



U.S. SOY for a growing world



EFFECTIVE USE OF PHYTASE IN POULTRY DIETS



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GRAIN PHOSPHORUS CONTENT



~ 0.3% (BRAN & GERM)

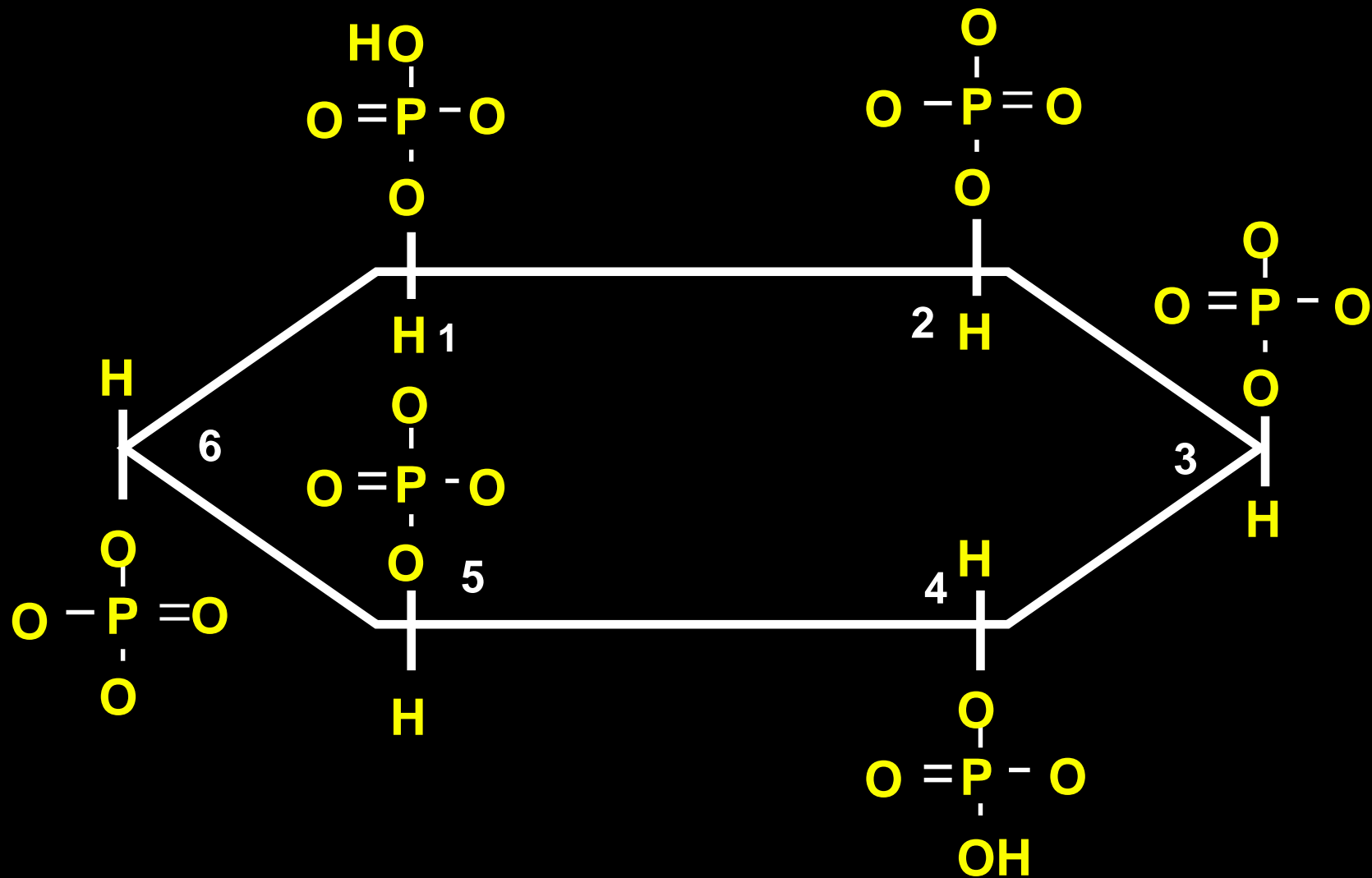
..HOWEVER..

