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Manipulation of Swine Diets to Mitigate Greenhouse Gas Emission and Reduce Swine Odor and Other Detrimental Environmental Impacts

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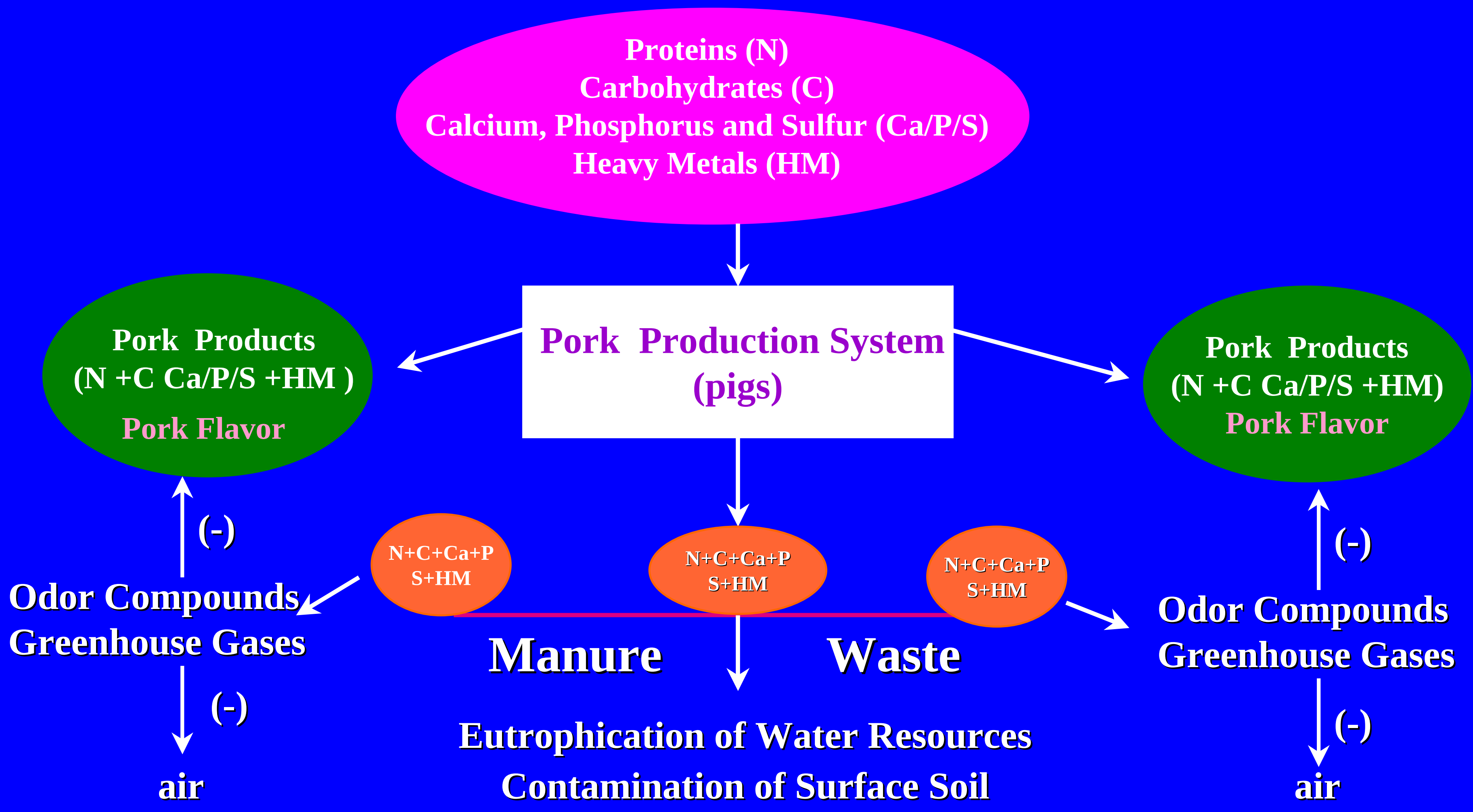
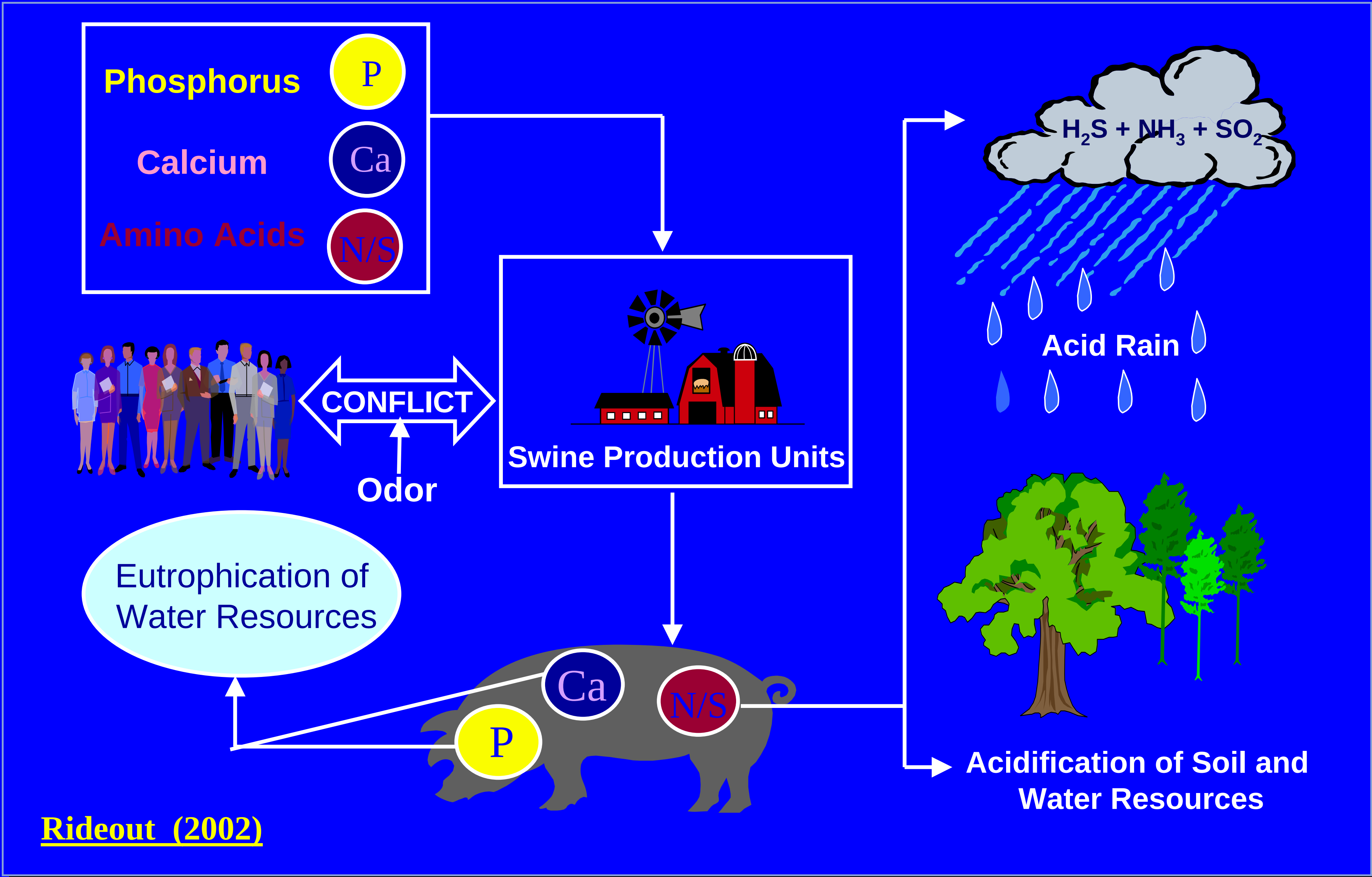
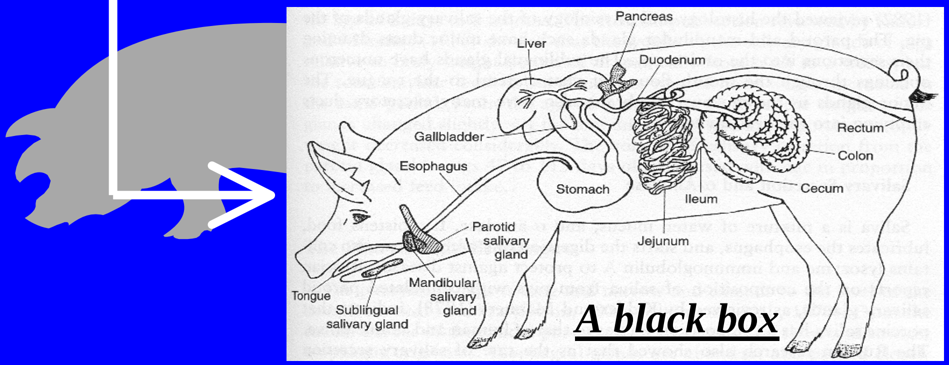
Environmental Impacts of Swine Production




