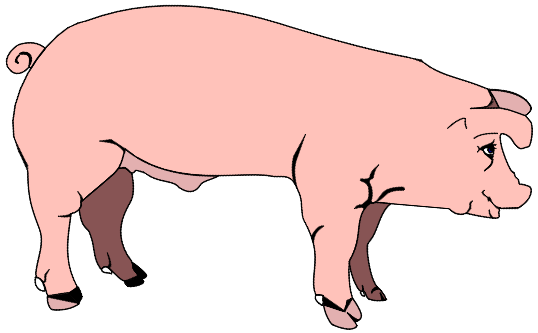

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Digestible Phosphorus and Calcium in Swine

Layi Adeola, Ph.D.

Professor

Department of Animal Sciences

OUTLINE

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- Phosphorus
- Calcium
- Additivity of Digestible P and Ca in Mixed Diets
- Summary/Take-Home Message

PHOSPHORUS

- **Skeletal Phosphorus**
  - **75% of the body P is stored in the skeleton**
  - **Hydroxyapatite**
  - **Framework as well as Reservoir of P**

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BODY PHOSPHORUS

- Important roles in BODY METABOLISM
  - Component of Nucleotides (DNA, RNA, ATP)
  - High-E compounds (PEP, 1,3BPG, ATP, creatine phosphate)
  - Serves in Enzyme Regulation (Phosphorylated proteins)
  - Phospholipids (phosphoglycerides and sphingomyelin)

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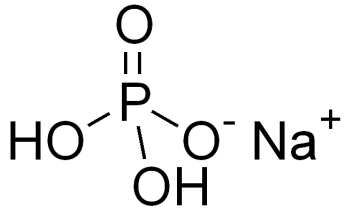
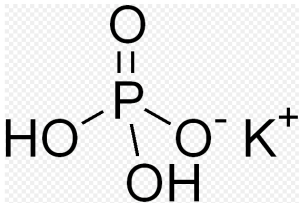
FEED PHOSPHORUS

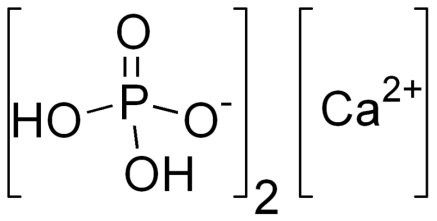
- Inorganic Sources
- Organic Sources

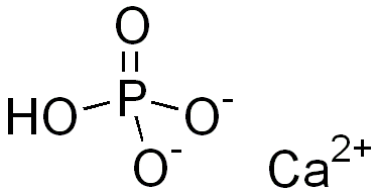
PHOSPHORUS IN FEED

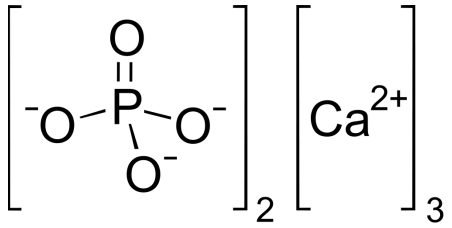
- **Inorganic**
  - **Monosodium phosphate**
  - **Potassium phosphate**
  - **Mono-, di-, tri-calcium phosphates**
  - **Varying proportions of digestible phosphorus**



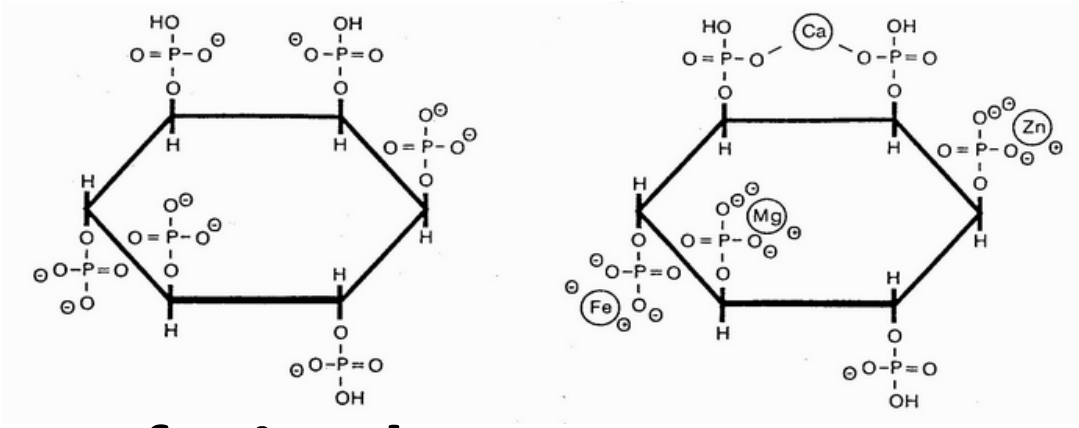








PHOSPHORUS IN FEED



- **Organic**
  - **Phytin**
    - Organic form of P in plant
    - Myoinositol 1,2,3,4,5,6-hexakisphosphate complexed with mixed cations such as Ca, Zn, Mg, and Cu

PHOSPHORUS IN FEED

- **Phytin**
  - Constitutes up to 3% of many of the oilseed meals and cereals used in animal feeds
  - **Phytate P** constitutes 50-80% of the total P in most Swine and Poultry feedstuffs of plant origin

DIETARY PHOSPHORUS

- **Dietary P** supply **DOES NOT Guarantee total utilization**

Dietary supply P

≠

Utilized P by animal

→Excess P to Environment

CURRENCY OF P UTILIZATION

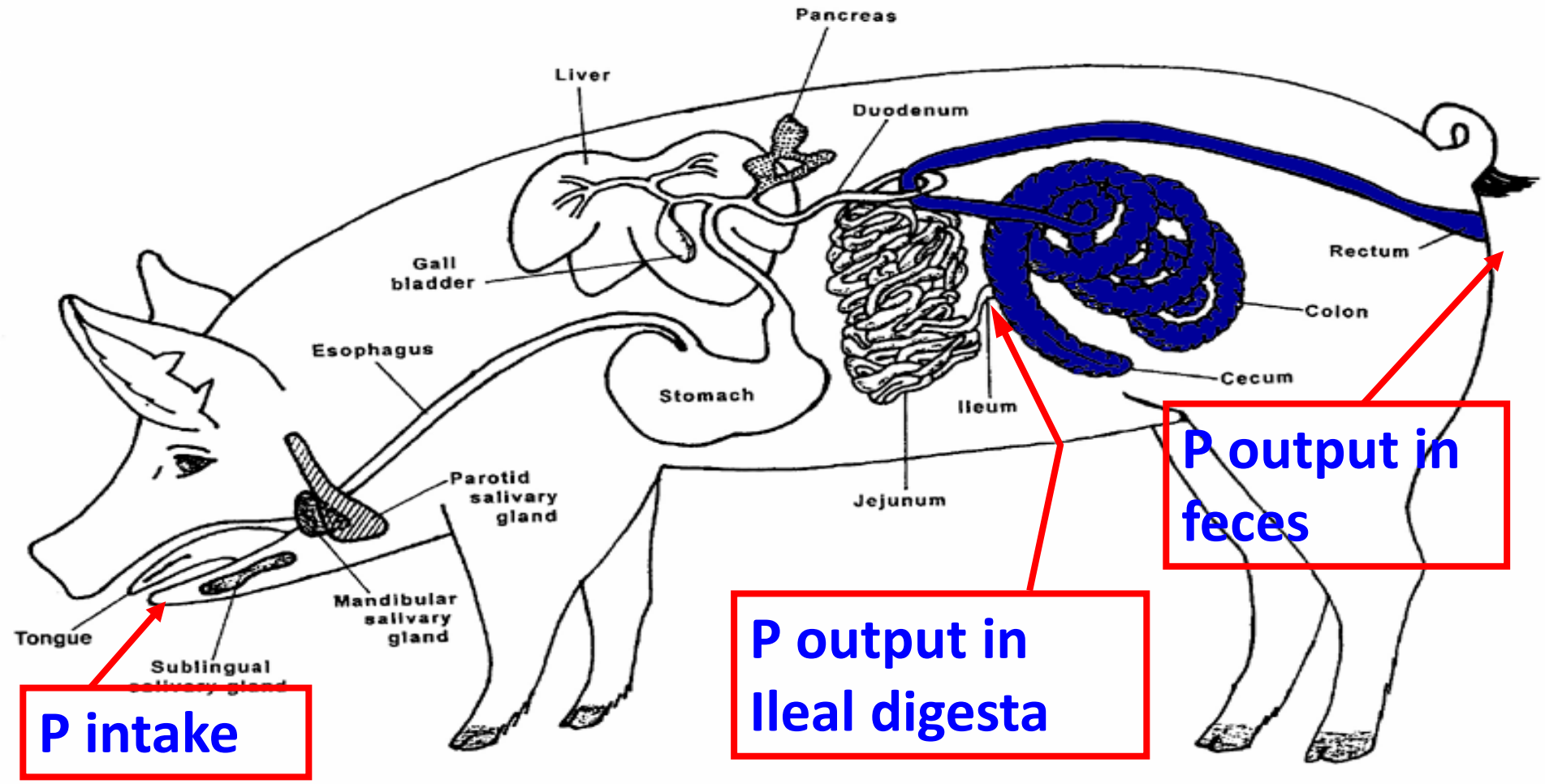
- Feed Evaluation & Animals' Requirement for Nutrients are Interdependent
- Underscores the importance of the development of appropriate systems for both

DIGESTIBLE PHOSPHORUS

- Input (Diet) / Output (Feces OR Excreta) Relationship
- Quantitative measure of P Input and P Output

$$\text{P Digestibility, \%} = \frac{\text{P Intake} - \text{P Output}}{\text{P Intake}} \times 100$$

Swine


Pancreas
Liver
Duodenum
Gall bladder
Esophagus
Stomach
Rectum
Colon
Cecum
Ileum
Jejunum
Parotid salivary gland
Mandibular salivary gland
Tongue
Sublingual salivary gland
P output in feces
P output in Ileal digesta
P intake

Swine

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Ileal digestibility of P = (P intake – Ileal P output)/P intake

Total tract digestibility of P = (P intake – fecal P output)/P intake

Swine

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Is ileal digestibility different from total tract digestibility of P ?

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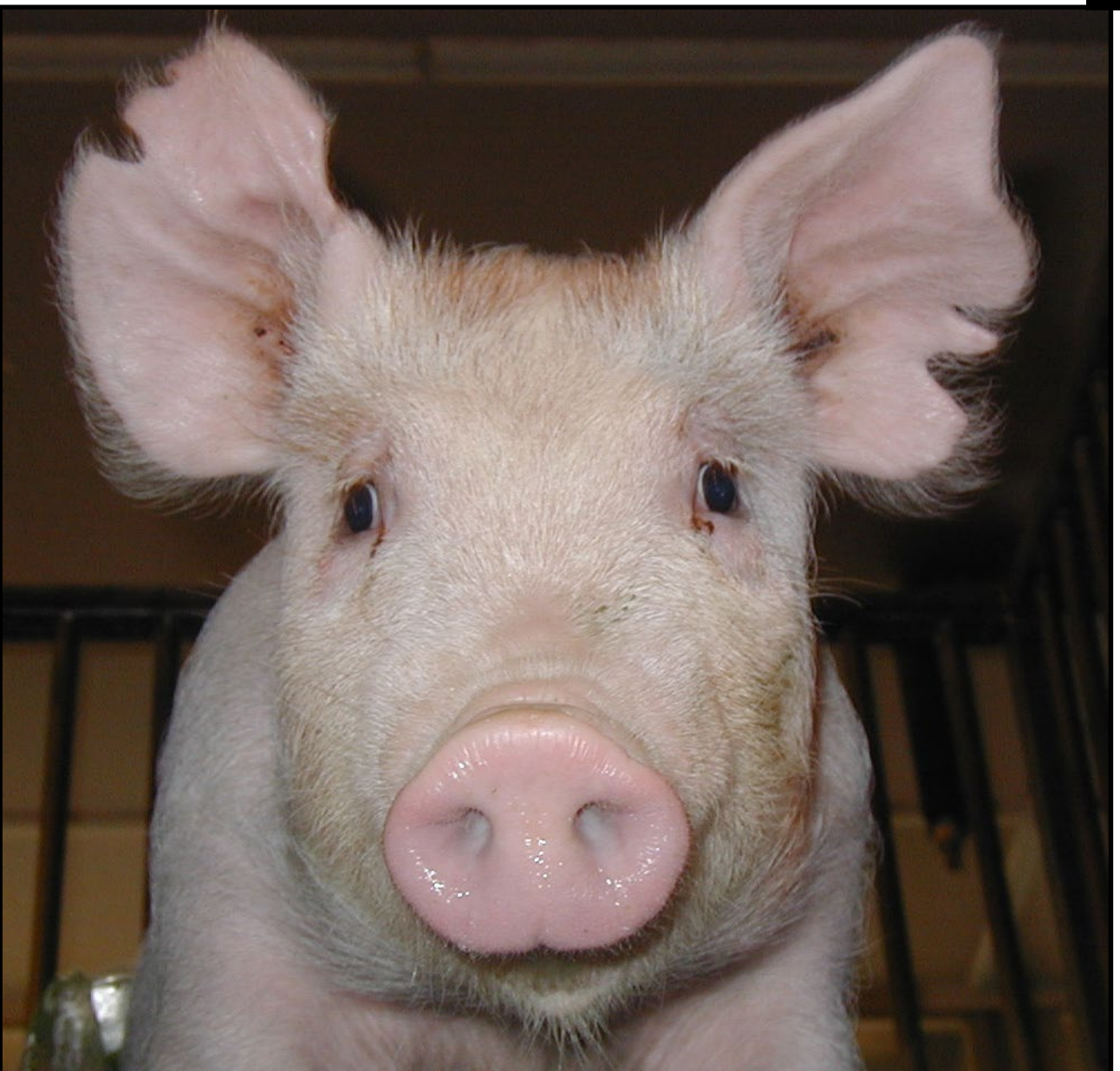