~ 50 - 70% AS PHYTATE

Cereals: In aleurone layer

**Oil seed meals: Associated with
storage proteins throughout seed**

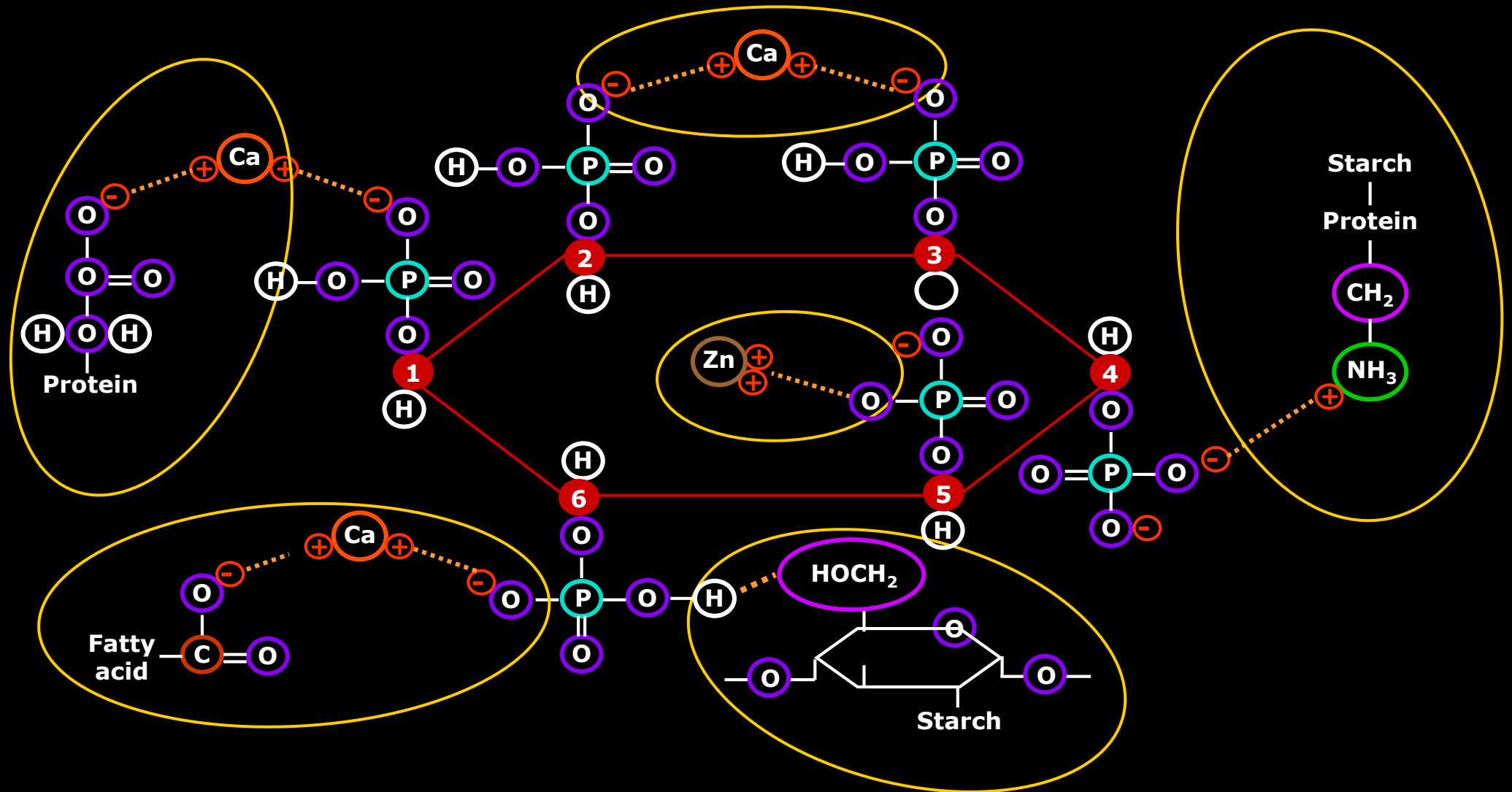
STRUCTURE OF PHYTIC ACID (Anderson, 1912)



PHYTATE PHOSPHORUS CONTENT OF SELECTED FEEDSTUFFS FOR ANIMALS (Ravindran, 1996)

Ingredient	Phytate P, g/100	Phytate P, as % of total P
Barley	0.23	63
Corn	0.21	68
Oats	0.22	61
Sorghum	0.22	71
Triticale	0.25	67
Wheat	0.23	65
Soybean meal	0.39	60
Cottonseed meal	0.84	70
Canola meal	0.54	52
Average		64

Phytate, P source and anti-nutrient in feed



NUTRITIONAL IMPORTANCE OF P

- **Skeletal structure (80% - 85% in bones and teeth)**
- **Nutrient metabolism (ATP)**
- **Cell membranes (phospholipids)**
- **Nucleic acids (DNA, RNA)**
- **Intracellular buffer**

CONSEQUENCES OF A DEFICIENCY

- Rickets, Osteomalacia
- Pica
- Decreased performance
- Mortality
- Loss of income

RICKETS



Normal



**Vitamin D/Ca
deficiency**



**Phosphorus
deficiency**

ENVIRONMENTAL CONCERNS

- **Phytates in plant products**
- **Unavailable to poultry**
- **Requires non-phytate P (iP, oP)**
- **Results in hi P in excreta**

ENVIRONMENTAL CONCERNS

- Results in hi P in excreta
- How is excreta P disposed of?
- Applied to crop land and pastures
- Source of both P and N

Application of liquid manure



Application of litter



INITIAL AND FINAL SOIL ANALYSES FOR A BERMUDA GRASS PASTURE FERTILIZED WITH SWINE LAGOON EFFLUENT (Kornegay, 1996)

Depth (cm)	P_2O_5		Zn		Ca	
	1990	1992	1990	1992	1990	1992
			kg/ha			
0 - 15	540	973	2.6	10.6	0.9	5.3
15 - 30	180	869	0.8	4.8	1.0	3.3
30 - 61	20	209	0.4	2.8	0	3.5
61 - 91	16	64	0.5	2.0	0	2.4

Algae growth due to N/P



Fish Kill in Rivers, Lakes & Streams





ENZYMES



**CATALYSTS THAT FACILITATE FEED
DIGESTION**

...QUESTION...