Phosphorus
P
Calcium
Ca
Amino Acids
N/S
CONFLICT
Odor
Swine Production Units
Eutrophication of Water Resources
Ca
N/S
P
$H_2S + NH_3 + SO_2$
Acid Rain
Acidification of Soil and Water Resources
Rideout (2002)

Dietary nutrient loading and ingredients are the carrier and precursor compounds - “scientific feeding”

Proteins (N), carbohydrates (C), calcium (Ca), phosphorus (P), sulfur (S) and heavy metals (HM) associated with bulky feed ingredients and feed additives in diets



Pork Products

Manure rich in:
Water
N
C
Ca
P
S
HM
Microbes

fermentation

Evaporation
Runoff
Leaching

Odor
Climate
Water
Soil

(I) Manipulating Dietary Crude (CP) Protein Levels to Address Manure Nitrogen(N)-Related Environmental Concerns in Intensive Swine Operations

Biological Origins of Ammonia and Amines

⇒ ***Ammonia:***

AA-undigested proteins —Deamination→ $^{*}NH_3$

Urea/uric acid —Microbial urease→ $^{*}NH_3$

⇒ ***Amines:***

AA-undigested proteins —Decarboxylation→ amines

(Mackie *et al.*, 1998)

Why Do We Worry about NH_3 Emission???