Pig Studies

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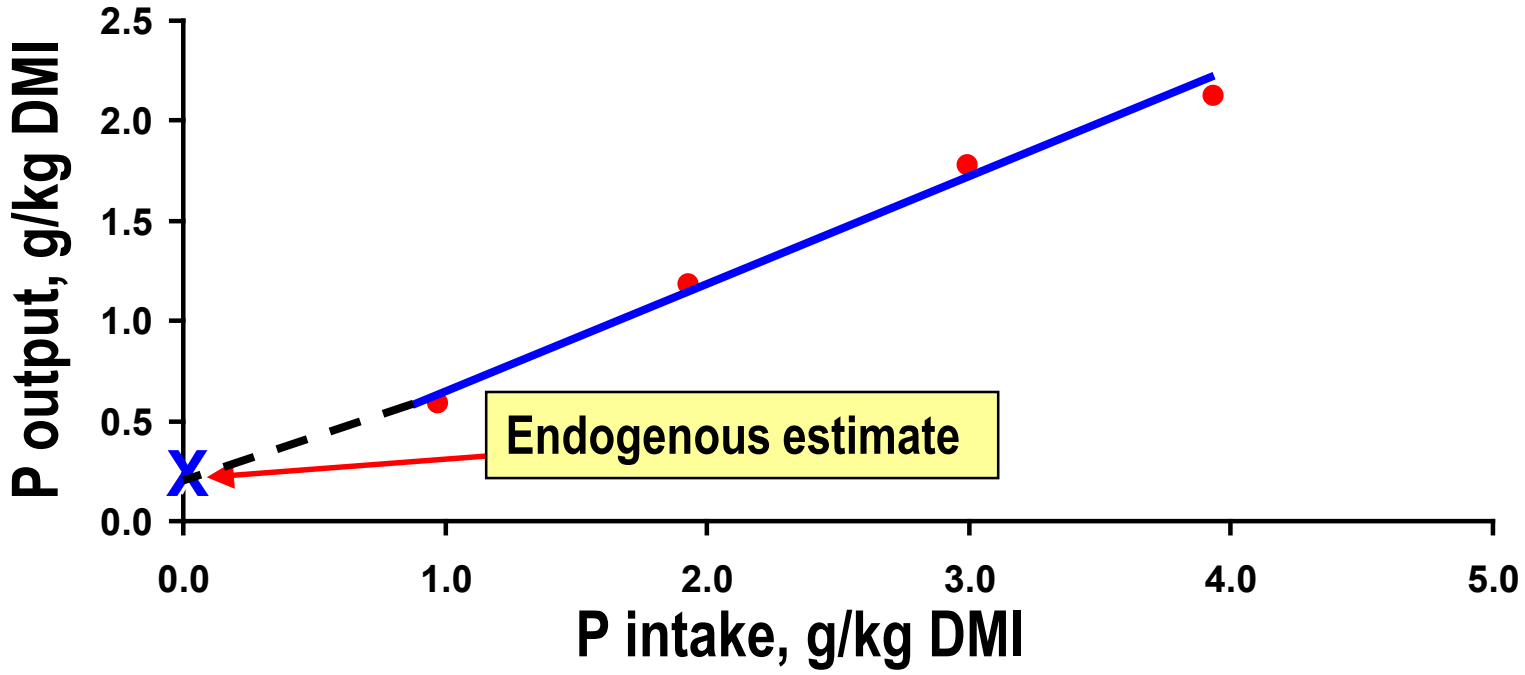
Linear regression approach



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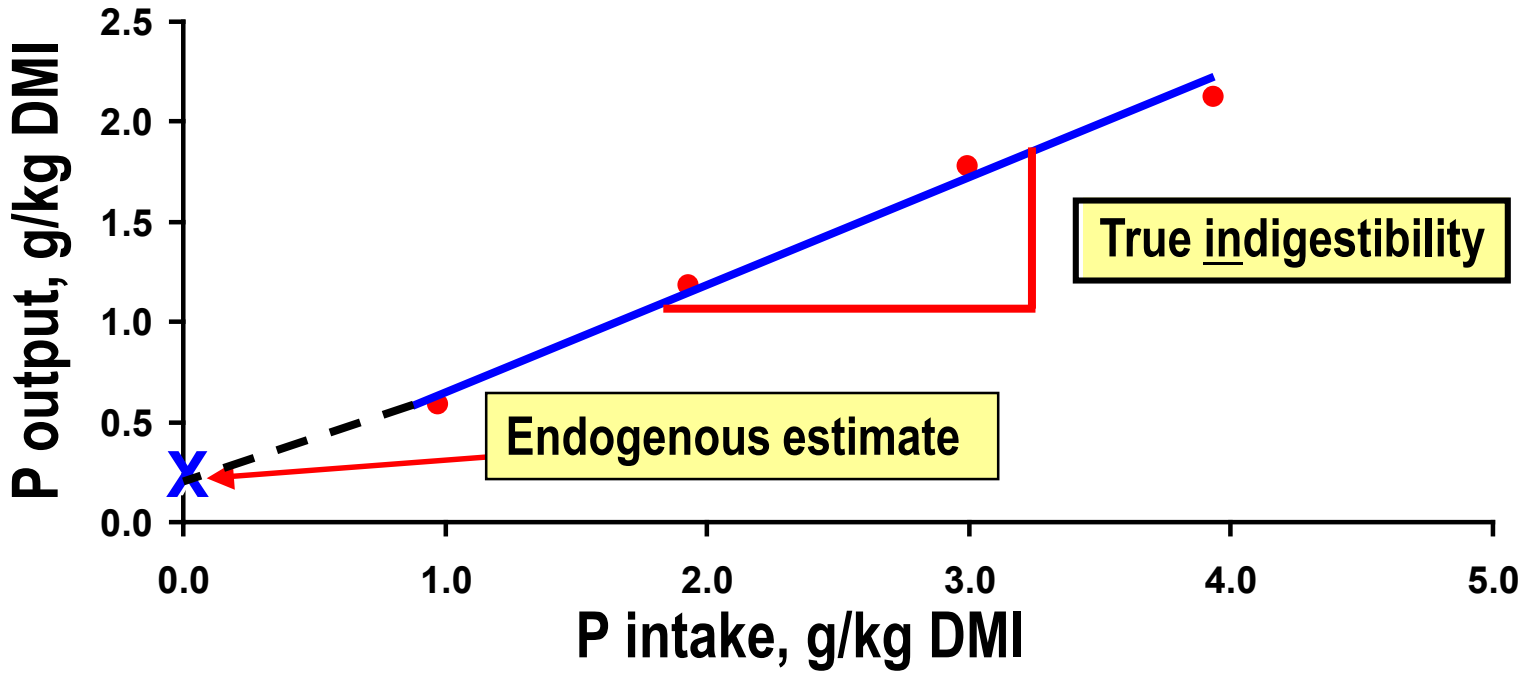
Linear regression approach



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Using Conventional and Low-phytin SBM:

- Simultaneously estimate endogenous losses and true digestibility
- Compare P utilization of conventional and low-phytin SBMs

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Dietary treatments

- 2 varieties of SBM (conventional and low-phytin)
- 4 graded inclusion levels of each SBM
- 8 semipurified cornstarch-based diets
- Feed allowance per individual pig at 90 g/kg $BW^{0.75}$ for duration of each feeding period

Dietary Treatments

	Diets							
	Conventional SBM				Low-phytin SBM			
Item	1	2	3	4	5	6	7	8
SBM, g/kg	132	264	396	528	132	264	396	528
Total P intake	0.97	1.93	2.99	3.94	0.92	1.80	2.48	3.25
Ca intake	0.79	1.21	1.68	2.21	0.92	1.55	2.15	2.57

Differences in graded P and Ca intake levels due to differences in mineral content between SBM types

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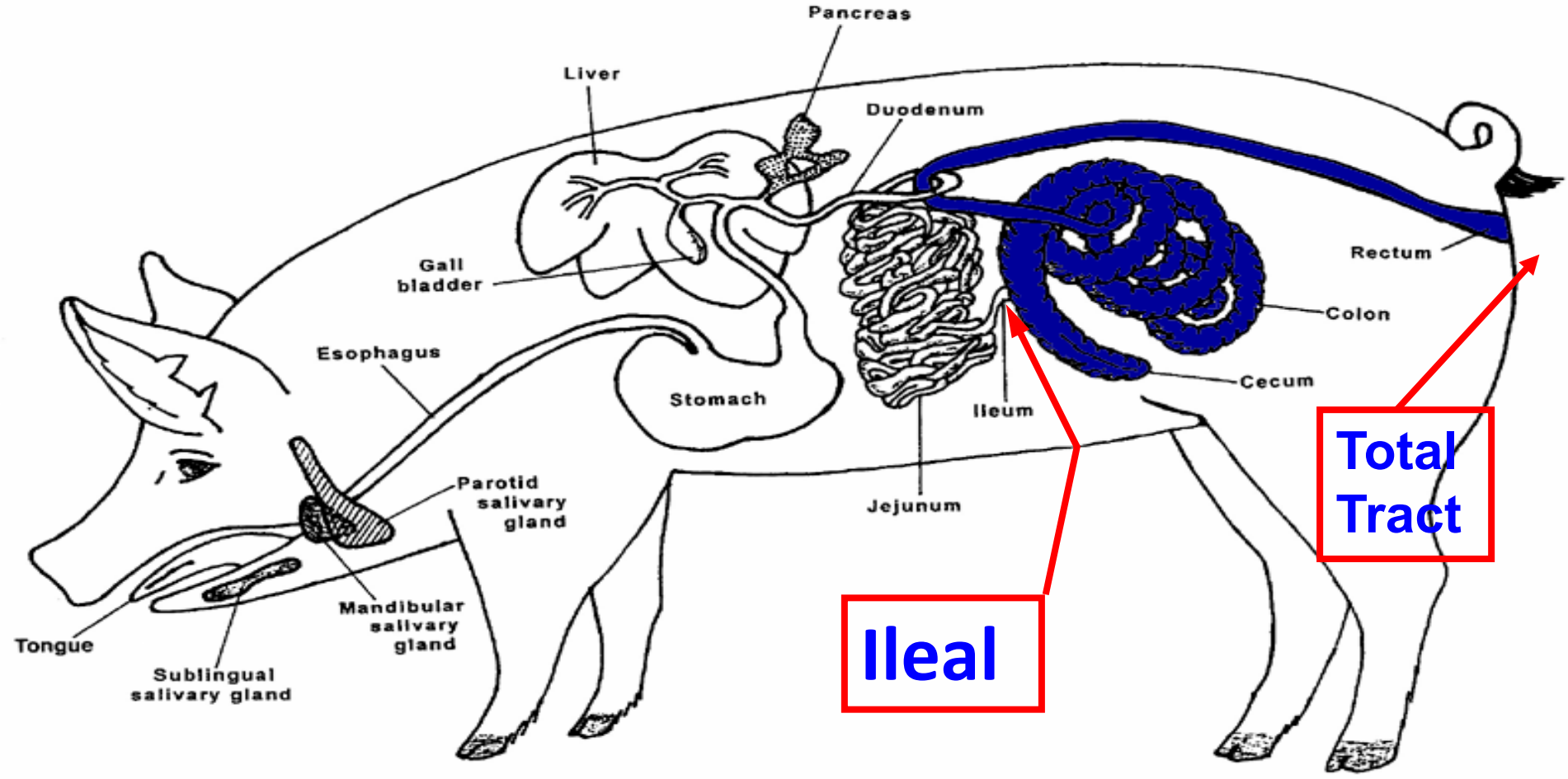
Sampling Sites



