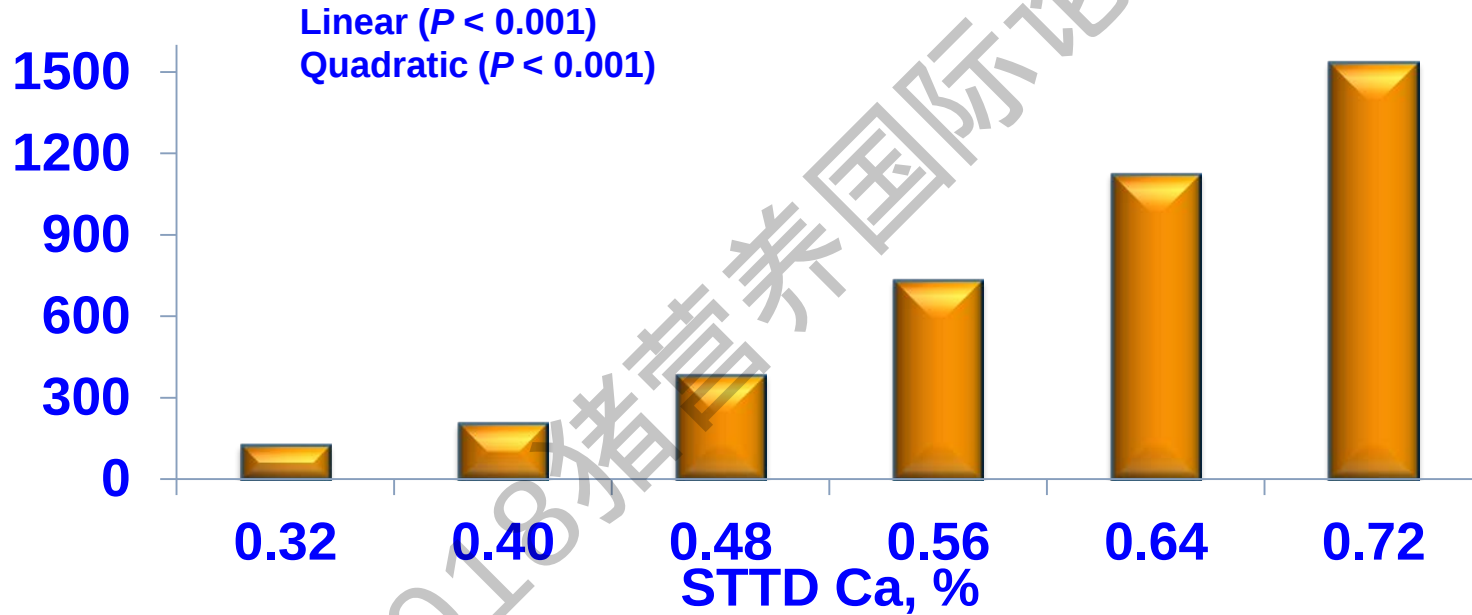
High Ca Concentrations



*Linear $P < 0.001$

Bronner, 1987
Gonzalez-Vega et al., 2016a

Urine Ca output, mg/d

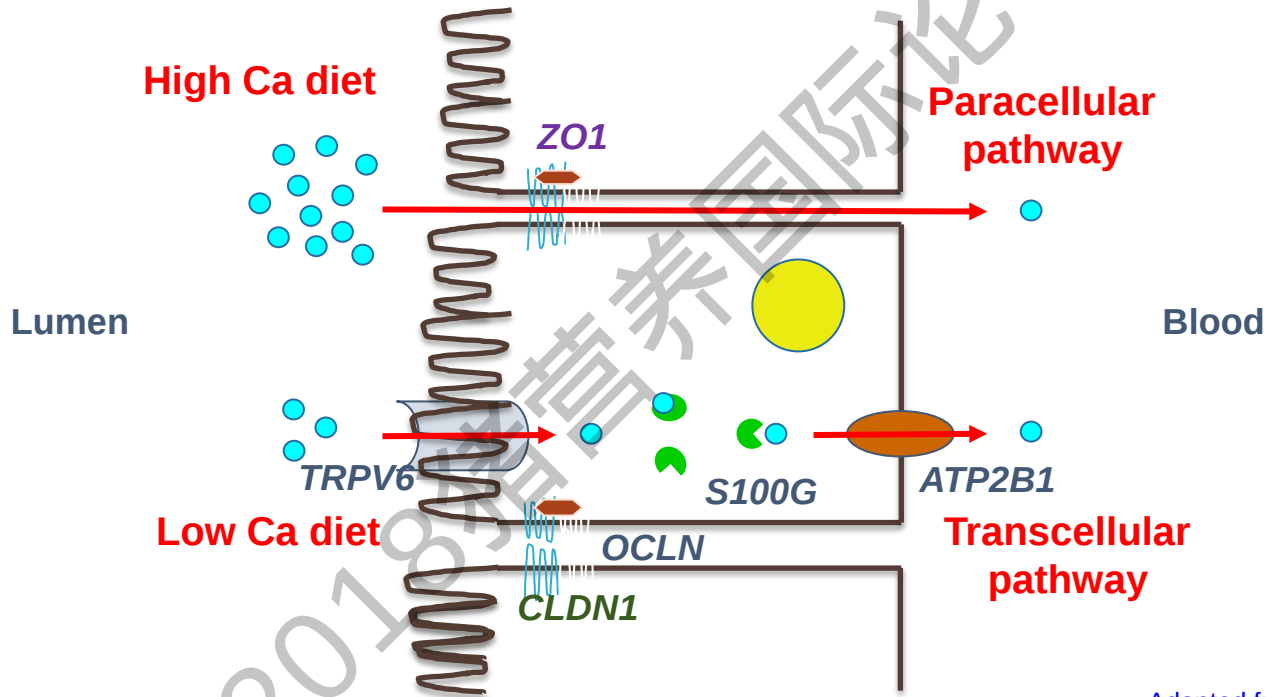


Gonzalez-Vega et al., 2016a

Requirements for STTD Ca by 11- to 25-kg pigs



Intestinal Ca absorption



Adapted from Christakos et al., 2014.