HOW DO ENZYMES WORK ???

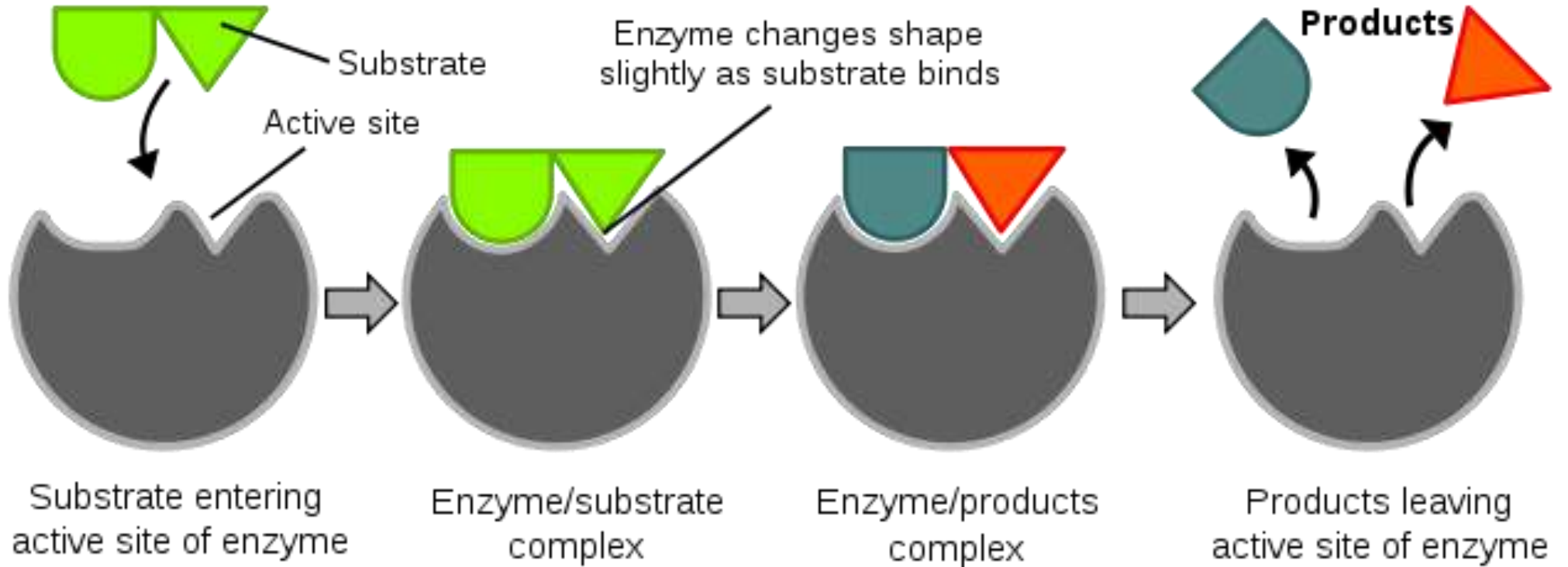
ALL ENZYMES DO ONLY ONE THING
“THEY ACT ON A SUBSTRATE”



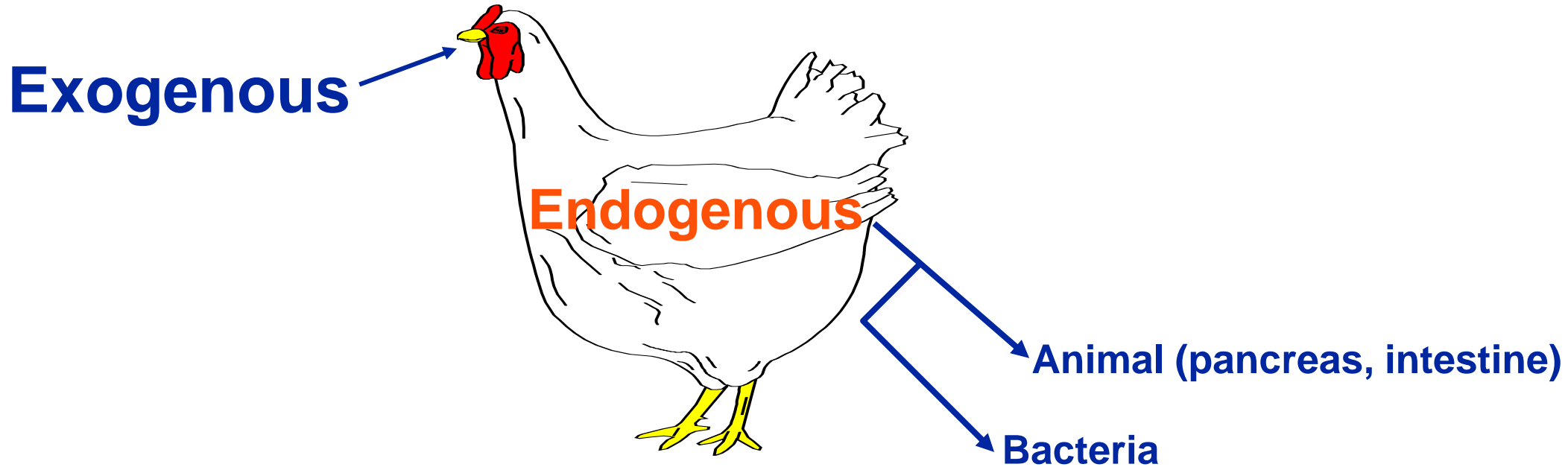
...FACT...