NH_3

↓

Air

↓ moving by wind

Various locations

↓ nitrification + acidification

Nitrate (H^+ + NO_3^-)

Soil | forestry | surface water | underground water

Your swine manure is very high in soluble and volatile nitrogen compounds: odor, and acid rain effects!!

- A large proportion of swine manure nitrogen (N): urea N from urine and converted to ammonia (NH_3) after excretion;
- Swine manure slurry with 90-95% and an alkaline pH (8-9) under normal feeding condition;
- About 60-70% of manure N will be lost through emission as ammonia after excretion during the first 3-4 weeks of storage.

Low-Protein Pig Diets to Help Tackle This?

- Regular dietary protein: 20-23% for weaner; 16-18 for grower; and 14-15% for finisher pigs;
- Soybean meal (SBM) is primarily used for providing limiting essential amino acids: Lys and Thr;
- Dietary supplementation of crystalline Lys and Thr to reduce SBM and crude protein (CP) levels to reduce urinary N levels;
- 1% reduction in CP ---------> 8% reduction in urinary N: 3-4% CP reduction in diets practically possible!! ---------> reducing 30% ammonia emission from manure!!

Biogenesis of Major Greenhouse Gases

⇒ CO_2: Amino acids are preferentially catabolized!

AA ---- first-pass catabolism in gut -- → CO_2 + Heat

⇒ Soluble nitrogen compounds (urea/NH_4^+): the major precursors for biogenesis of N_2O

Urea/NH_4^+ --- anaerobic fermentation -- → N_2O + Heat

(Mackie *et al.*, 1998)

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(II) Formulating Swine Diets on True Digestible Calcium (Ca) and Phosphorus (P) Supply to Reduce Feeding Costs and Environmental Concerns in Intensive Swine Operations

Phosphorus Nutrition and Environment

- Phosphorus (P): the major nutrient responsible for surface water pollution, i.e., eutrophication
- P is the 3rd most expensive nutrient in swine diets
- Non-legume crops and hays require much more N than P for growth
- Phosphorus content in swine manure: a major potential limiting factor for spreading manure