Material and Methods

Experimental diets
STTD Ca : STTD P

	Total Ca, %	0.21	0.45	0.70	0.94	1.19
	STTD Ca, %	0.14	0.29	0.44	0.59	0.74
STTD P, %	0.16	0.88:1	1.81:1	2.75:1	3.69:1	4.63:1
	0.33	0.42:1	0.88:1	1.33:1	1.79:1	2.24:1
	0.42	0.33:1	0.69:1	1.05:1	1.40:1	1.76:1
	0.50	0.28:1	0.58:1	0.88:1	1.18:1	1.48:1

Material and Methods

640 Pigs
4 pigs / pen (2♂ – 2♀)



Growth
performance

Right femur
Duodenal tissue



Bone characteristics
Gene expression

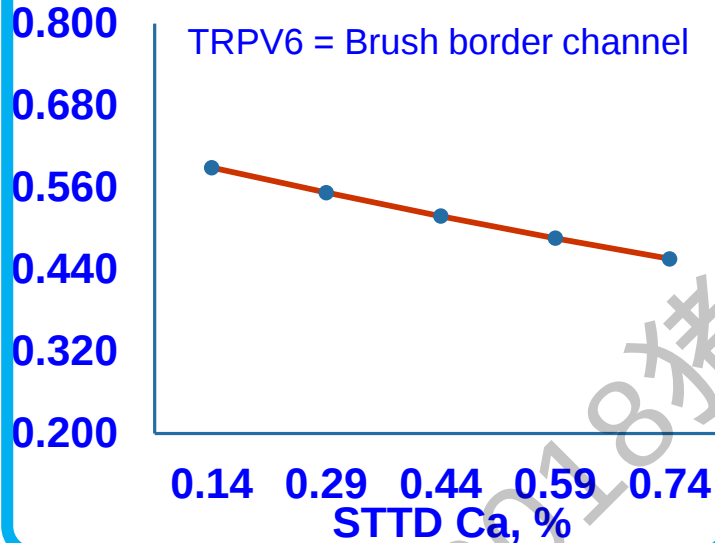
Transcellular Ca absorption related genes

$$GE = a + (b \times \text{Ca}) + (\cancel{c \times \text{Ca}^2}) + (\cancel{d \times \text{P}}) + (\cancel{e \times \text{P}^2}) + (\cancel{f \times \text{Ca} \times \text{P}}) + (\cancel{g \times \text{Ca}^2 \times \text{P}}) + (\cancel{h \times \text{Ca} \times \text{P}^2}) + (\cancel{i \times \text{Ca}^2 \times \text{P}^2})$$

$P < 0.05$

TRPV6

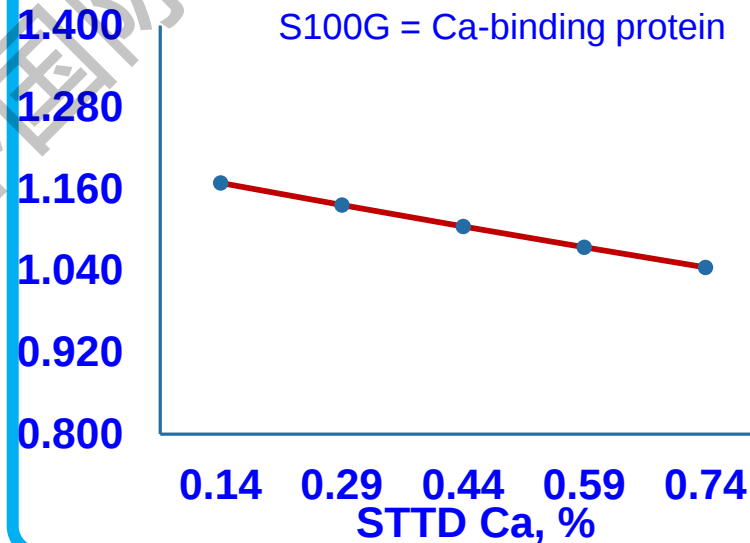
TRPV6 = Brush border channel



$P < 0.05$

S100G

S100G = Ca-binding protein



Lagos et al, 2018

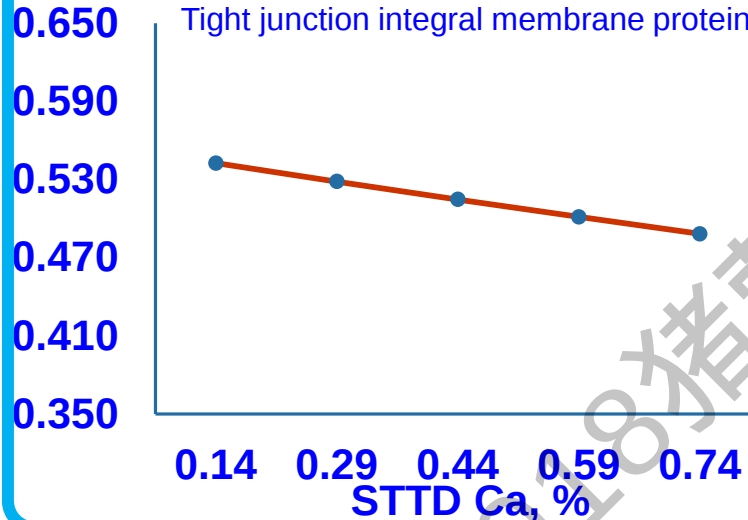
Paracellular Ca absorption related genes

$$GE = a + (b \times \text{Ca}) + (c \times \text{Ca}^2) + (d \times \text{P}) + (e \times \text{P}^2) + (f \times \text{Ca} \times \text{P}) + (g \times \text{Ca}^2 \times \text{P}) + (h \times \text{Ca} \times \text{P}^2) + (i \times \text{Ca}^2 \times \text{P}^2)$$