ENZYME EFFECTIVENESS IS BASED ON “ACTIVITY” NOT “WEIGHT”

HOW DO ENZYMES WORK?



ENZYMES



PHYTASE HISTORY

- T. S. Nelson, T. R. Shieh, R. J. Wodzinski and J. H. Ware. 1968. Poultry Science, 47:1842-1848.

“The availability of phytate phosphorus in soybean meal before and after treatment with a mold phytase”

- T. S. Nelson, T. R. Shieh, R. J. Wodzinski and J. H. Ware. 1971. Journal of Nutrition, 101:1289-1293

“Effect of supplemental phytase on the utilization of phytate phosphorus by chicks”

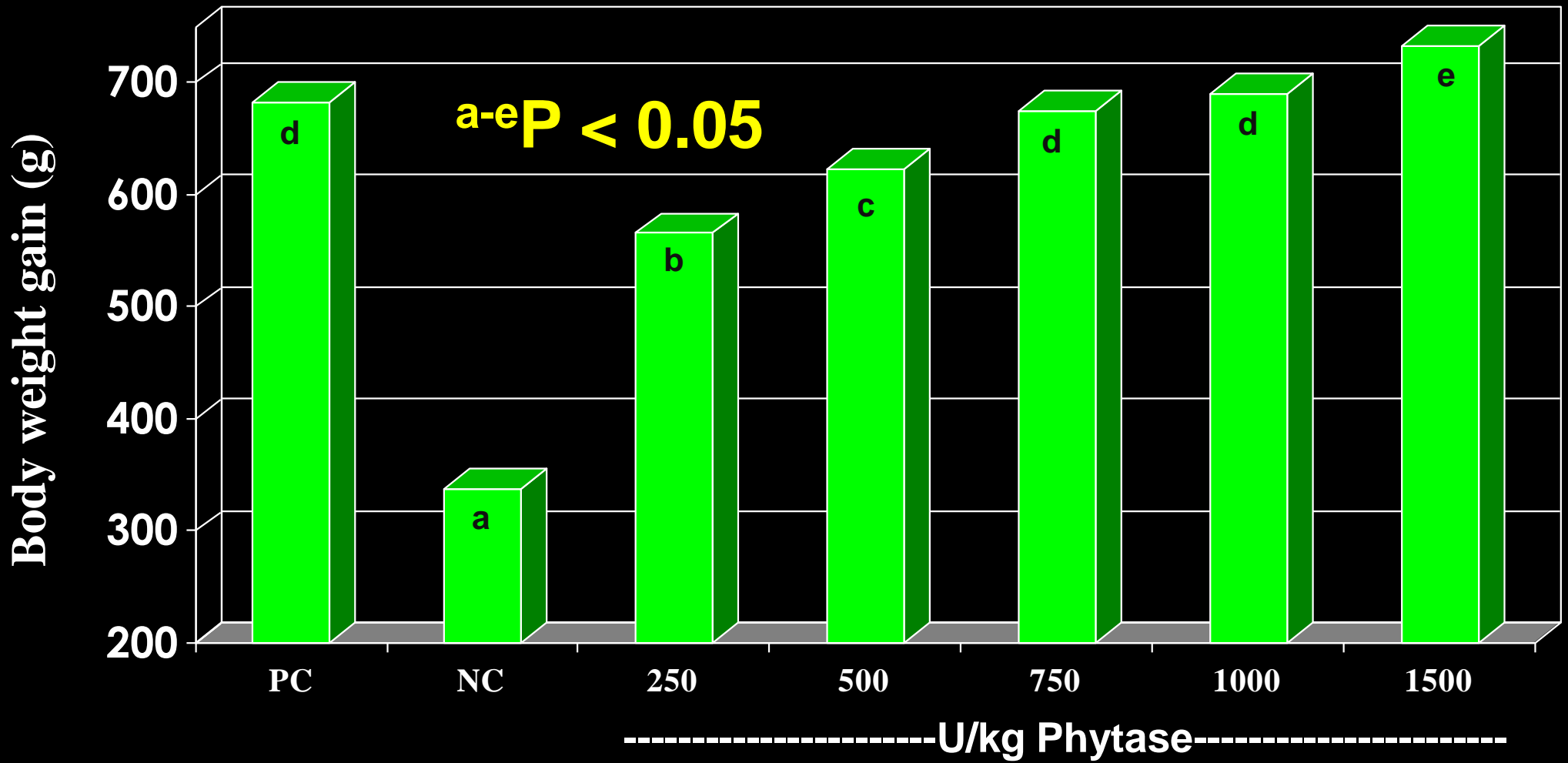
- **Phytase a solution to an environmental problem**