Phosphorus and "Eutrophication" of Water Resources

Phosphorus from wastes of industry and agriculture activities

↓ Run-off/leaching

Water Resources: Lakes, Ponds

↓

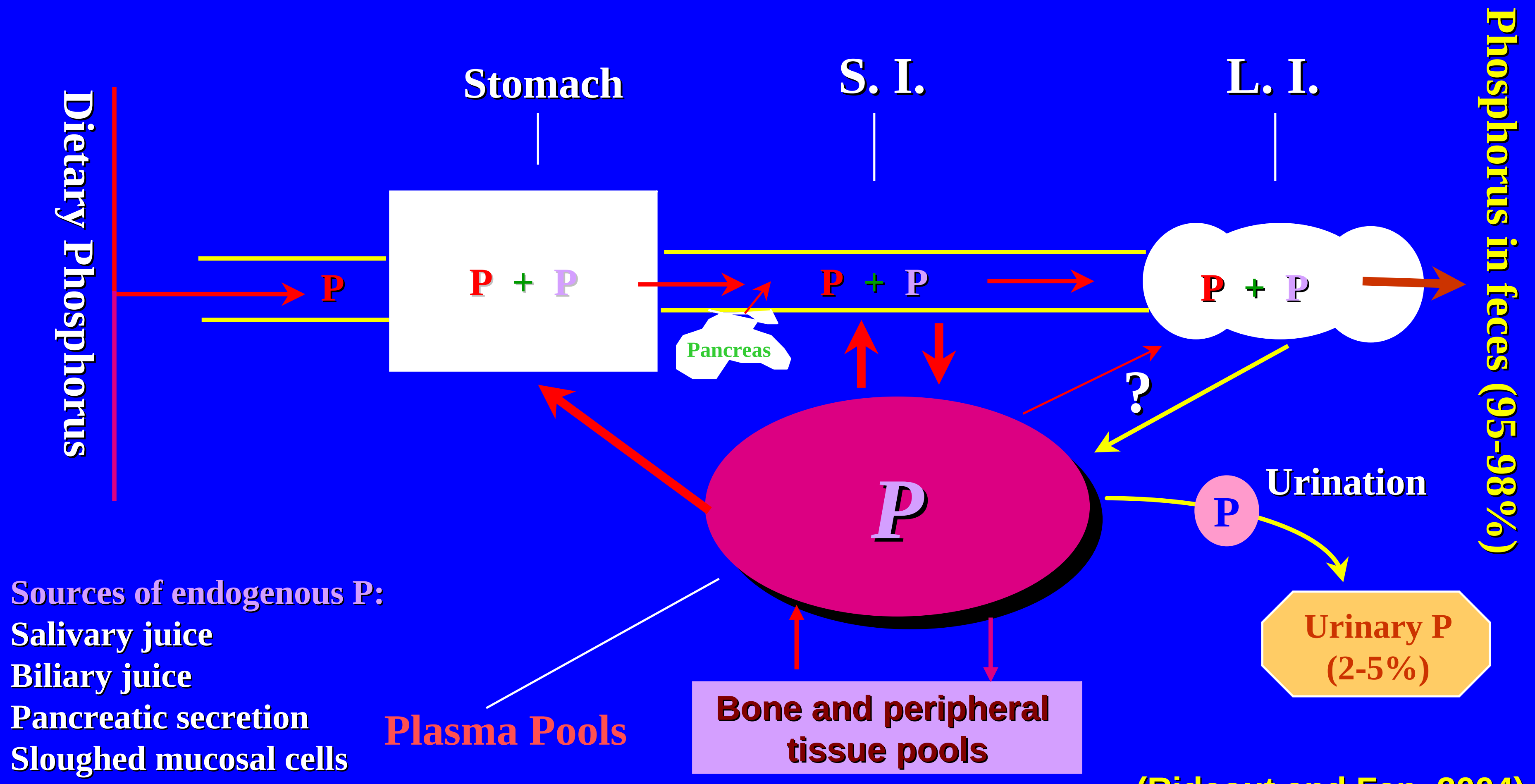
Algal booms - depletion of oxygen

↓

Eutrophication: fish death/cloudy water

Phosphorus is very mobile in soil: run-off and leaching - causing eutrophication of surface water

Major Routes of Phosphorus Utilization in Pigs



(Rideout and Fan, 2004)

Major Strategies for Improving Phosphorus Utilization in Pigs

- Dietary supplementation of optimal levels of microbial phytase preparations (Simons et al., 1990)

- Developing new crop cultivars that produce low levels of phytate phosphorus (Spencer et al., 2000)

- Developing transgenic pigs that express high levels of phytase activities (Golovan et al., 2001)

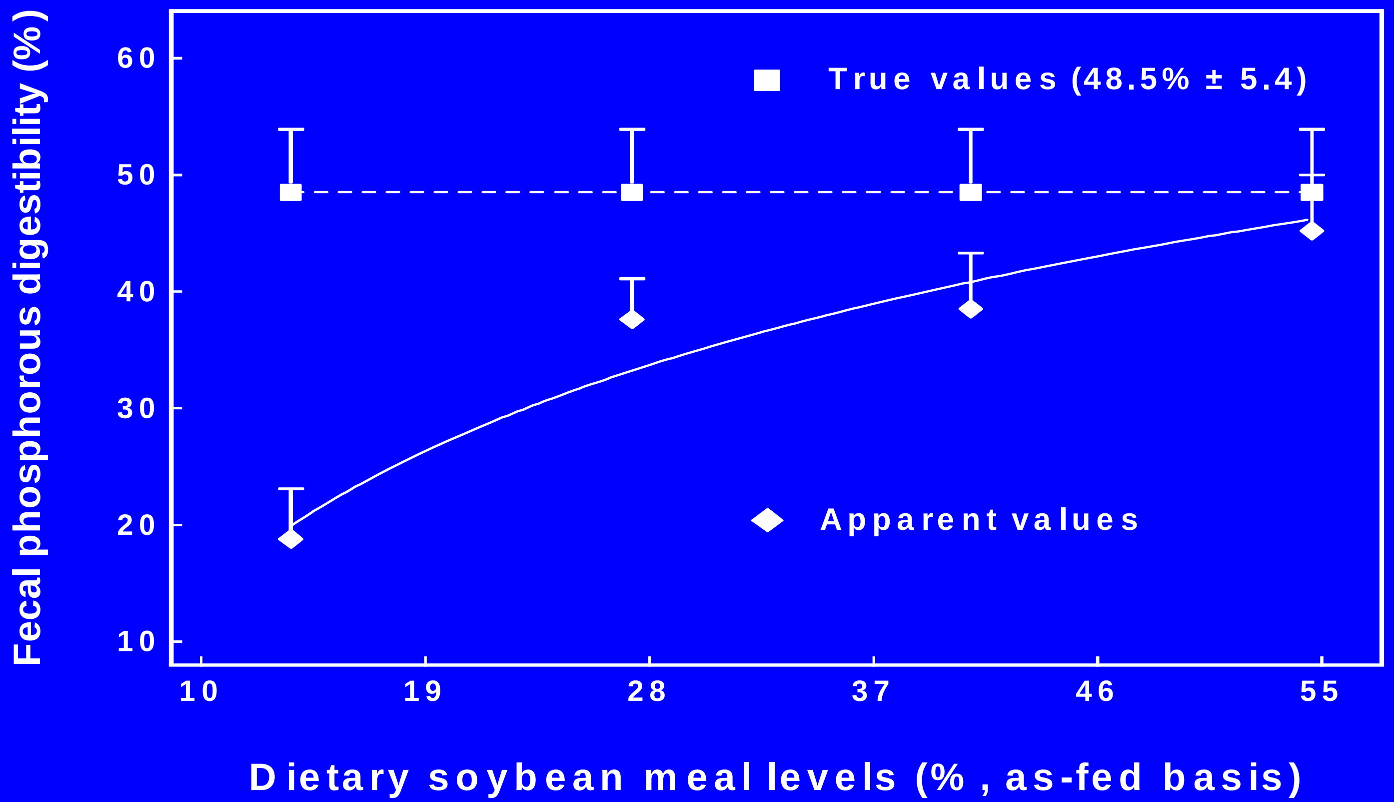
→ Formulation of swine diets on a true digestible P supply**