$P < 0.05$

OCN

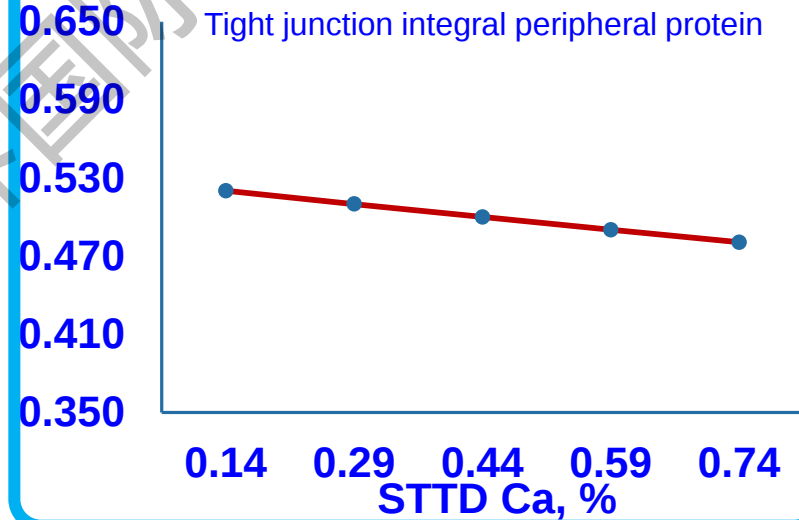
Tight junction integral membrane protein