Netherlands pollution issues - pigs (Simons *et al.*, 1990; Brit. J. Nutrition 64:525-540)

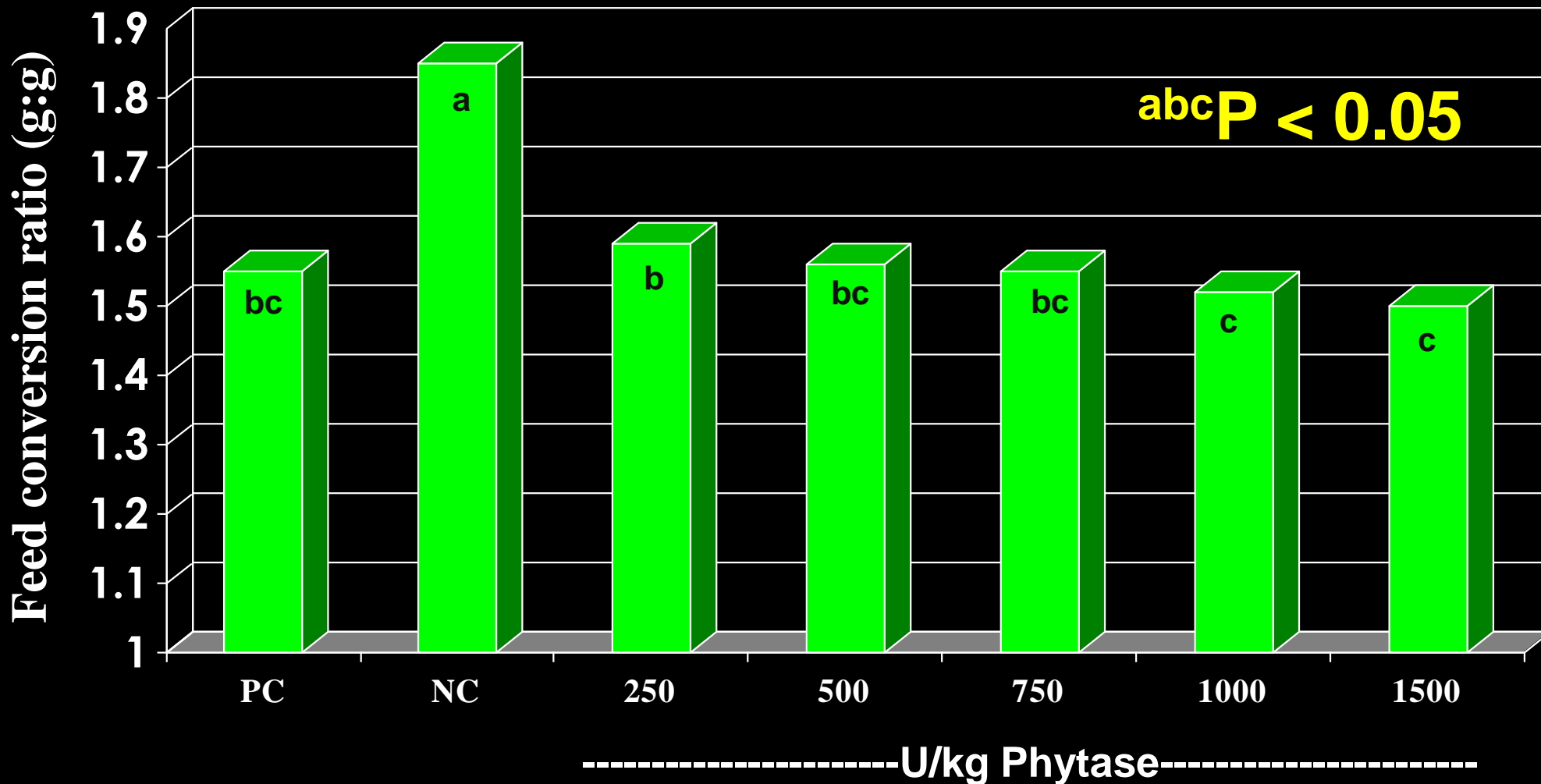
- Day old male broilers
- CRD; 2 reps of 11 birds each
- PC, 0.75% tP, 0.9% Ca
- NC, 0.45% tP, 0.60% Ca
- 0, 250, 500, 750, 1,000, and 1,500 U phytase/kg diet
- *Aspergillus ficuum* - 3 phytase
- Diets fed from day 1 to day 24

Effect of phytase on BWG of broilers from hatch to day 24 (Simons *et al.*, 1990)