Large Variation in "Apparent" Phosphorus Digestibility and "Availability" within the Same Ingredients for Swine

Feedstuffs	Digestibility (%)	Availability
Barley	16 - 51	29 - 51
Wheat	36 - 68	40 - 68
Corn	8 - 29	12 - 23
Peas	42 - 51	45
Beans	21 - 48	21
Soybean meal	15 - 38	21 - 38

Jongbloed et al. (1991); Weremko et al. (1997); NRC (1998)

Differences in Dietary Phosphorus Levels Largely Responsible for the Variability of Apparent Fecal Phosphorus Digestibility (n = 16)



(Fan et al., 2001)

Comparison of Phosphorus Bioavailability Values (%) in Corn and Soybean Meal for Pigs

Ingredients/sources	True Digestibility	Average old literature data
Corn (Shen et al., 2002)	54-60	22
Soybean meal (Fan et al., 2001) (Ajakaiye et al., 2003)	49-51	25

Taking home messages for practices: formulating your pig diets on the true digestible Ca/P supply to reduce mineral P supplementation!!

- True Ca/P digestibility in corn and soybean meal are underestimated by about 25-35% in the pig.

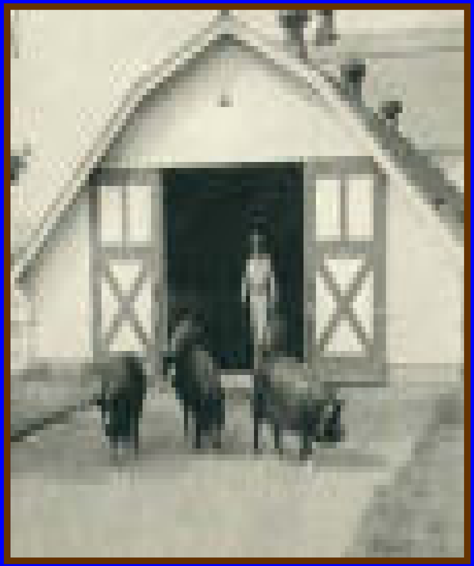
- Swine diet formulation should be based on true digestible rather than total or apparent digestible supply. Very little or no supplemental inorganic mineral P as well as microbial phytase is needed for swine diets that are corn and soybean meal-based.

- Potentially saving producers of feed cost by $0.75 for marketing each pig, about $3.8 million Canadian saving in feeding cost per annum in Ontario.

- Potentially reducing swine manure P excretion by about 25-30% if supplemental inorganic P is reduced or removed according to the suggestion.

(III) Formulating Low-Sulfur (S) Diets to Reduce Odor Concerns Facing the Present Intensive Swine Operations

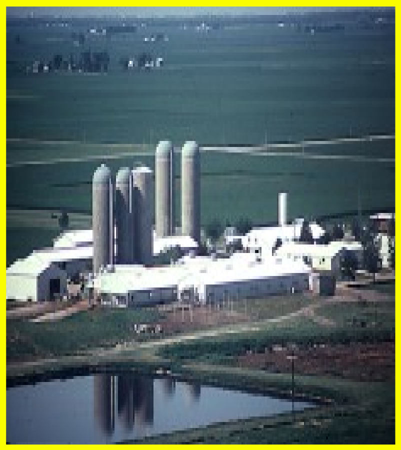
The Evolution of Modern Swine Production (Rideout, 2002)

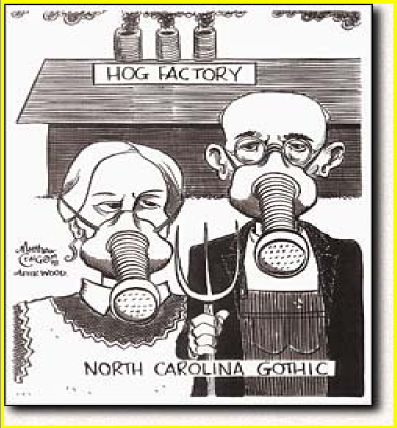


Public Demand

Advanced Technology

Global Economy





Traditional Farming System

Intensive Swine Units

late 1800's | mid 1950's | late 1900's

Definition of Odor

⇒ Definition: odor is something that stimulates the olfactory system or sense of smell (10,000 odorants)

⇒ Odor: like noise, is a nuisance or disturbance.

⇒ 'Odor' is not always related to 'pollution' of the "hardware" of our environment.