Adapted from Sisson, 1975; Shummer et al., 1979; and Moran, 1982

Methods

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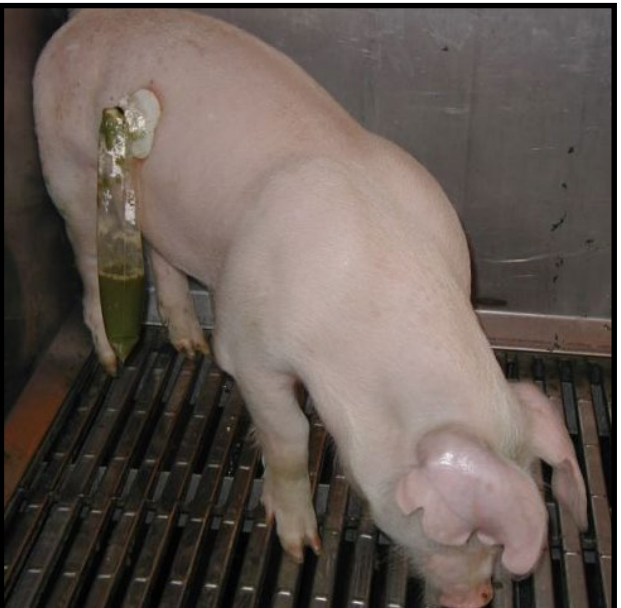
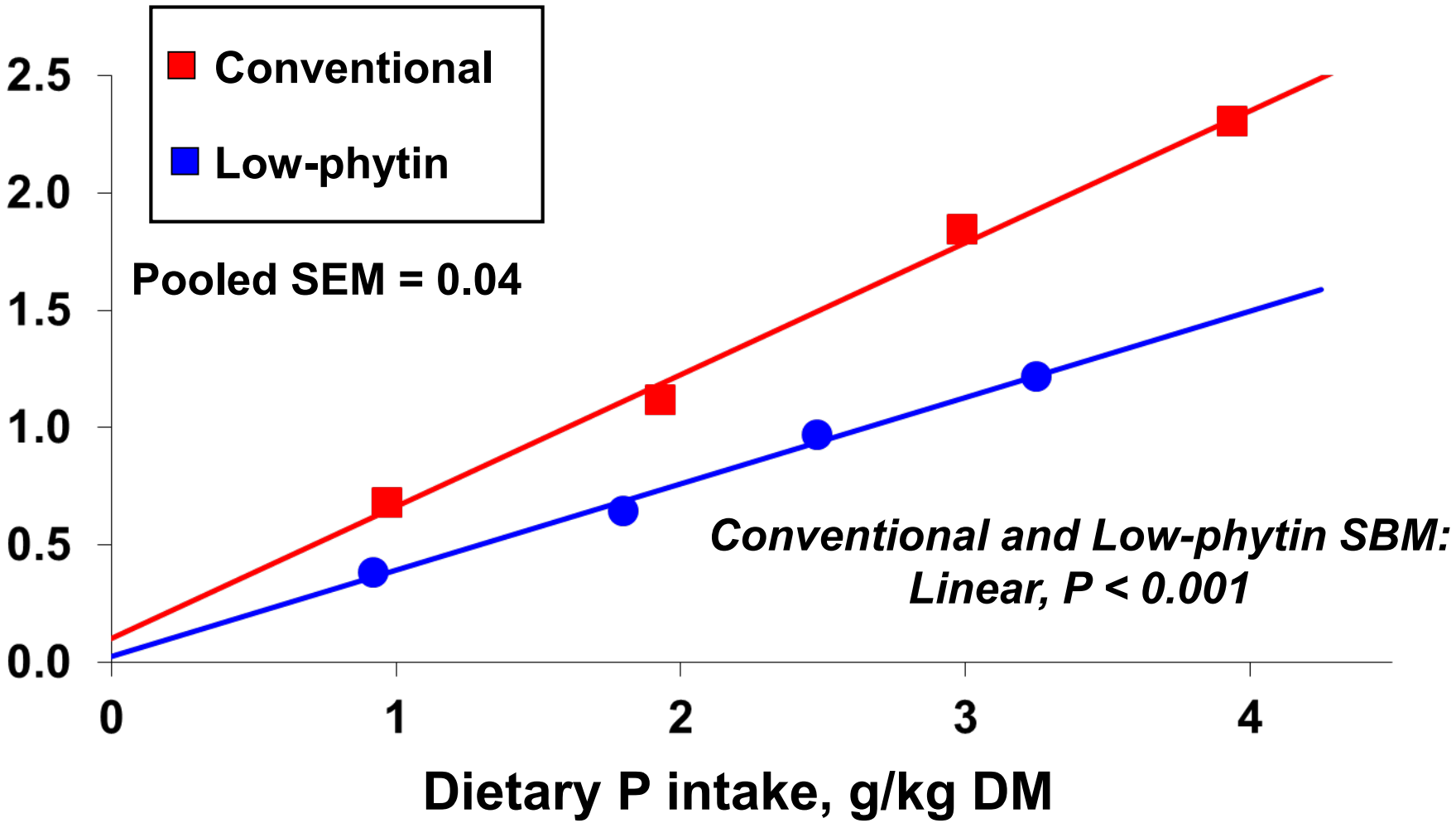
16 barrows fitted with

T-cannula at terminal ileum

Pigs assigned to metabolism crates in a replicated 8 x 8 Latin square



Ileal total P output, g/kg DMI



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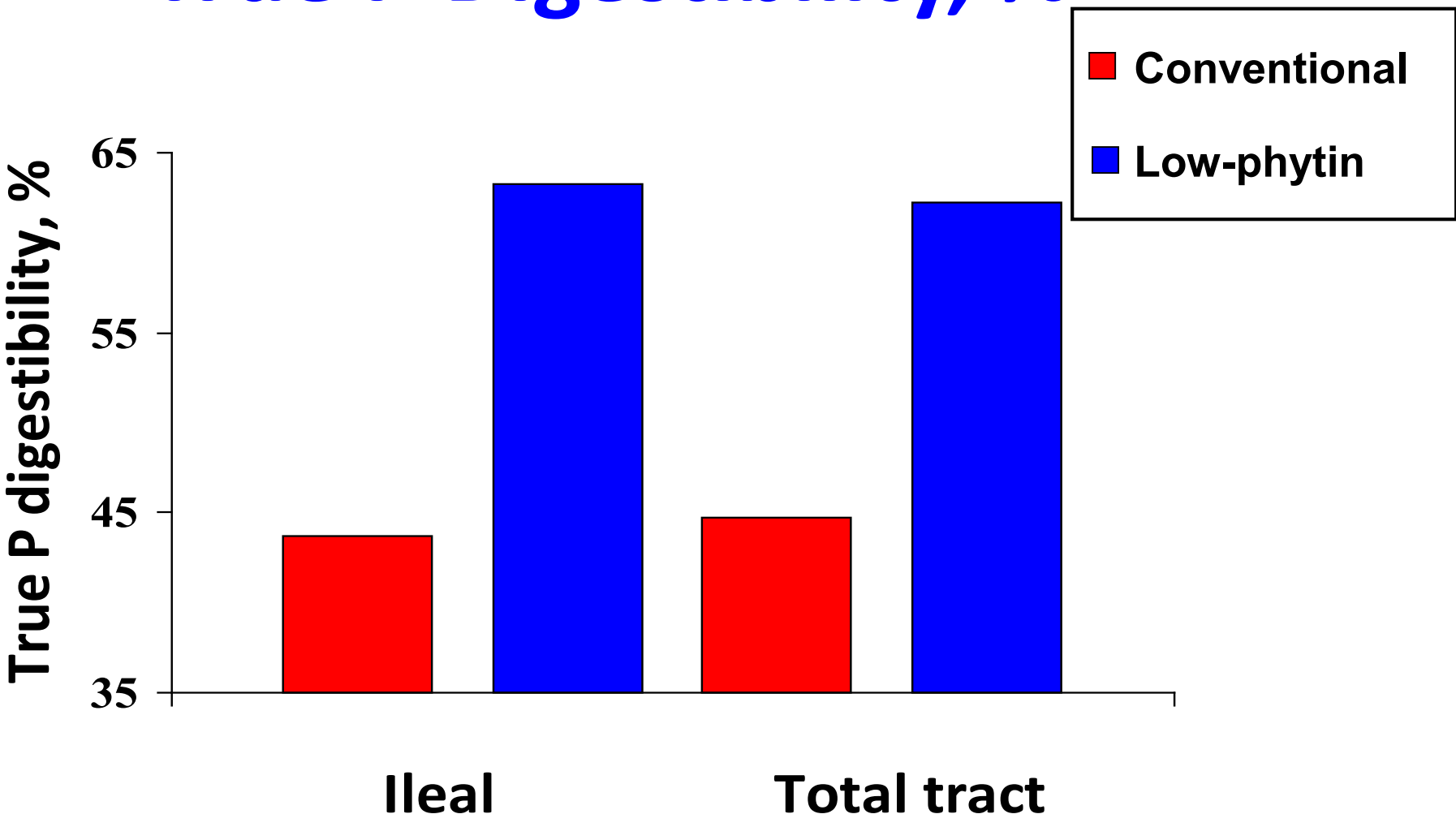
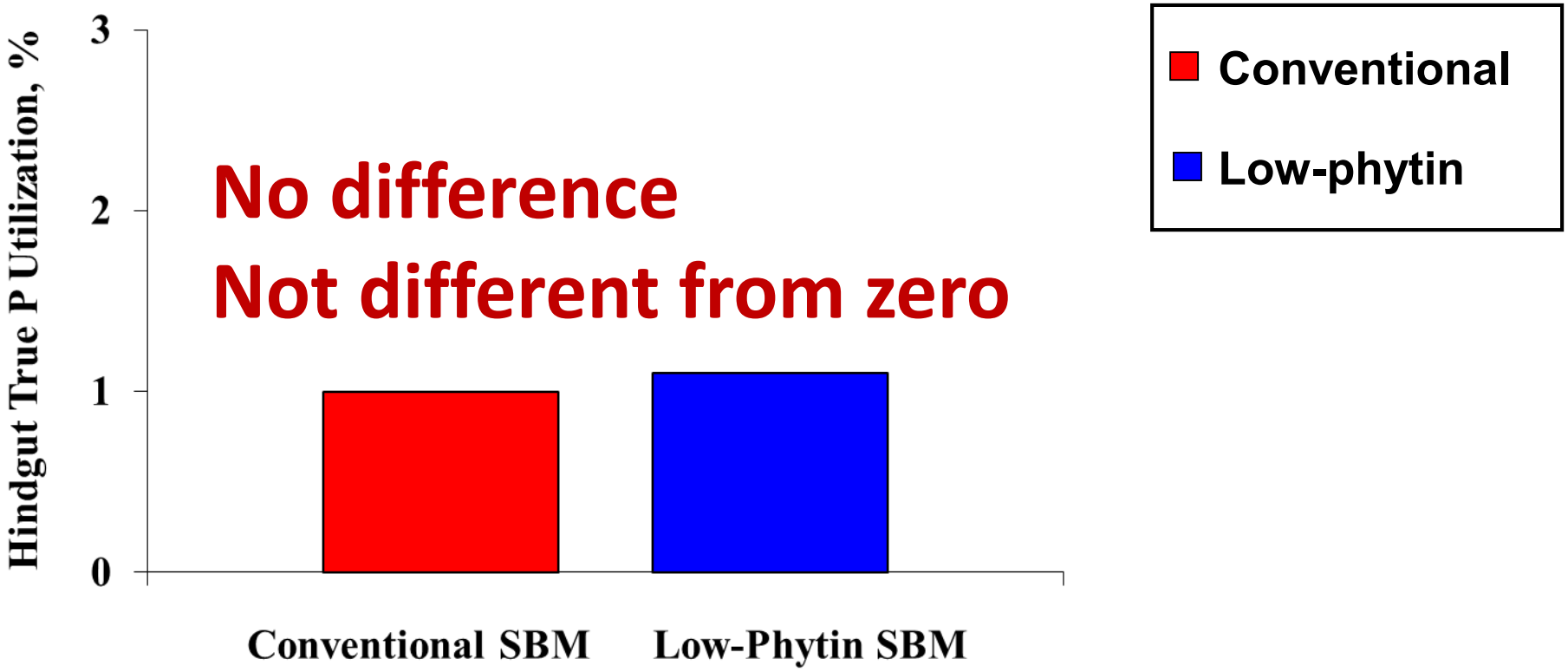
True P Digestibility, %