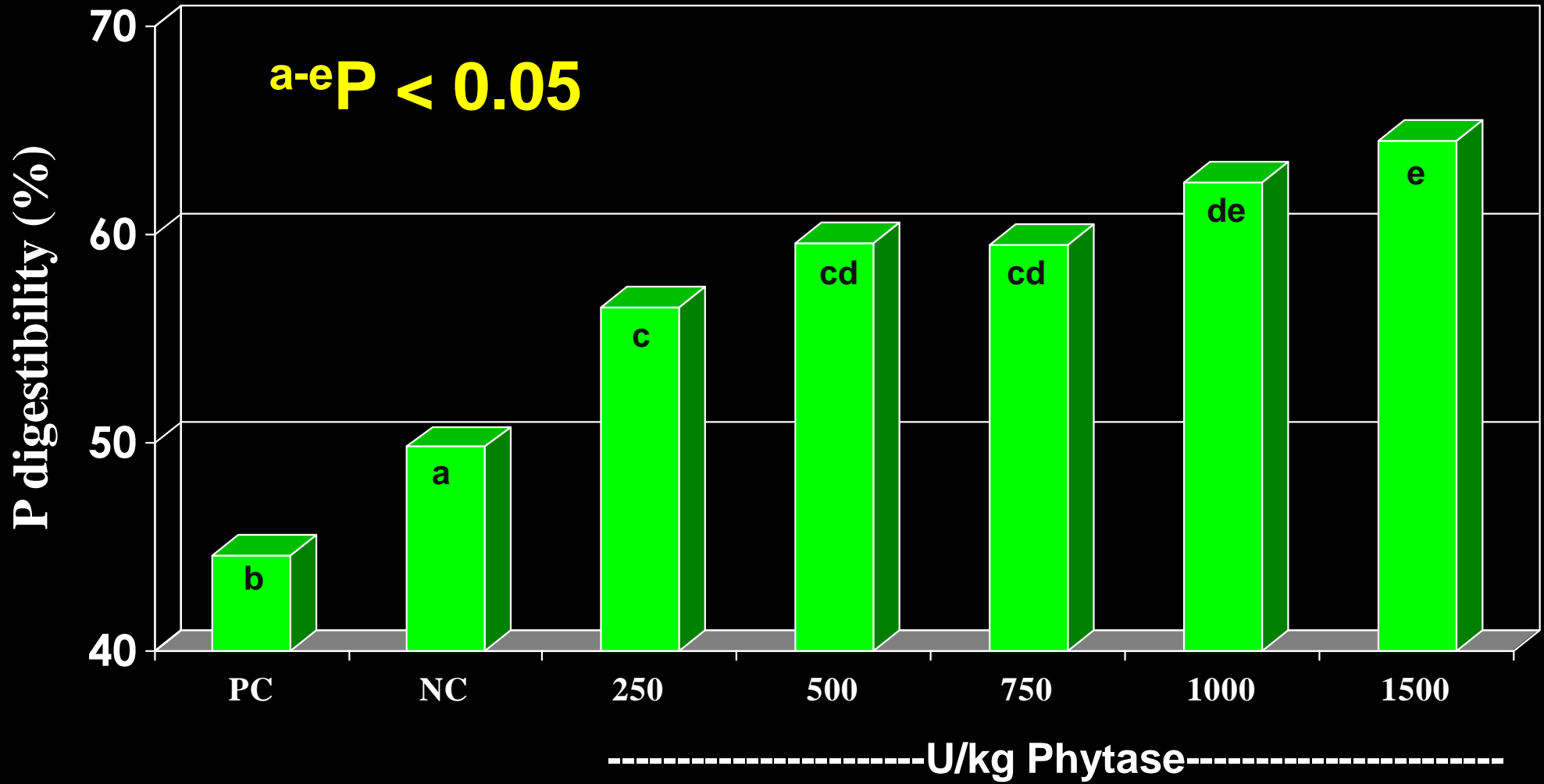
PC = 0.75% tP and 0.90% Ca; NC = 0.45% tP and 0.60% Ca

Effect of phytase on FCR of broilers from hatch to day 24 (Simons *et al.*, 1990)