$P < 0.05$

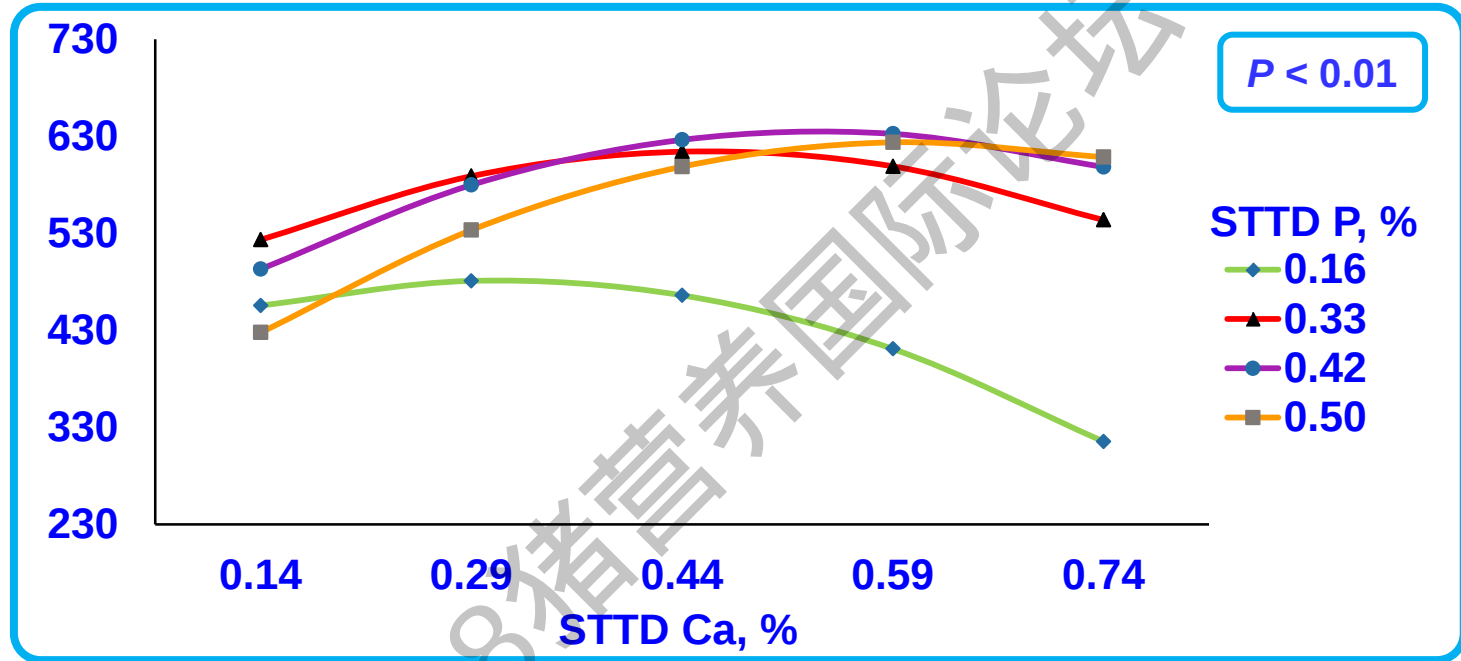
ZO1

Tight junction integral peripheral protein



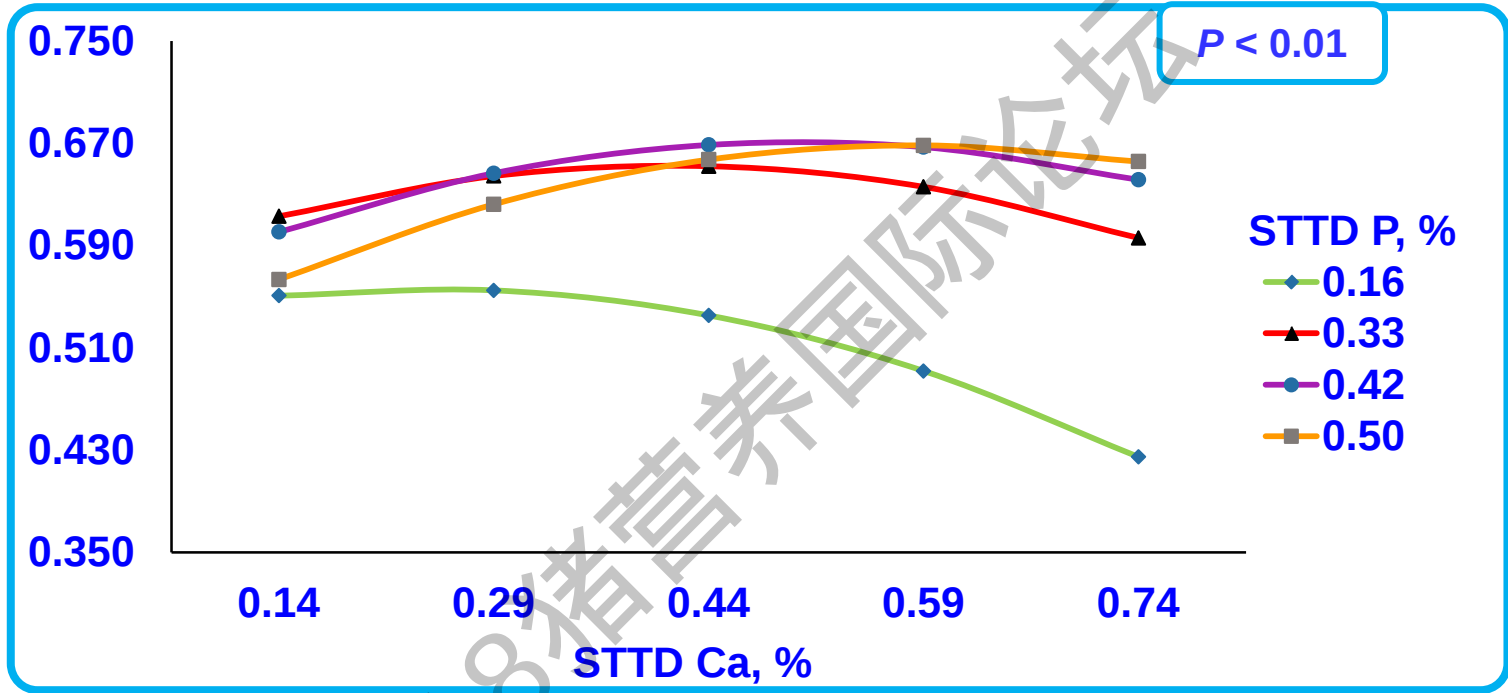
Lagos et al, 2018

Average daily gain, g



Lagos et al, 2018

Gain to Feed



Lagos et al, 2018

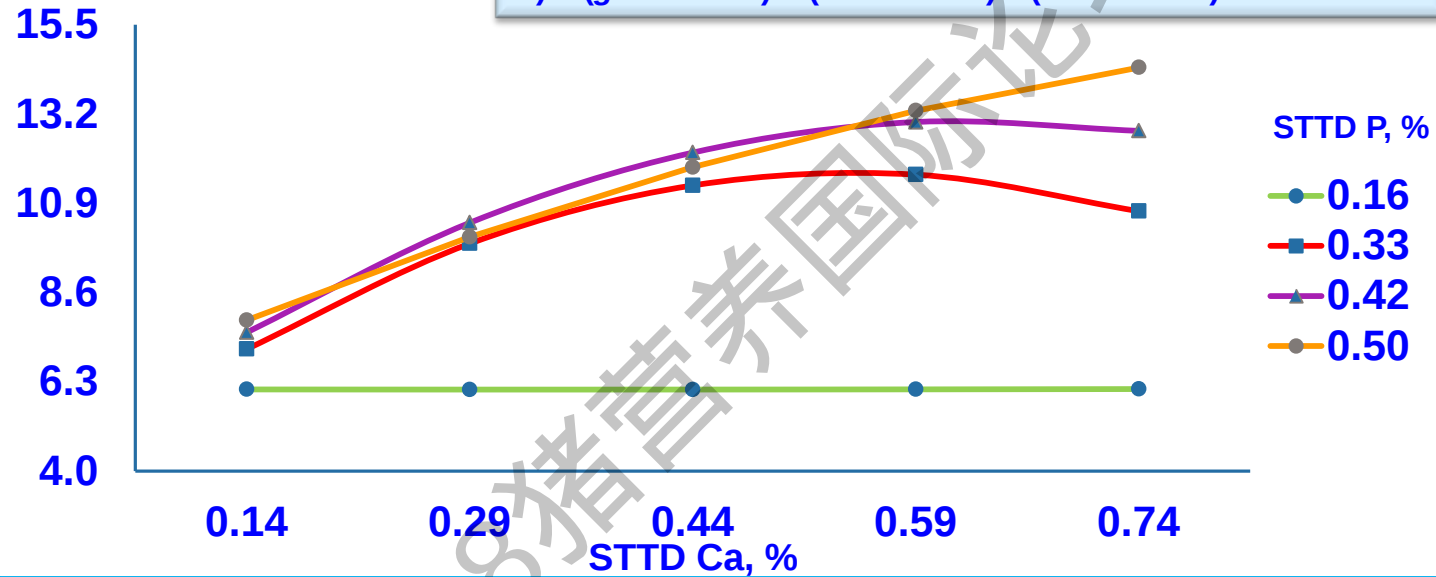
Bone mineralization



Bone Ash, g

$P < 0.01$

$$\text{Ash} = a + (b \times \text{Ca}) + (c \times \text{Ca}^2) + (d \times \text{P}) + (e \times \text{P}^2) + (f \times \text{Ca} \times \text{P}) + (g \times \text{Ca}^2 \times \text{P}) + (h \times \text{Ca} \times \text{P}^2) + (i \times \text{Ca}^2 \times \text{P}^2)$$