Hindgut Utilization of P, %



Swine

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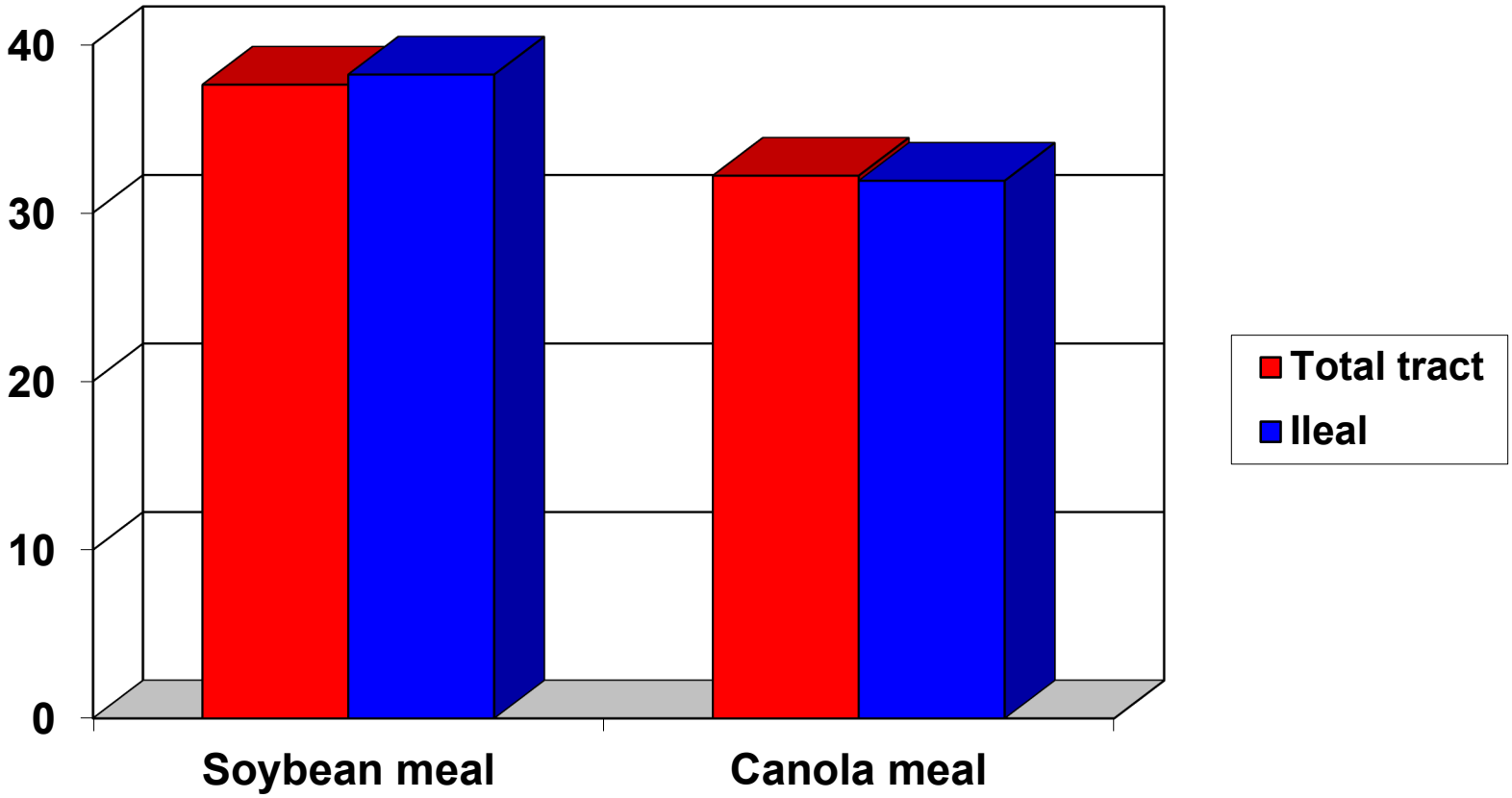
P Digestibility, %



Swine

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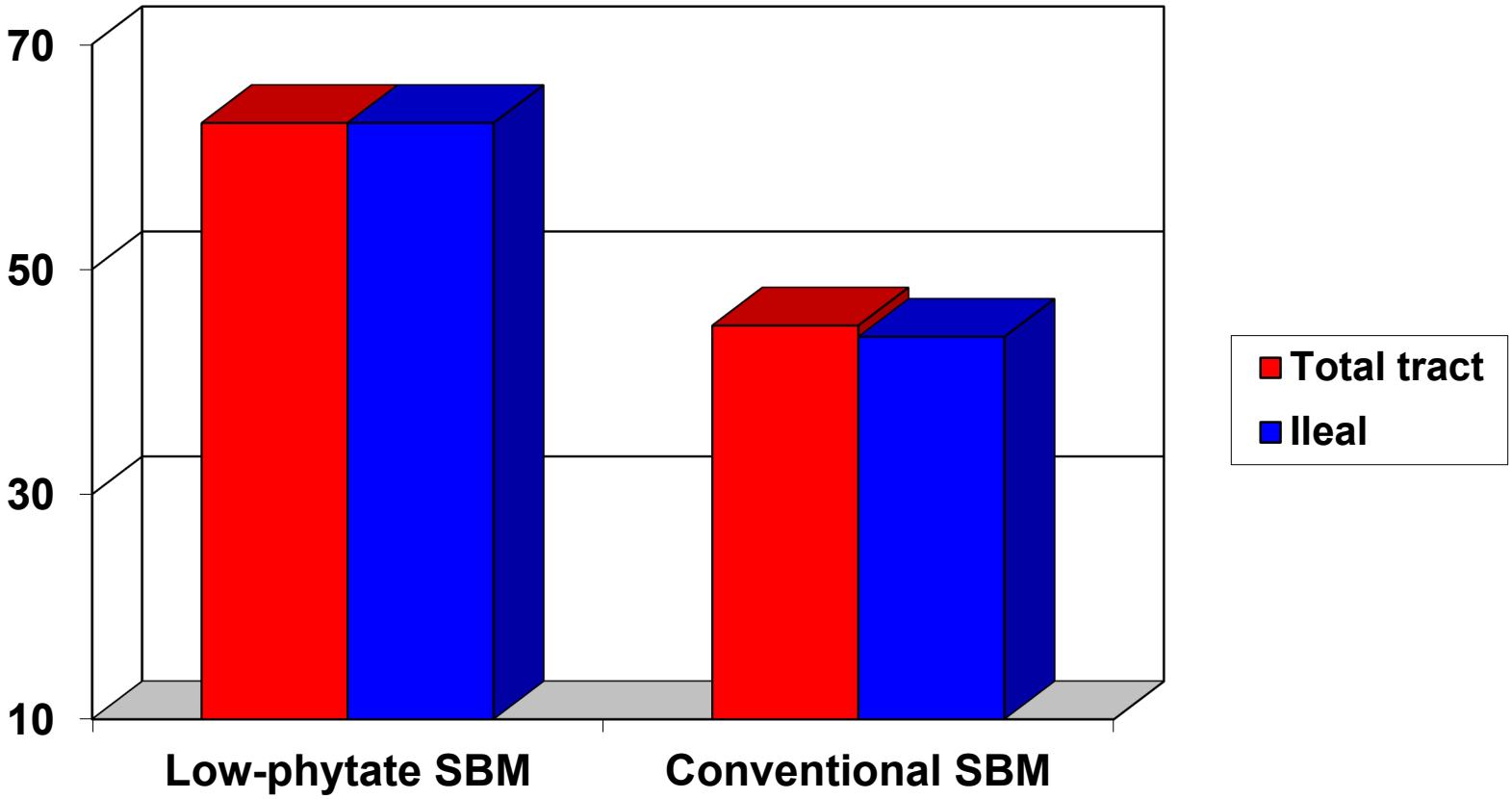
P Digestibility, %

	Low Phytate corn	Normal Corn	Soybean Meal
Total tract	56.5	28.3	37.2
Ileal	54.5	28.8	38.0

(Bohlke et al.)

Swine

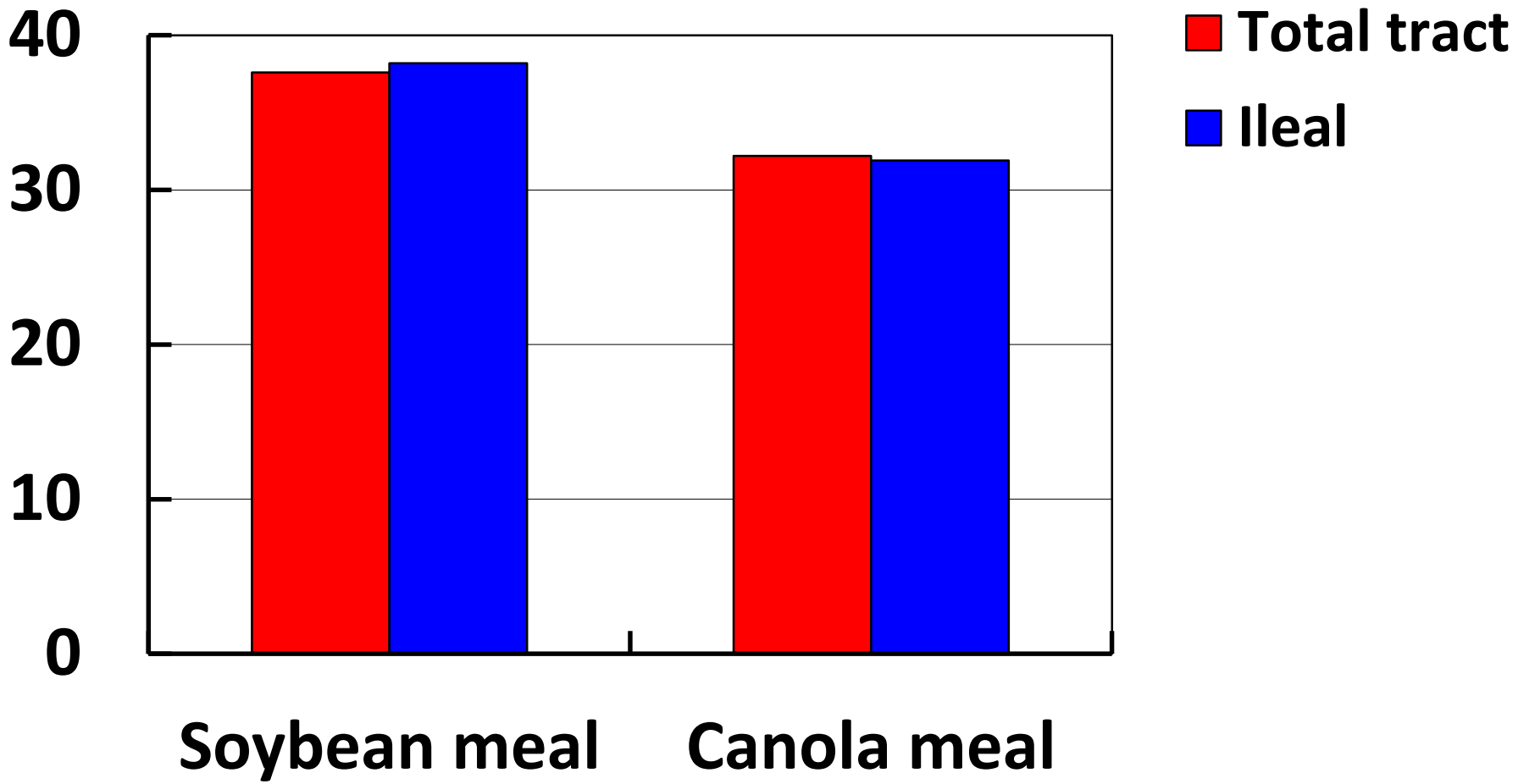
P Digestibility, %



(Dilger & Adeola)

Swine

P Digestibility, %



Swine

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Ileal digestibility is NOT different from total tract digestibility of P

Basis for adoption of total tract digestible P in Swine NRC (2012)

ENDOGENOUS P LOSSES (EPL)