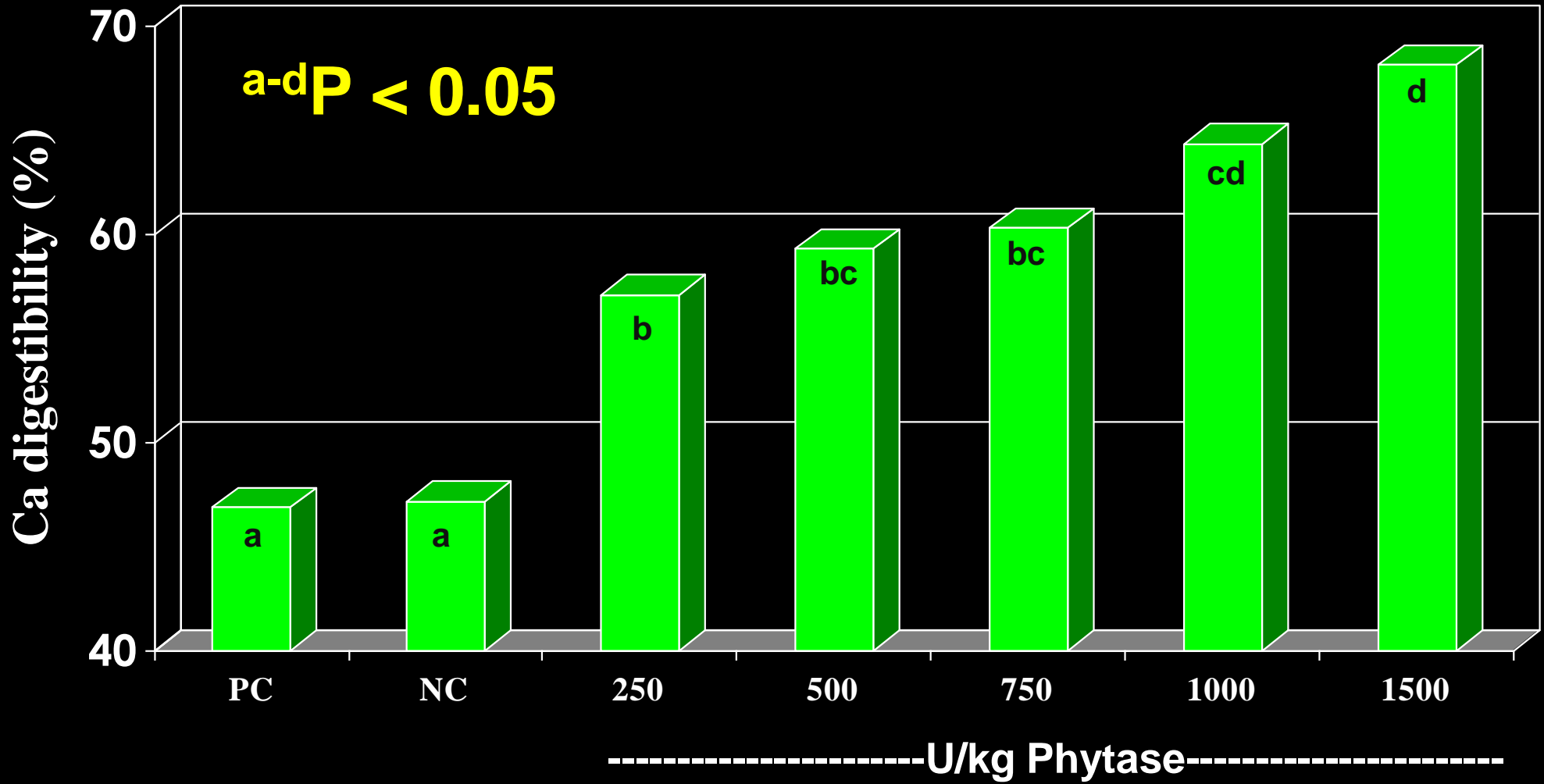
PC = 0.75% tP and 0.90% Ca; NC = 0.45% tP and 0.60% Ca

Effect of phytase on P digestibility by broilers from day 21-24 (Simons *et al.*, 1990)



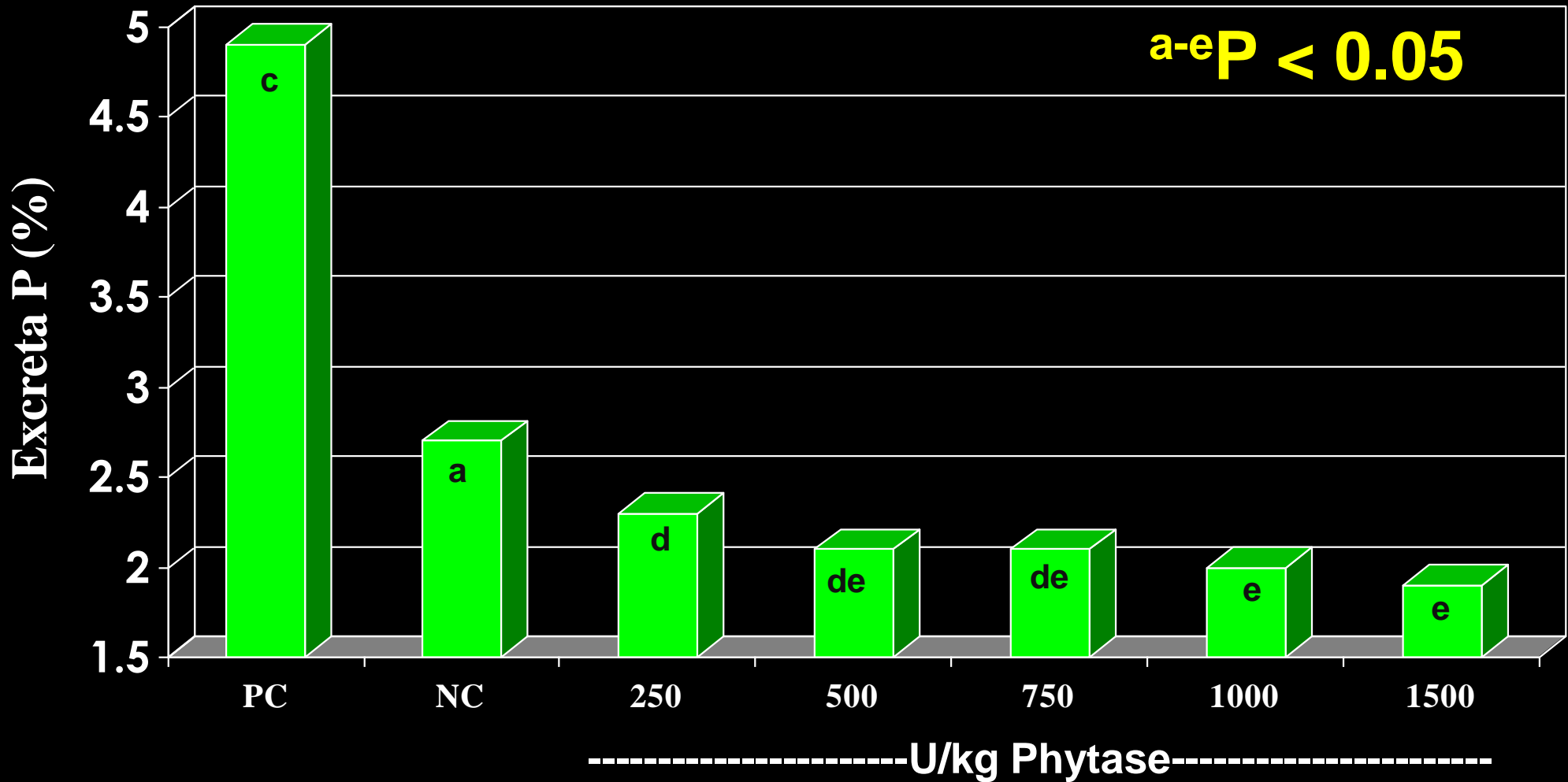
PC = 0.75% tP and 0.90% Ca; NC = 0.45% tP and 0.60% Ca