Lagos, 2018

STTD Ca requirements by 25 to 50 kg



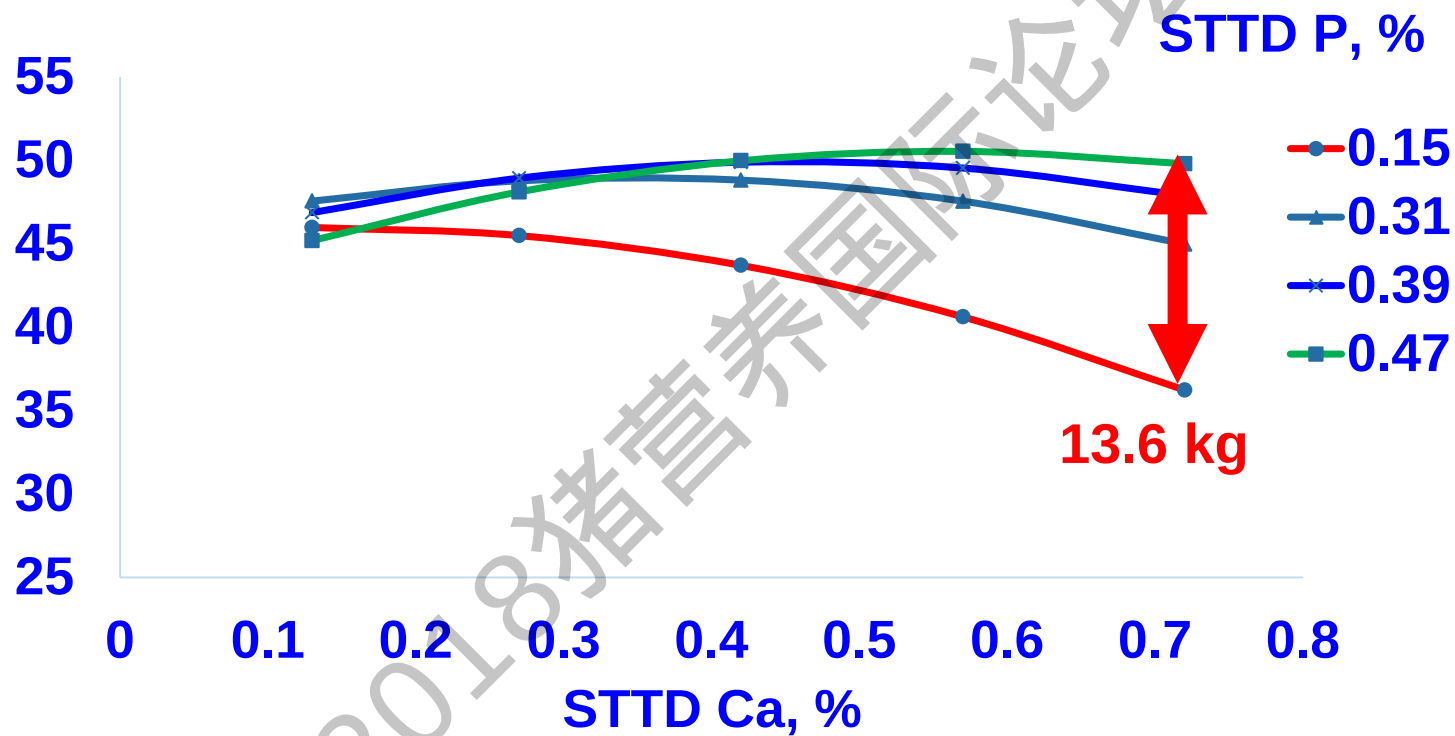
Diets and STTD Ca : STTD P ratios



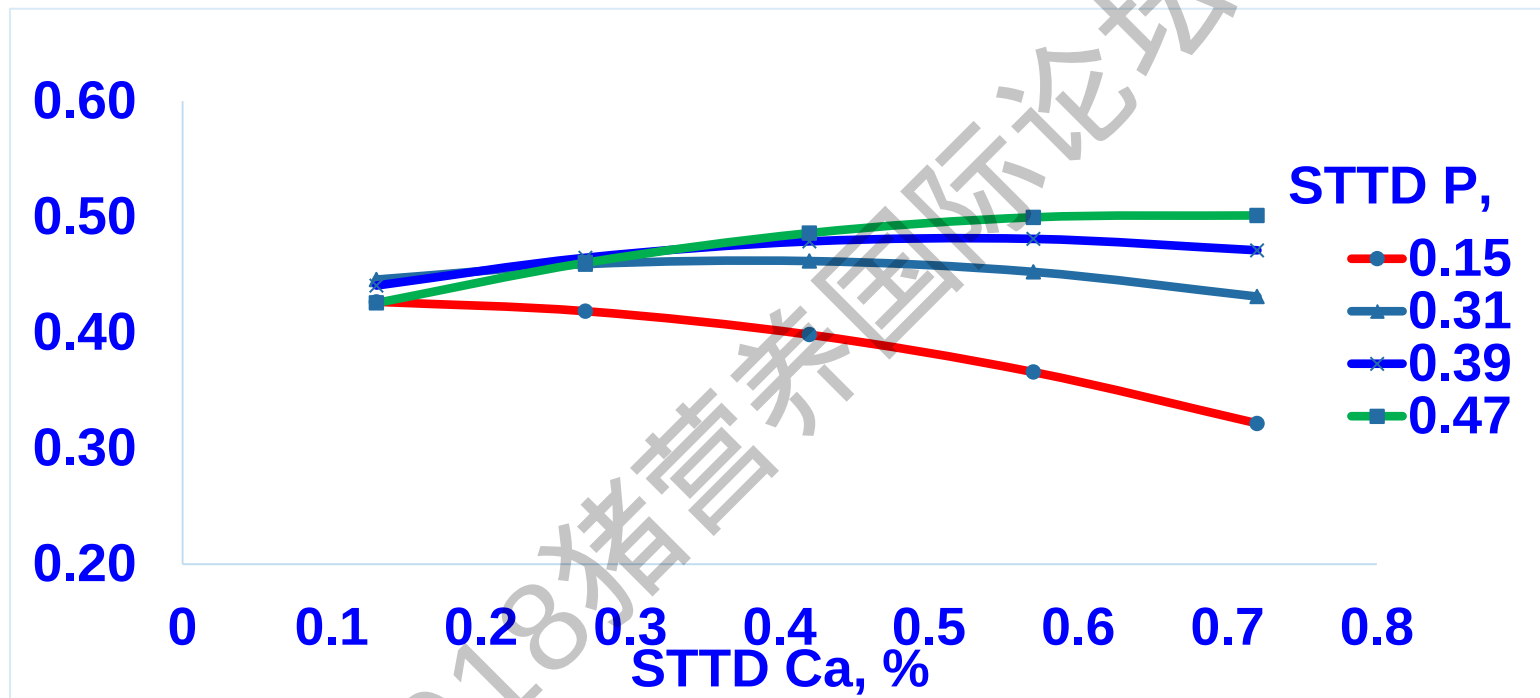
		STTD Ca, %				
		0.13	0.27	0.42	0.57	0.72
STTD P, %	0.15	0.87	1.80	2.80	3.80	4.80
	0.31	0.42	0.87	1.35	1.84	2.32
	0.39	0.33	0.69	1.08	1.46	1.85
	0.47	0.28	0.57	0.89	1.21	1.53