(Mackie *et al*., 1998)

Adverse Effects of Livestock Odor on Human Health

- ⇒ Sensory irritation: eyes, noses and throats
- ⇒ Implicated in allergic disorders and headaches
- ⇒ Being toxic at high concentrations: e.g., sulfides
- ⇒ Affecting brain activity and memory
- ⇒ Stress and mood: tension, depression, anger fatigue and confusion

(Mackie *et al.*, 1998)

Adverse Effects of Livestock Odor on Livestock production

⇒ Decreased immunity and increased susceptibility to diseases

⇒ Reduced growth performance

⇒ Poor quality of animal products, e.g., boar taint

(Mackie *et al*., 1998)

Major Malodorous Compounds??

⇒ Ammonia (NH_3) and amines

⇒ Volatile fatty acids (VFA), e.g., acetic acid

⇒ *S-containing compounds, e.g., H_2S, mercaptans

⇒ Indoles, e.g., indole and 3-methyl indole (skatole)

⇒ Phenols, e.g., *P*-cresol, phenol and 4-ethyl phenol

(Mackie *et al*., 1998)

Taking home messages for practices: excessive dietary inorganic sulfate salts and organic sulfur are one of the major odor-causing sources!!

- **Excessive amounts of inorganic sulfates are incorporated into swine diets as sulfate (SO_4^{2-}) mineral salts: e.g., $ZnSO_4$, and $CuSO_4$.**
- **Sulfate (SO_4^{2-}) is excreted in urine and converted to the volatile hydrogen sulfide (H_2S) during the anaerobic storage.**
- **Use non-sulfate based mineral salts such as $ZnCO_3$/$ZnCl_2$ or $CuCl_2$/proteinated trace minerals to formulate low-sulfate diets for reducing the odor impact from sulfides.**

(VI) Manipulation of Intestinal Fermentation by Adding Suitable Levels of Soluble Non-Starch Polysaccharide (NSP - Fiber) in Diets to Reduce Odor Concerns Facing the Present Intensive Swine Operations

Biological Origins of Indoles

Dietary and Intestinal Tryptophan

Indole ← **anaerobic bacterial fermentation!!**

↓

Indole + Pyruvate

↓

Indole lactate

↓

Indole acetate

↓

3-Methyl Indole: skatole

(Mackie *et al.*, 1998)

Biological Origins of Phenols

Phenylalanine (Phe)/Tyrosine (Tyr)

Phenol

anaerobic bacterial fermentation!!

OH-phenyl Pyruvate

OH-phenyl lactate

OH-phenyl actate

OH-phenyl propionate

P-cresol

4-ethyl phenol

Phenyl propionate

(Mackie *et al.*, 1998)

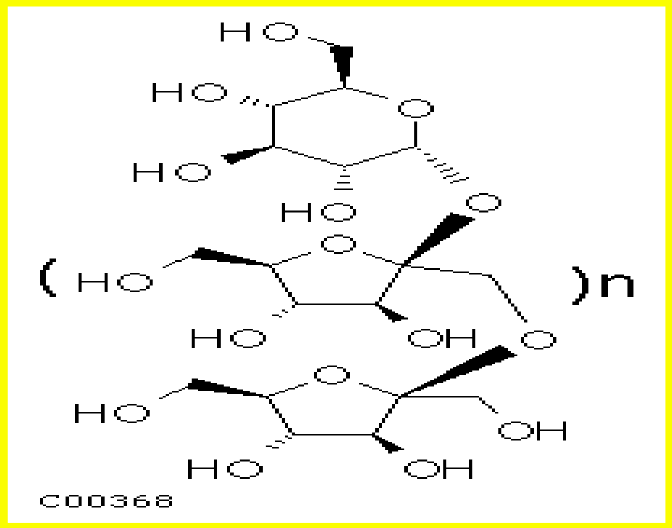
Some facts about your current swine diets:

- Your current corn-soybean meal-based swine diets: insoluble fiber content at 6-8%; water-soluble fiber at 2%;
- So current corn-soybean meal-based swine diets are inadequate in soluble fiber levels;
- An extra soluble-fiber supplementation would potentially modify microflora and reduce odor impact.

(Gao, 2002; Rideout, 2002)