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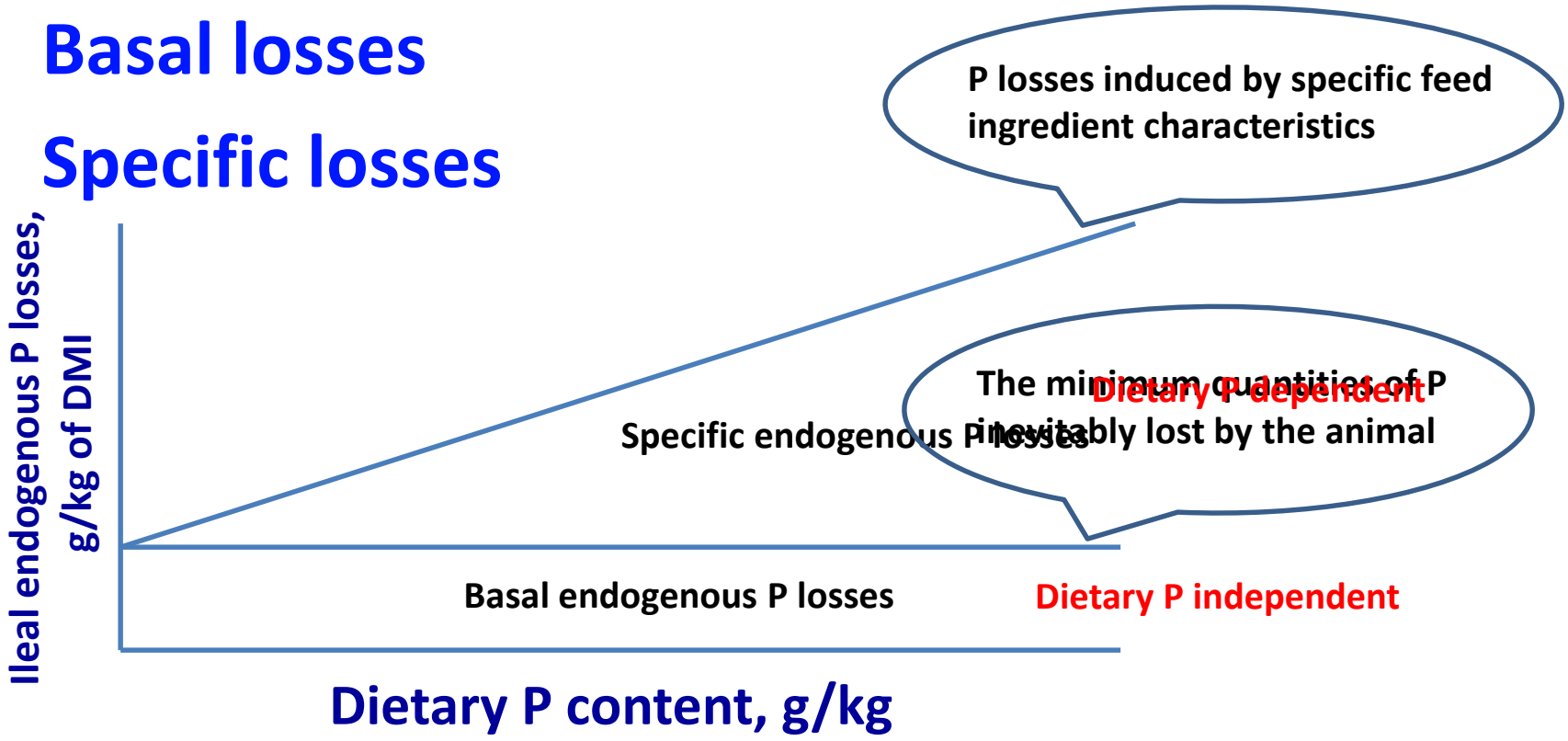
Total EPL may be divided into 2 main components

- Basal losses
- Specific losses



Definition

Apparent Digestibility

= (Intake – output)/Intake

Standardized Digestibility

= (Intake – (output – EPL_{basal}))/Intake

True Digestibility

= (Intake – (output – EPL_{total}))/Intake

SWINE NRC (2012)

- 11th Revised Edition
- Standardized total tract digestible (STTD) P was adopted as the currency for expressing
  - The requirements of pigs for P
  - The utilized phosphorus in feeds

SUMMARY

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- **Currency for P**
  - **Nutritionally adequate P**
  - **Additive in diet formulation**
  - **Minimize the excretion of phosphorus for environment**

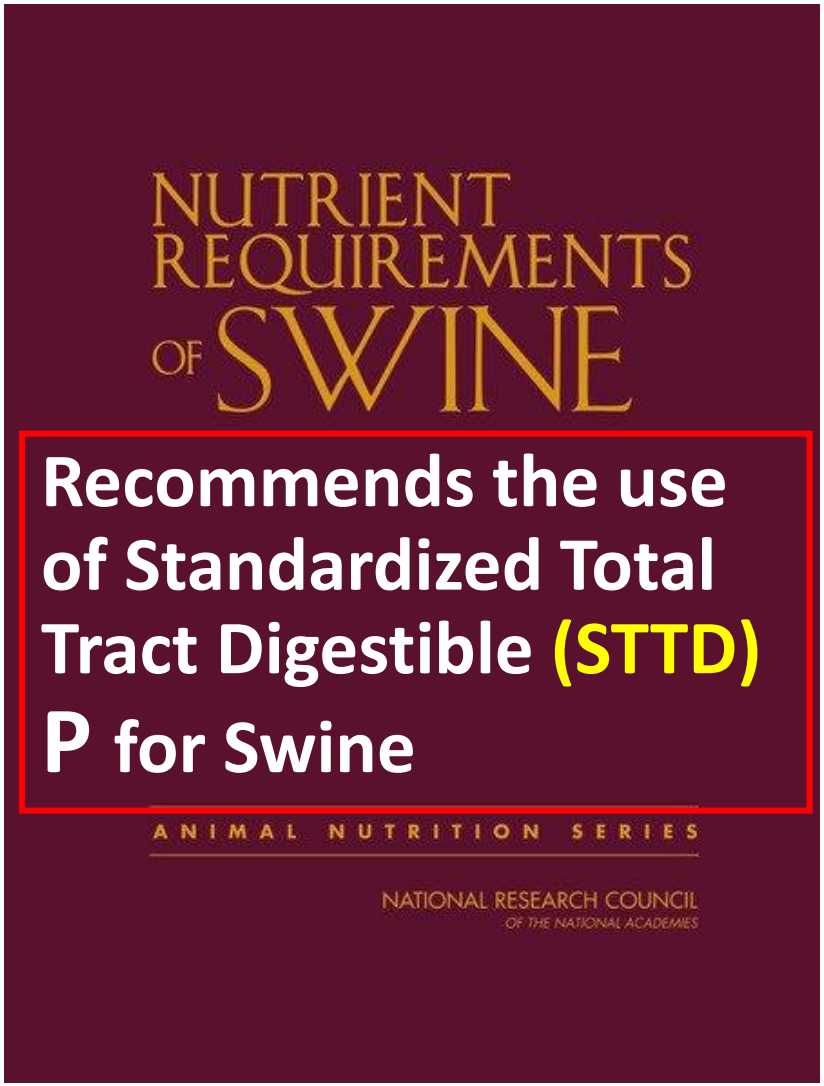
Swine

PURDUE UNIVERSITY

Ileal digestibility is NOT different from total tract digestibility of P

Basis for adoption of total tract digestible P in Swine NRC (2012)

Swine NRC (2012)



SWINE

As in P,
Ileal digestibility
is NOT different from
total tract digestibility
of Ca

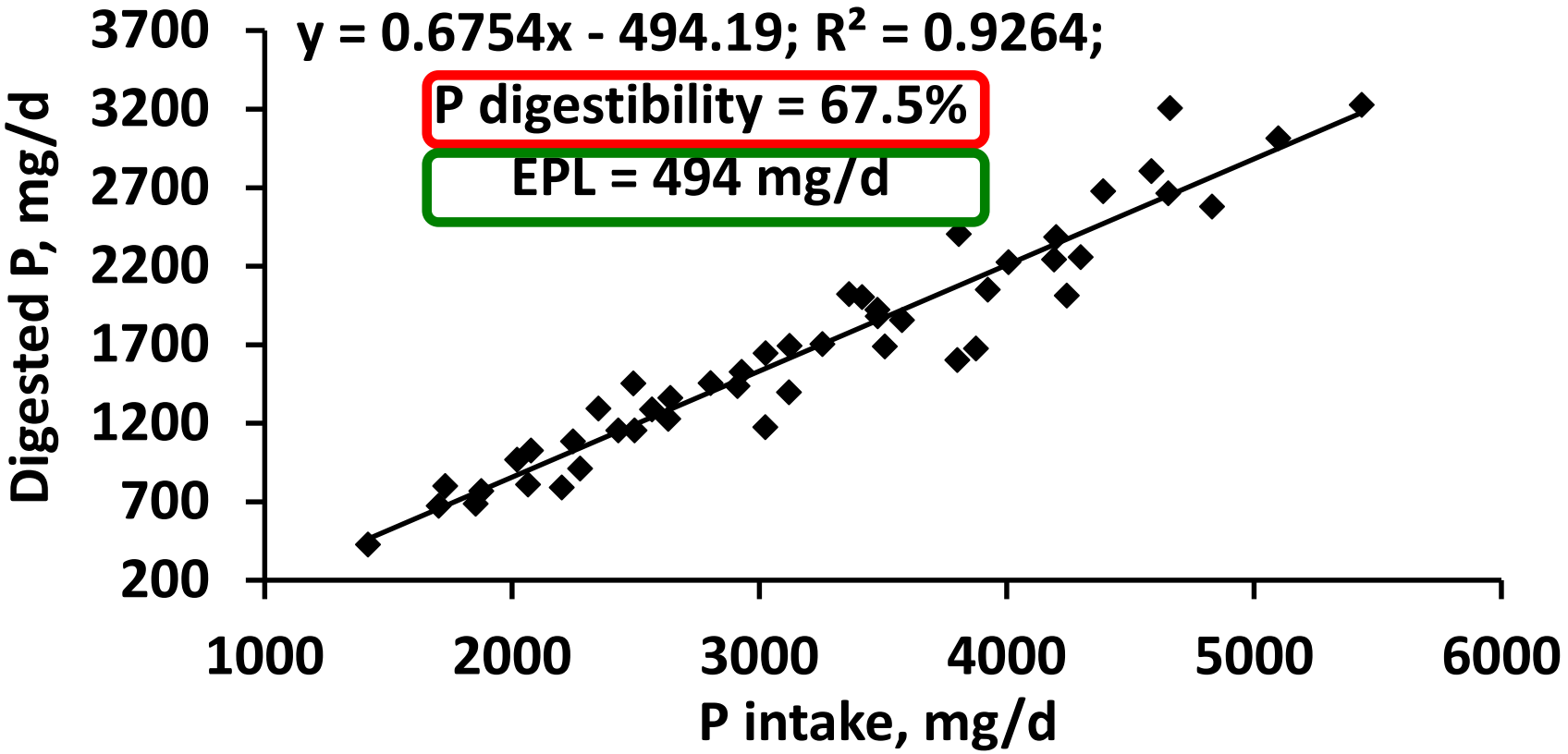
True total tract digestibility of P in monocalcium phosphate for 15-kg pigs

MATERIALS & METHODS

- Randomized complete block design
- 48 pigs (initial BW: 15.7 ± 1.5 kg)
- 8 diets
  - Corn and SBM-based diet
  - 8 levels of monocalcium phosphate
- 6 replicates per diet
- Adaptation for 5 d followed by a 5-d collection period

Ingredient composition of diets, g/kg

	Total P							
Item	3.30	4.04	4.77	5.51	6.24	6.98	7.71	8.45
Corn-SBM	900	900	900	900	900	900	900	900
Limestone	6.05	6.90	7.75	8.60	9.45	10.30	11.15	12.00
MCP	0.0	3.5	7.0	10.5	14.0	17.5	21.0	24.5
Analyzed nutrients								
Ca, g/kg	4.49	5.16	5.92	6.99	7.64	8.63	10.03	10.32
P, g/kg	3.31	4.00	4.66	5.70	6.24	6.84	7.62	8.58
Ca:P	1.36	1.29	1.27	1.23	1.22	1.26	1.32	1.20



True total-tract digestibility of P in monocalcium phosphate and endogenous P losses (EPL)

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CONCLUSION

The True Total-Tract Digestibility of P in monocalcium phosphate was determined to be 67.5% using the regression technique