Gonzalez-Vega et al., 2016b

BW 28d, kg



G:F d0-28



Gonzalez-Vega et al., 2016b

Requirements for STTD Ca by 50- to 85-kg pigs



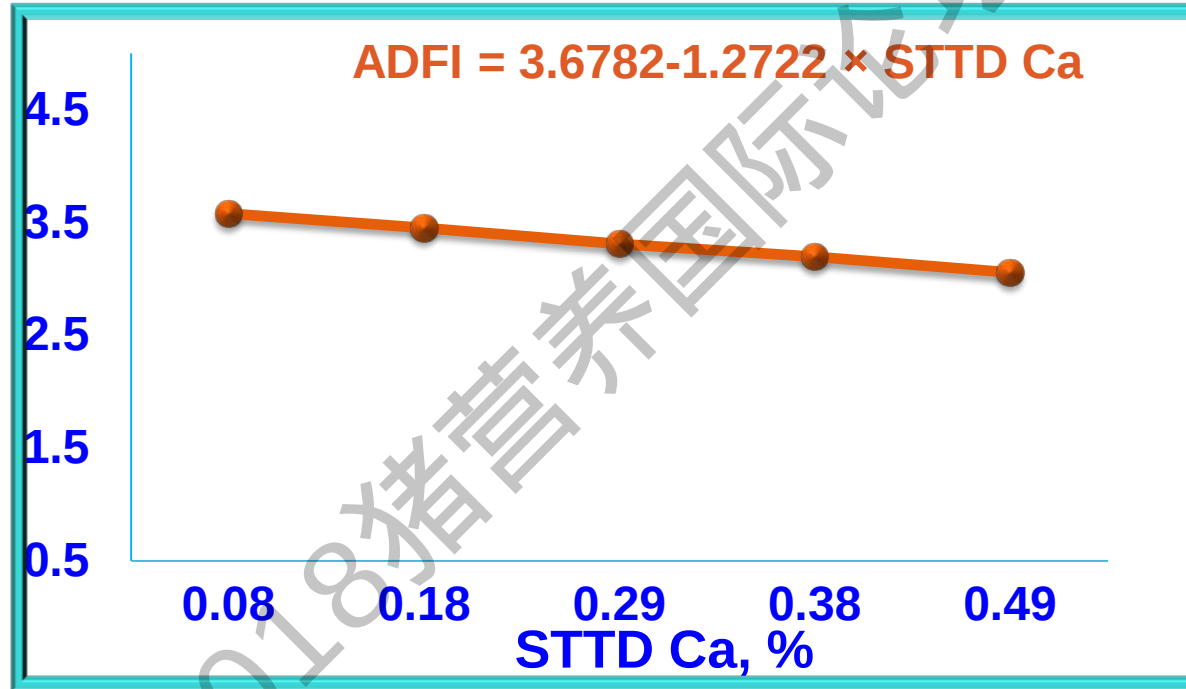
High Ca Low Ca



Requirement for STTD Ca by Finishing Pigs (100 to 130 kg)