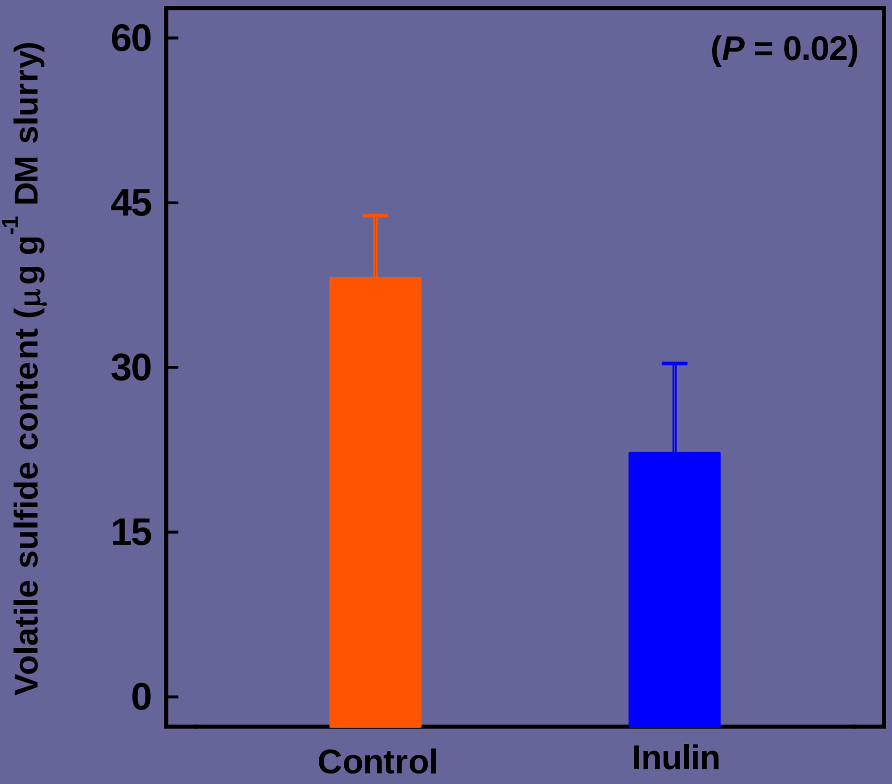
Chicory Inulin

- Natural food ingredient
- Plant storage carbohydrate
- Extracted from chicory roots
- Unique structure – polydisperse β(2-1) fructan
- Water-soluble fiber properties
- Non-starch polysaccharide (NSP)



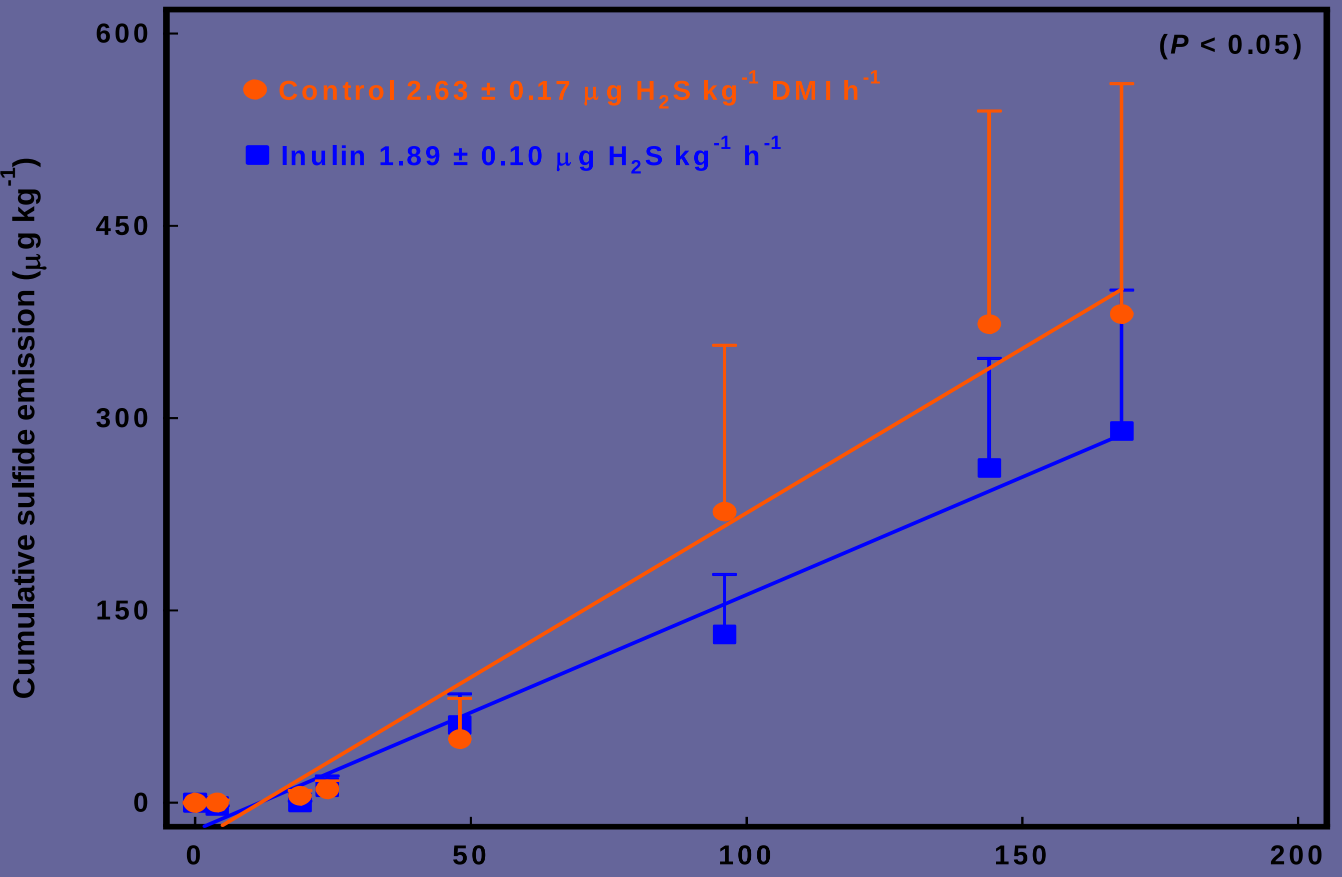
(Rideout, 2002)