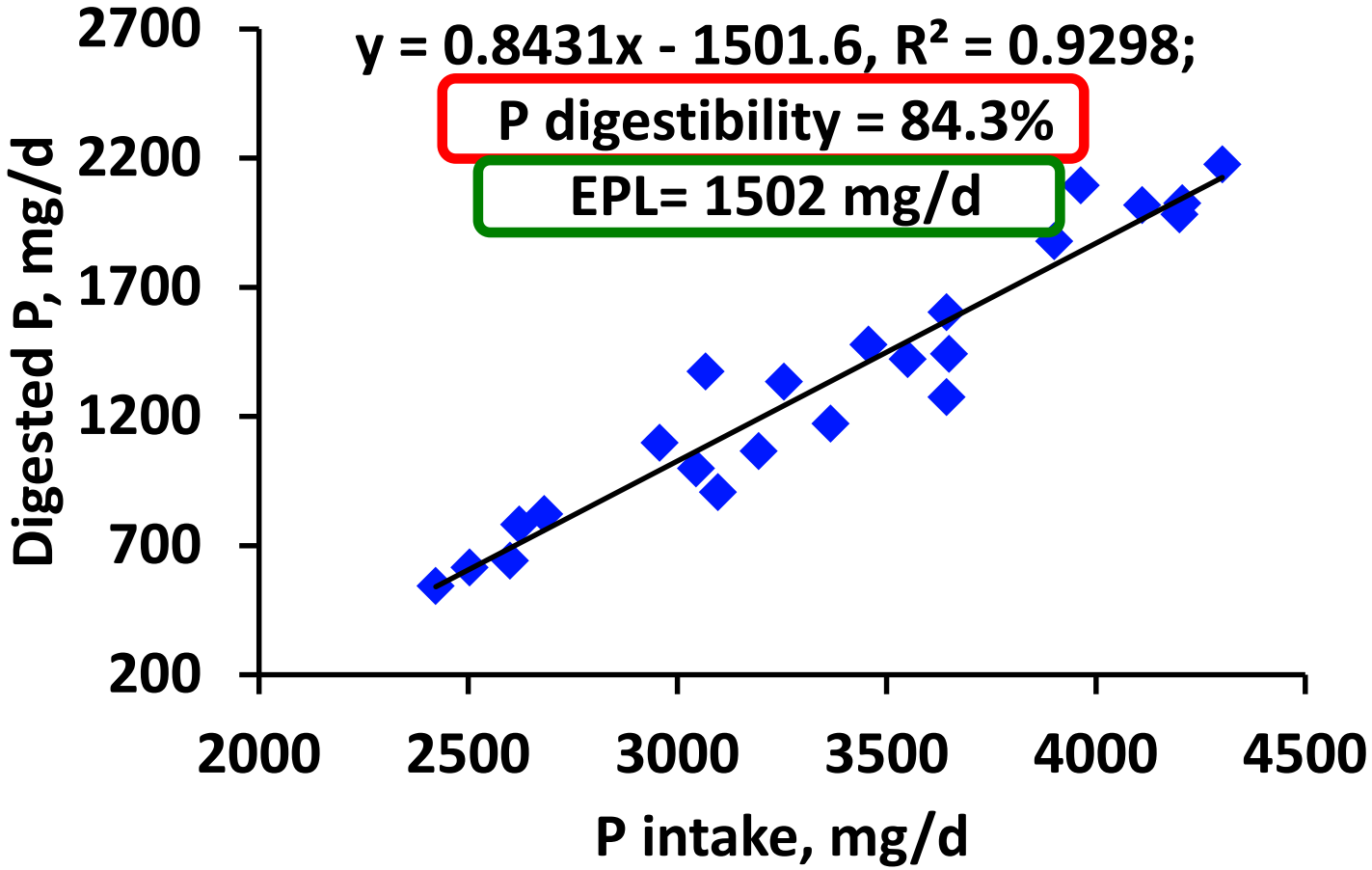
True total tract digestibility of P in monocalcium phosphate for 25-kg pigs

MATERIALS & METHODS

- Randomized complete block design
- 24 pigs (initial BW: 25.2 kg)
- 4 diets
  - Corn and SBM-based diet
  - 4 levels of monocalcium phosphate
- 6 replicates per diet
- Adaptation for 5 d followed by a 5-d collection period

Ingredient composition of diets, g/kg

	Total P			
Item	2.96	3.46	3.96	4.46
Corn-SBM	880	880	880	880
Limestone	5.61	6.19	6.78	7.36
MCP	0.00	2.40	4.80	7.20
Ca, g/kg	3.70	4.06	4.80	5.30
P, g/kg	2.98	3.63	4.14	4.78
Ca:P	1.24	1.12	1.16	1.11



True total tract P digestibility in monocalcium phosphate and endogenous P losses (EPL)

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CONCLUSION

The True Total-Tract Digestibility of P in monocalcium phosphate was determined to be 84.3% using the regression technique

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Additivity in Feed Formulation

FEED FORMULATION

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Assumption

Supply of nutrients in a **mixed diet**

=

Sum of the supply of nutrients from the **individual ingredients**

Additivity of nutrients is fundamental in the formulation of diets

ADDITIVITY IN FEED FORMULATION

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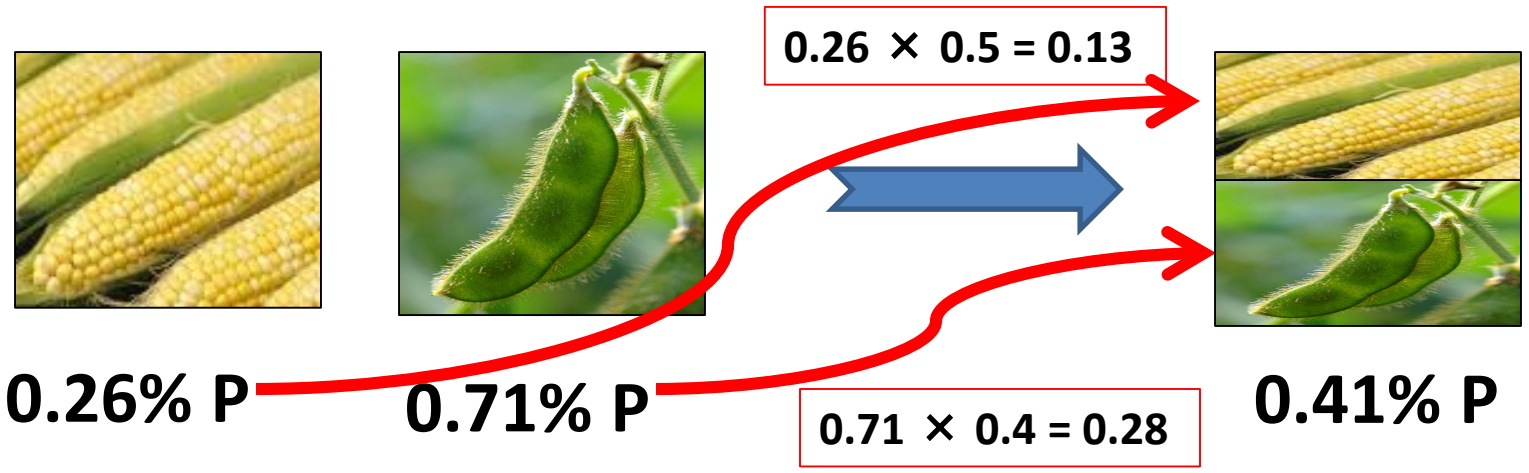
- Corn (0.26% P) & SBM (0.71% P)
- Mix together in ratio of 50 : 40
- Mixed diet P: 0.13 + 0.28 = 0.41%
  (Additivity)



ADDITIVITY IN FEED FORMULATION

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	Corn	SBM	50% Corn	40% SBM	Mixed Diet
Total P, %	0.26	0.71	0.13	0.28	0.41
Digestibility, %	26	39			
Digestible,%*	0.07	0.28	0.035	0.112	**0.147**

*Apparent Digestible OR Standardized Digestible OR True Digestible

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HYPOTHESIS

True total tract digestibility of P in corn and soybean meal for 15-kg pigs are additive in corn-soybean meal diet

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MATERIALS AND METHODS

- RCBD (randomized complete block design)
- 54 pigs (initial BW: 14.7 ± 1.6 kg)
- 6 diets
  - 3 P sources:

    Corn, SBM, and Corn : SBM (2:1)
  - 2 P levels: high and low
- 9 replicates per diet
- Adaptation for 5 d followed by a 7-d collection period

Ingredient composition of assay diets, as-fed basis

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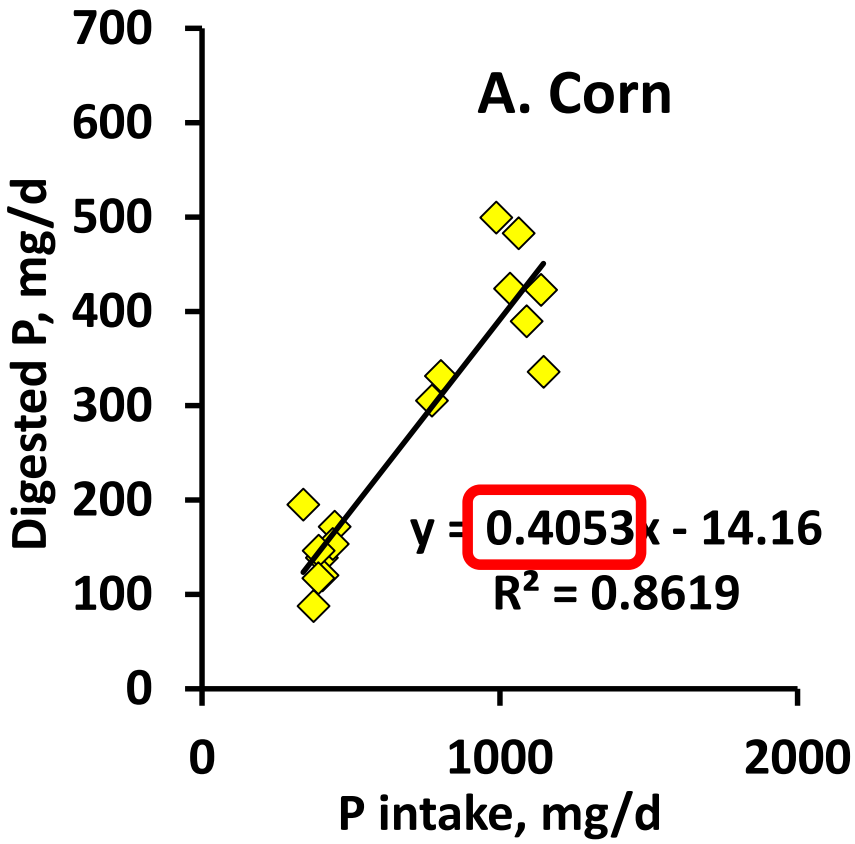
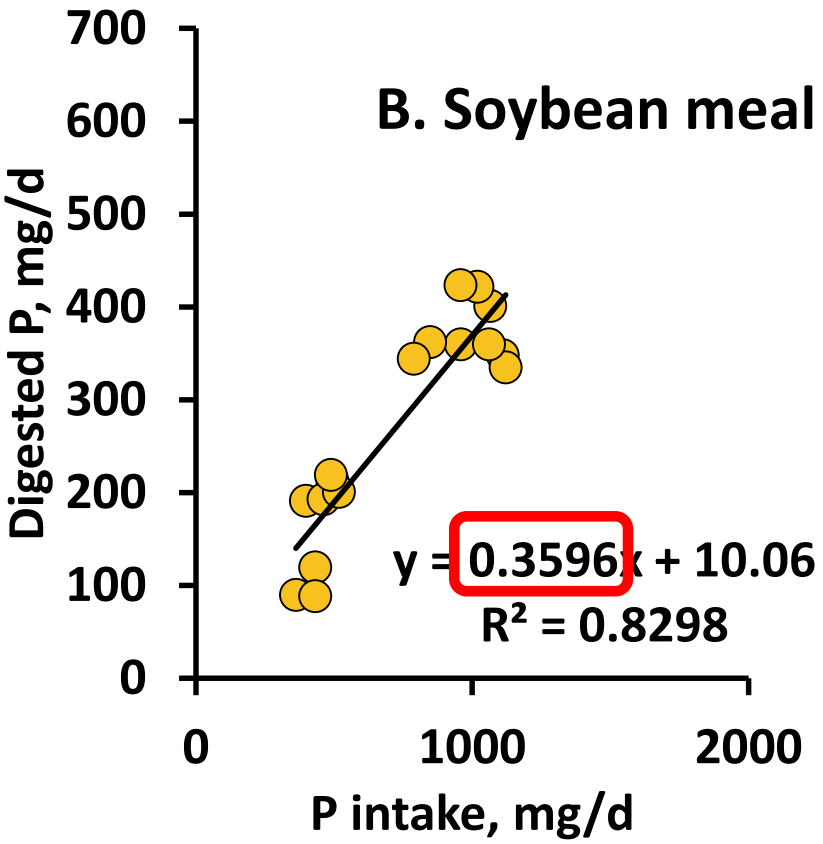
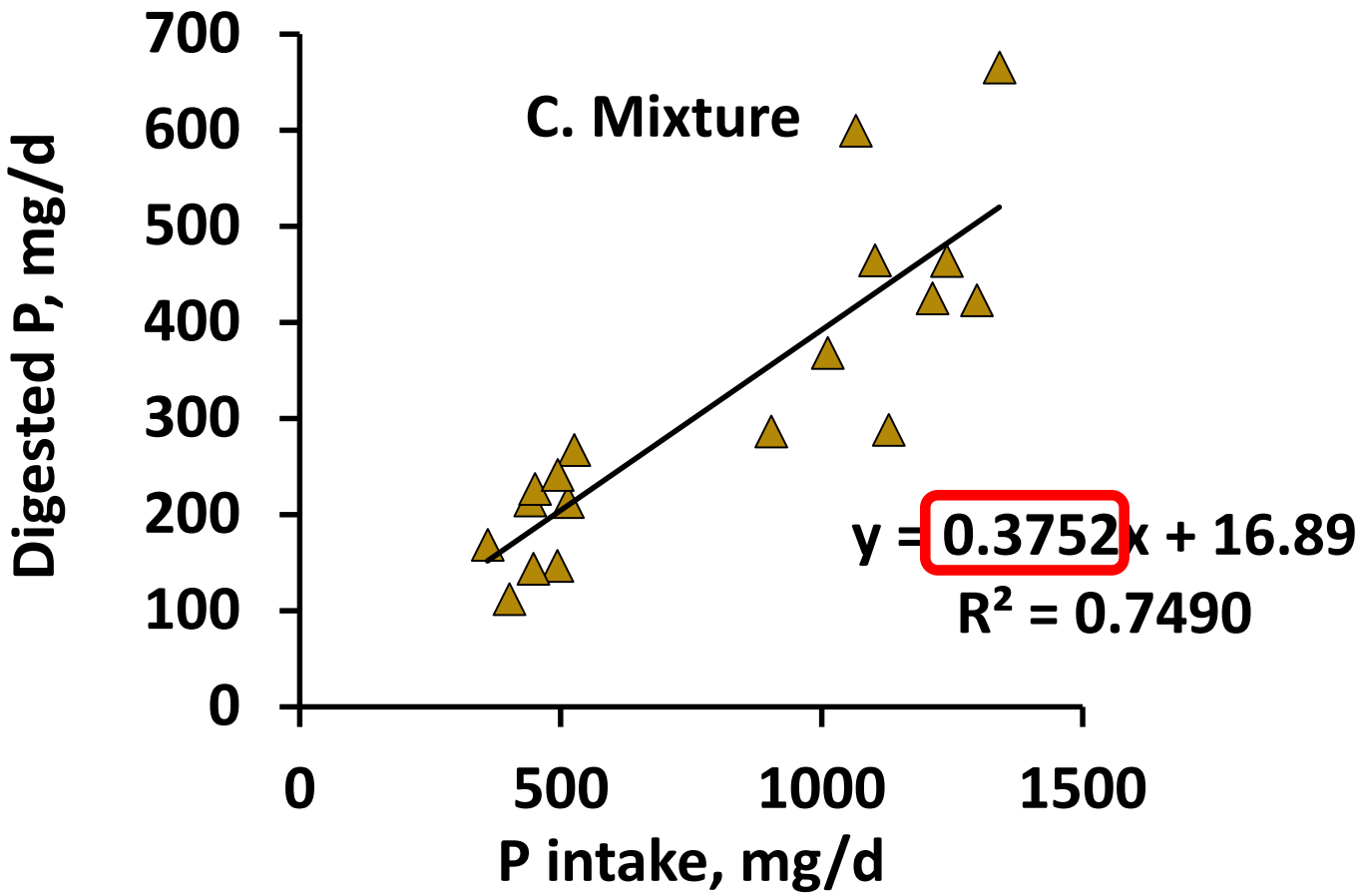
	Corn		Soybean meal		Mixture	
Item	Low	High	Low	High	Low	High
Corn	300	860	-	-	140	420
Soybean Meal	-	-	120	330	70	210
Limestone	2.20	6.35	0.65	1.80	1.40	4.30
Analyzed nutrients						
Ca, g/kg	1.14	2.78	1.30	2.98	1.24	3.18
P, g/kg	0.96	2.30	1.04	2.27	1.05	2.62
Ca:P	1.19	1.21	1.25	1.31	1.18	1.21