Average Daily Feed Intake, kg

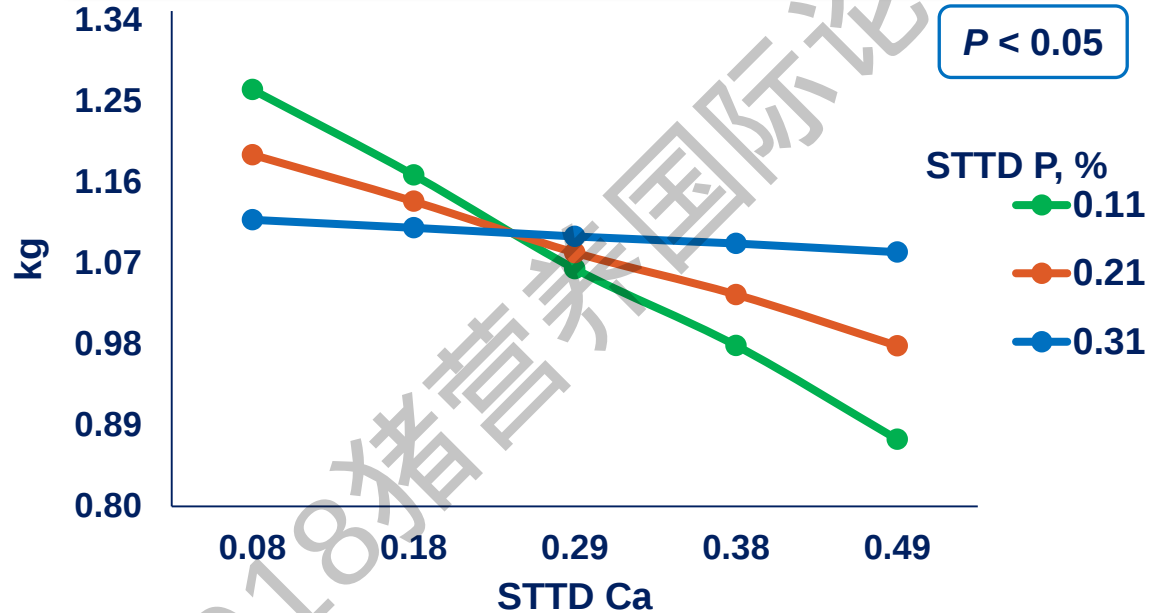


Merriman et al., 2017

ADG, d 1-28

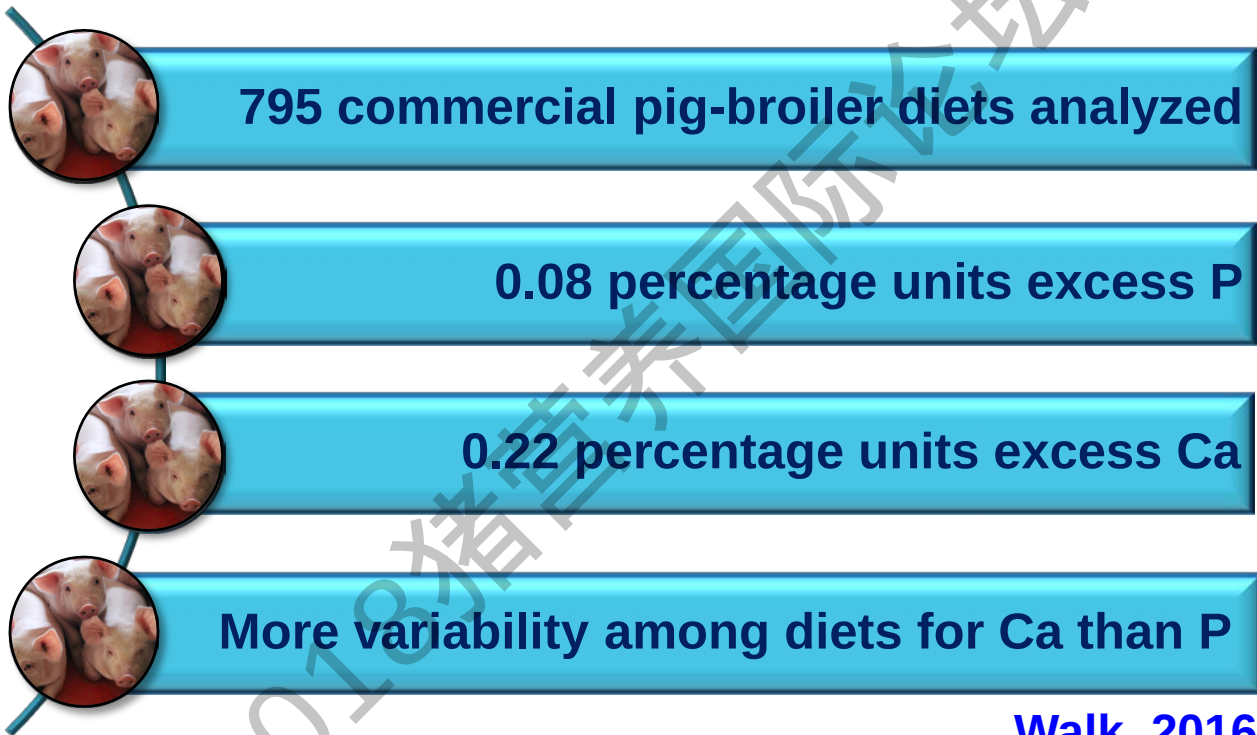
$$\text{ADG} = 1.46 - (1.42 \times \text{Ca}) - (1.07 \times \text{P}) + (4.29 \text{ Ca} \times \text{P})$$