Reducing Volatile Sulfide Content of Manure Slurry (μg g^{-1} DM)



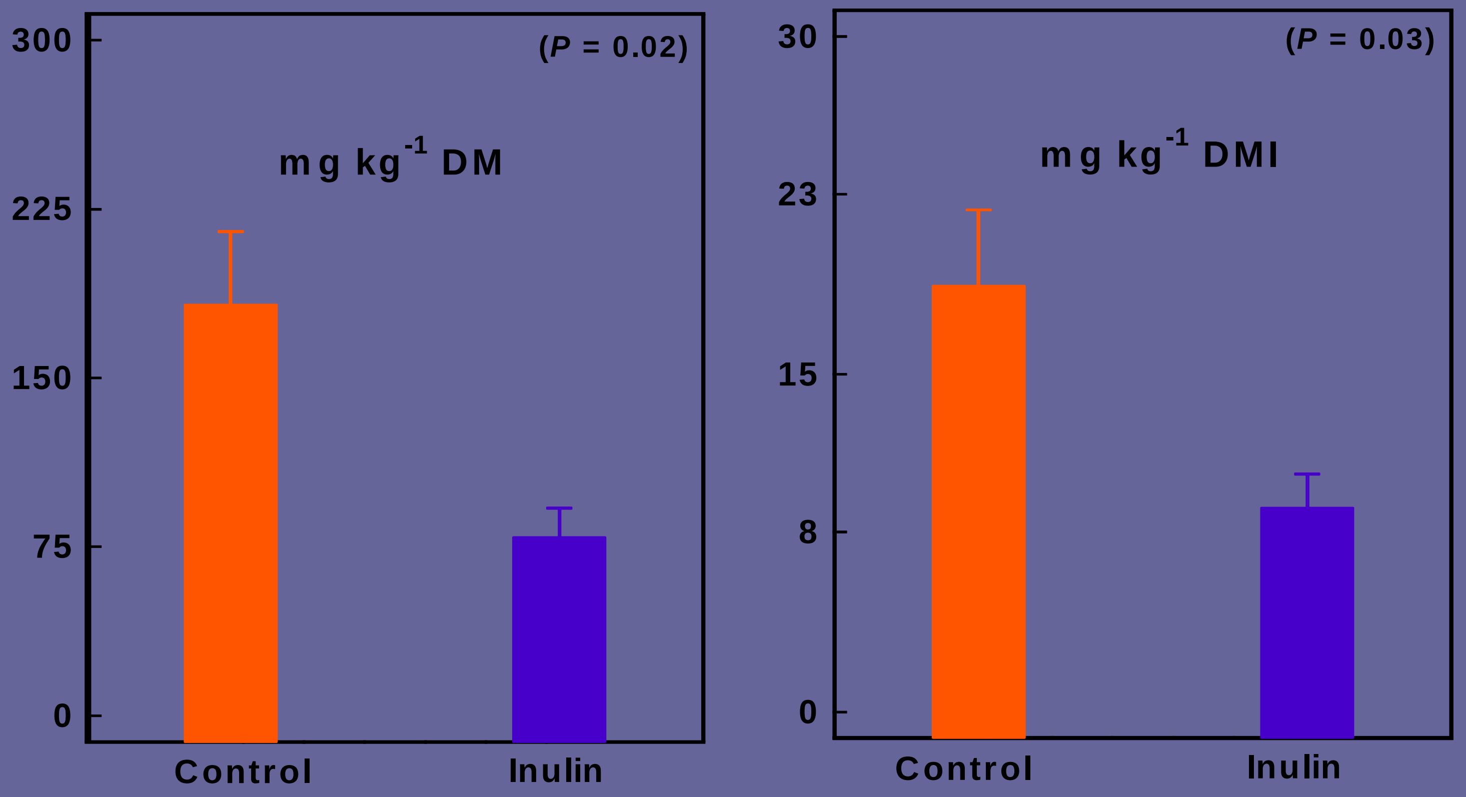
(Rideout, 2002)

Reducing Cumulative Sulfide Emission Rate (μg H_2S kg^{-1} DMI h^{-1})



(Rideout, 2002)

Reducing Fecal Excretion of Skatole



(Rideout et al., 2004)

Taking Home Messages for Practices: "Summary"

- **Formulating low-CP diets (by 3%) by using crystalline Lys and Thr to reduce ammonia, CO_2, and N_2O emission by up to 30%;**
- **Formulating diets on true digestible P supply for decreasing the uses of supplemental P and phytase to reduce feeding cost ($0.75/pig) and manure P excretion (by 30-40%);**
- **Formulating low-sulfate diets by using non-sulfate trace mineral supplements for reducing odor impact;**
- **Supplementing exogenous sources of water-soluble fiber in diets for reducing odor impact.**

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- Canadian Pork Council (CPC) Related Programs;
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- The Natural Science and Engineering Research Council (NSERC)

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