Regression of digested phosphorus (P) against P intake for corn (A) and soybean meal (B)



Regression of digested P against P intake for the mixture of corn and soybean meal (C)

ADDITIVITY

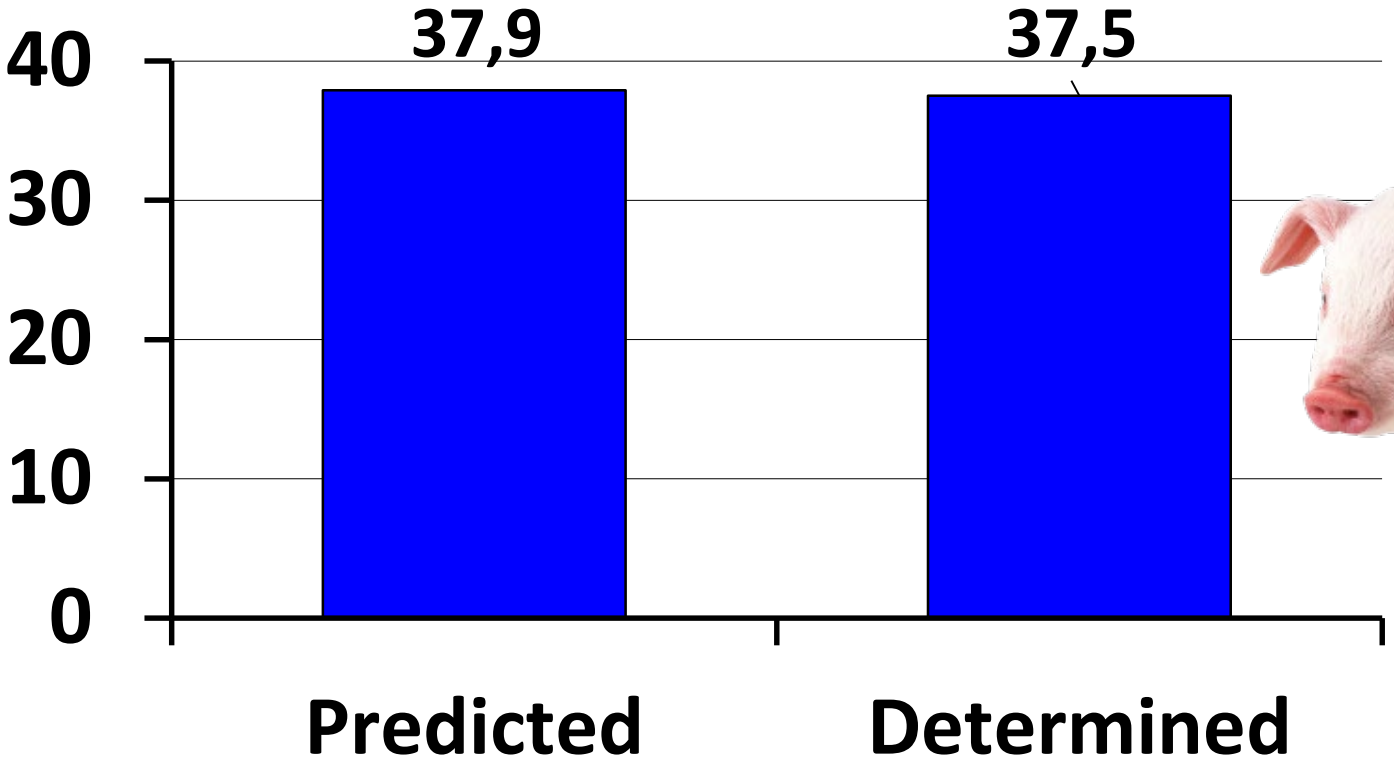
P source	Corn	Soybean meal	Mixture
TTTD of P, %	40.5	35.9	37.5

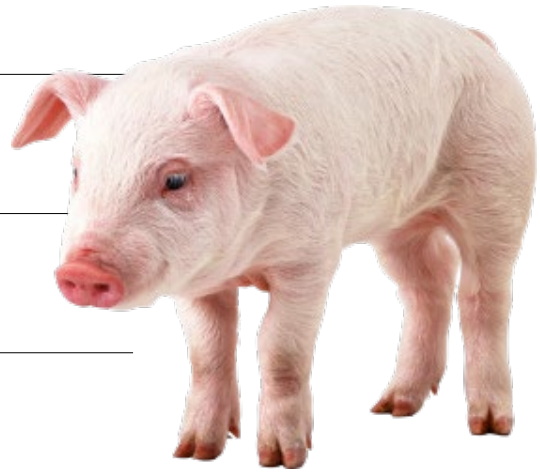
P source	Corn	Soybean meal
P contribution in Mixture, %	43	57

Mixture: $TTTDP_{Predicted}$ = 37.9%

SWINE

P Digestibility, %





Predicted is not different from determined

TTTD of P in corn and SBM for pigs

CONCLUSIONS

- Regression-derived True total tract digestibility (TTTD) of P in corn and SBM were 40.5% and 35.9%, respectively
- The TTTD of P is additive in a mixed diet of Corn and SBM for pigs

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HYPOTHESIS

There is no difference between the determined TTTD of Ca ($TTTDCa_D$) and predicted TTTD of Ca ($TTTDCa_P$) in the mixed diet