$P < 0.05$



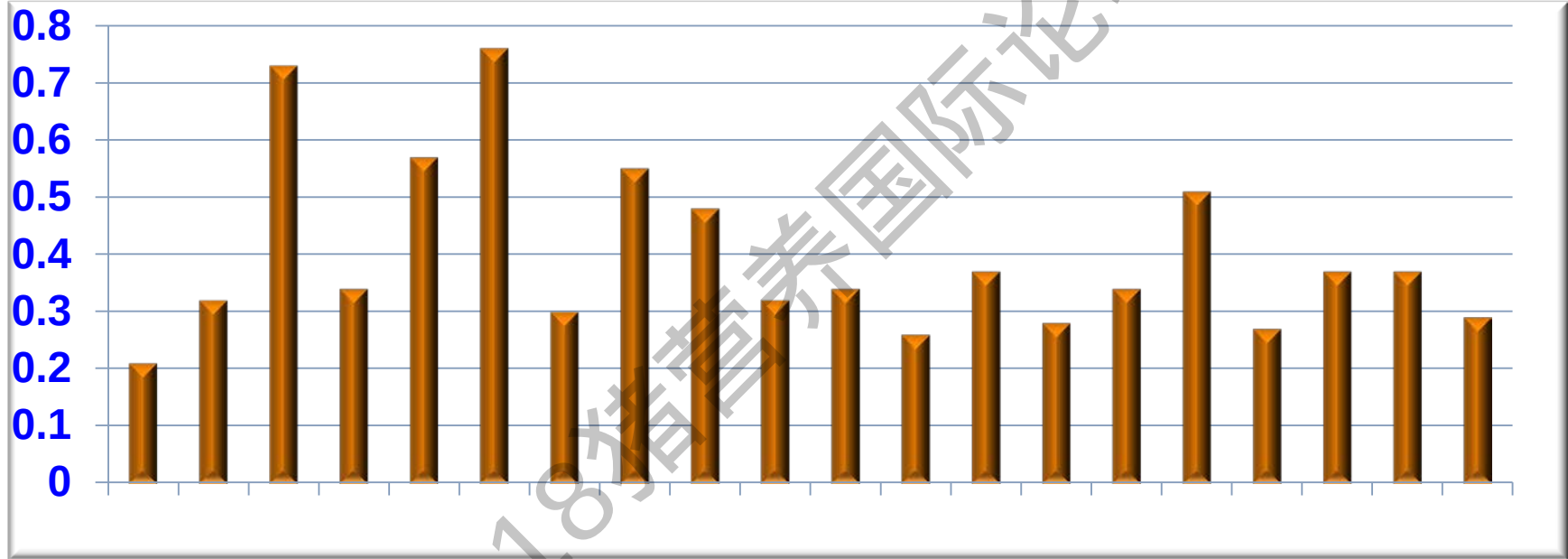
Merriman et al., 2017

Excess Ca in Commercial Diets



Walk, 2016

Calcium in Soybean meal (%)



Sotak-Peper et al., 2016

Conclusions

2

Phytase
increases STTD
of Ca

4

Regulation of
Ca mainly in
kidney

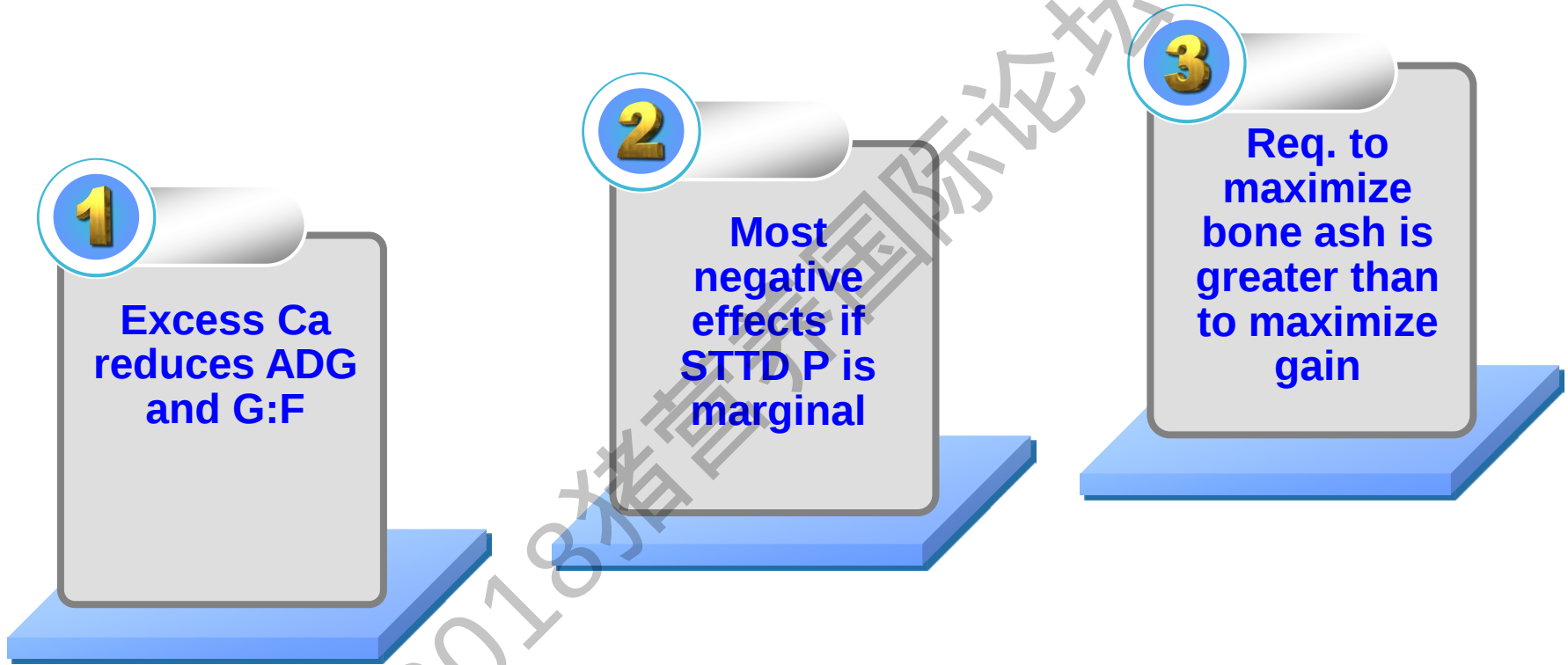
1

STTD Ca available
for most
ingredients

3

Minimum
regulation of Ca
absorption

Conclusions, cont.



Overall conclusion

Requirements for STTD Ca:STTD P by growth stage and body weight range

STTD P at the requirement

	Body weight range, kg		
	11 to 25	25 to 50	50 to 85
Performance	< 1.40:1 ~1.70:1	< 1.35:1 ~1.80	< 1.25:1 ~2.0:1

STTD P at the requirement

	Body weight range, kg			
	11 to 25	25 to 50	50 to 85	100 to 130
Growth performance	< 1.40:1	< 1.35:1	< 1.25:1	< 1.10:1
Bone ash	~1.70:1	~1.80	~2.0:1	~2.30:1

Gonzalez-Vega et al., 2016b; Merriman et al., 2017; Lagos, 2018

Lagos, 2018

Implications

Need to account for
all sources of dietary
Ca

Extremely important
to acknowledge
phytase effect

NRC Requirements
for Ca are absolute
maximum values

***Do not overfeed
Calcium to pigs***



Acknowledgement



<http://nutrition.ansci.illinois.edu>