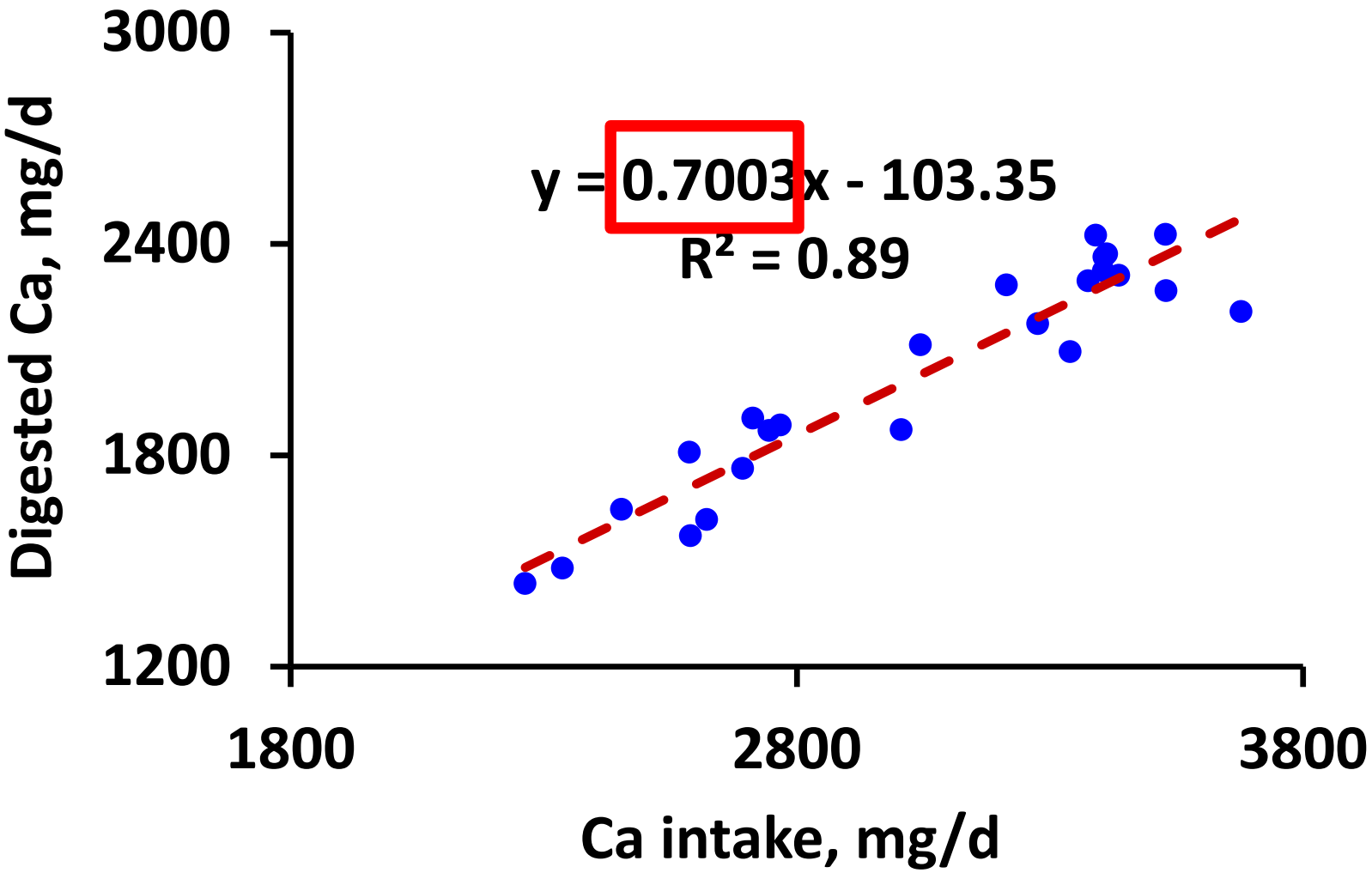
Ho: $TTTDCa_D = TTTDCa_P$

Ingredient composition of assay diets, as-fed basis

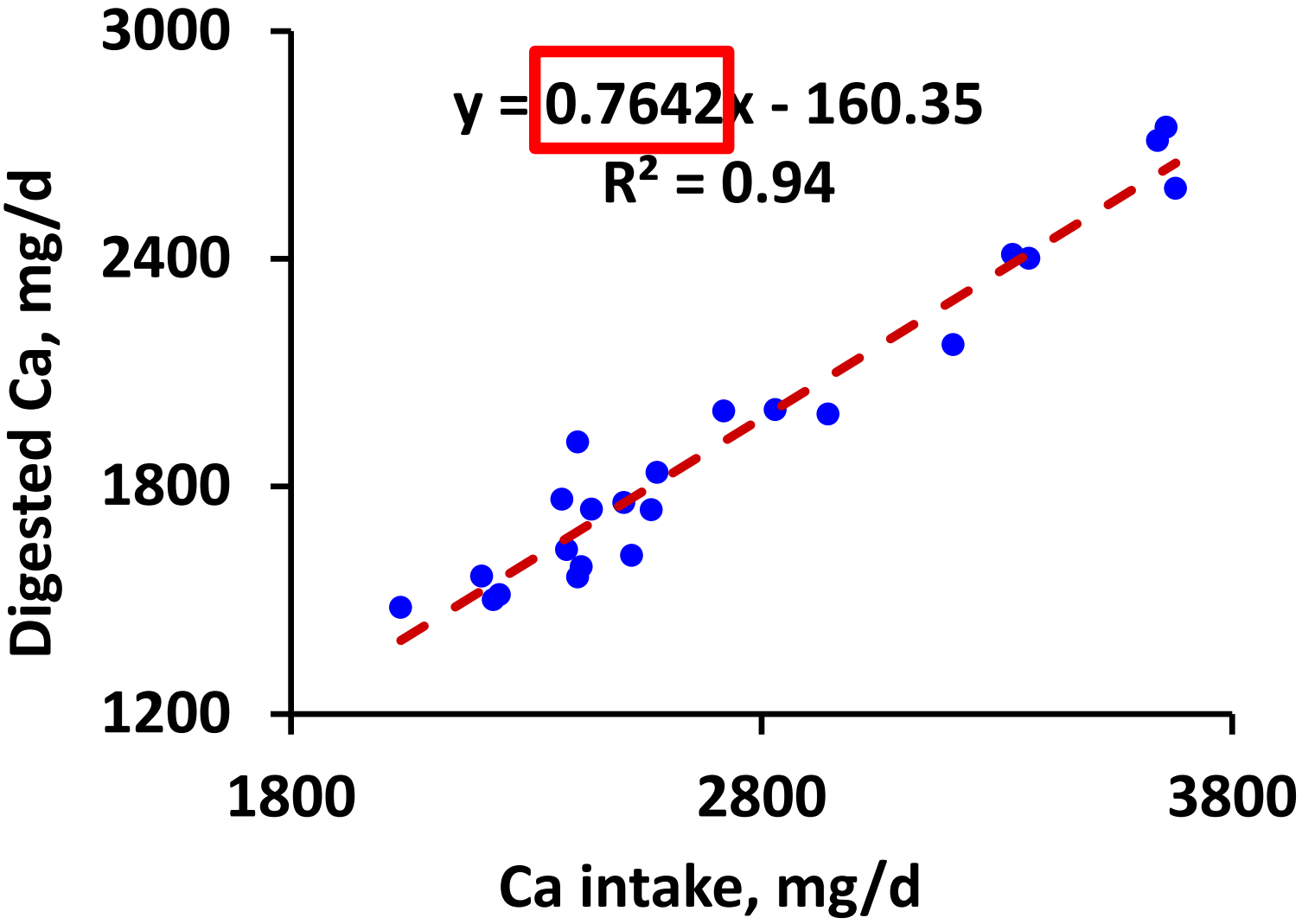
	Limestone			DCP			Limestone + DCP		
Item	4.0	5.0	6.0	4.0	5.0	6.0	4.0	5.0	6.0
Limestone	10.9	13.7	16.5	0.0	0.0	0.0	6.5	8.1	9.7
DCP	0.0	0.0	0.0	15.8	19.8	23.8	6.5	8.1	9.7
Potassium phosphate	13.0	17.0	21.0	0.0	0.7	1.4	7.6	10.6	12.6
Potassium carbonate	4.0	1.5	0.0	11.0	10.7	10.3	7.0	5.0	4.0
Others	721	678	625	732	688	645	724	682	640

Maintain tCa : tP ratio = 1.0 : 1

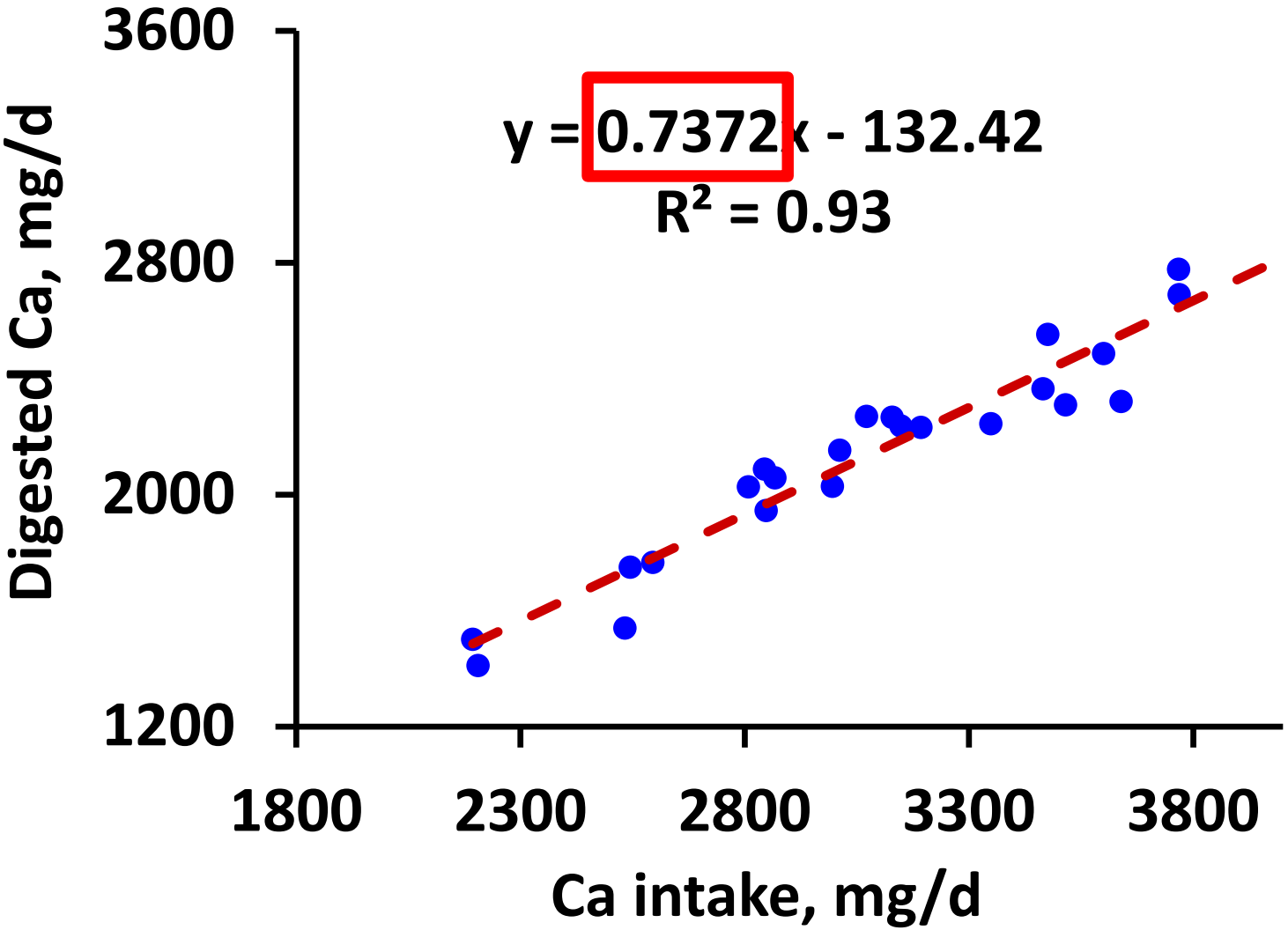
True total tract digestibility of Ca in limestone



True total tract digestibility of Ca in DCP



True total tract digestibility of Ca in mixture

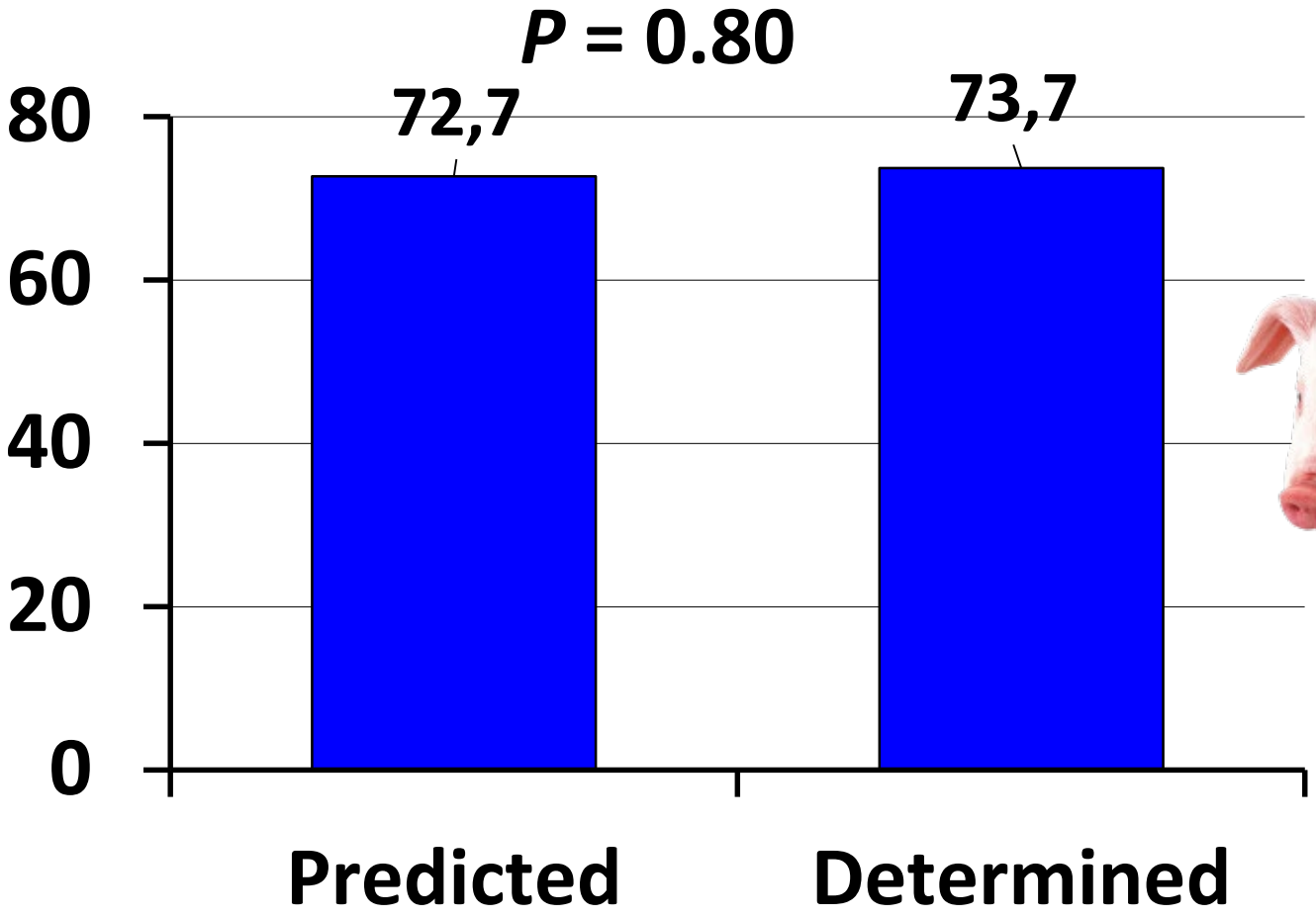


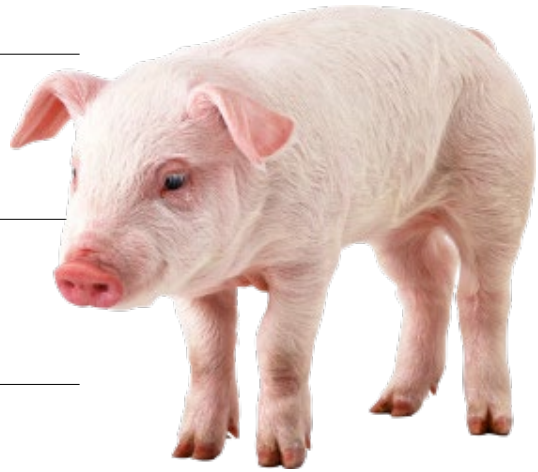
Ca source	Limestone	DCP	Mixture
TTTD of Ca, %	70.0	76.4	73.7

Ca source	Limestone	DCP
Ca contribution in Mixture, %	59.0	41.0

Mixture: $TTTDCa_{Predicted}$ = 72.7%

True total tract digestibility of Ca, %





Predicted is not different from determined TTTD of Ca in limestone and DCP for pigs

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CONCLUSIONS

- Regression-derived TTTD of Ca in Limestone and Dicalcium phosphate (DCP) were 70% and 76%, respectively
- True total tract digestibility of Ca in Limestone and DCP is additive in mixed diet for pigs

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- **Ingredient evaluation essential for formulating ideal diets**

- **Ideal diets that match nutrient requirements with usable nutrients in feed ingredients**

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- Essential for efficient production of lean meat for human population
- Also essential for reducing nutrient excretion into the environment
- All are central to sustainable agriculture


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