Effect of phytase on Ca digestibility by broilers from day 21-24 (Simons *et al.*, 1990)



PC = 0.75% tP and 0.90% Ca; NC = 0.45% tP and 0.60% Ca

Effect of phytase on excreta P of broilers from hatch to day 24 (Simons *et al.*, 1990)

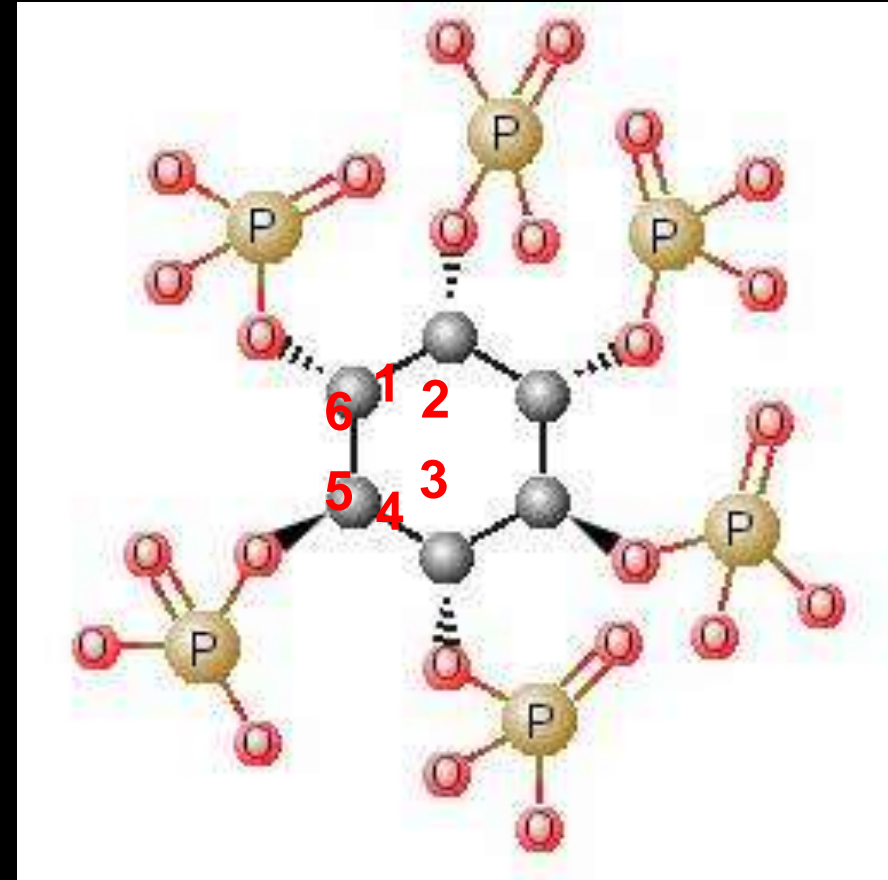


PC = 0.75% tP and 0.90% Ca; NC = 0.45% tP and 0.60% Ca

COMMERCIAL PHYTASE SOURCES

- 3 - phytases
- 6 - phytases
- Fungal or Bacterial
- Submerged liquid fermentation
- Solid-state fermentation

Phytate



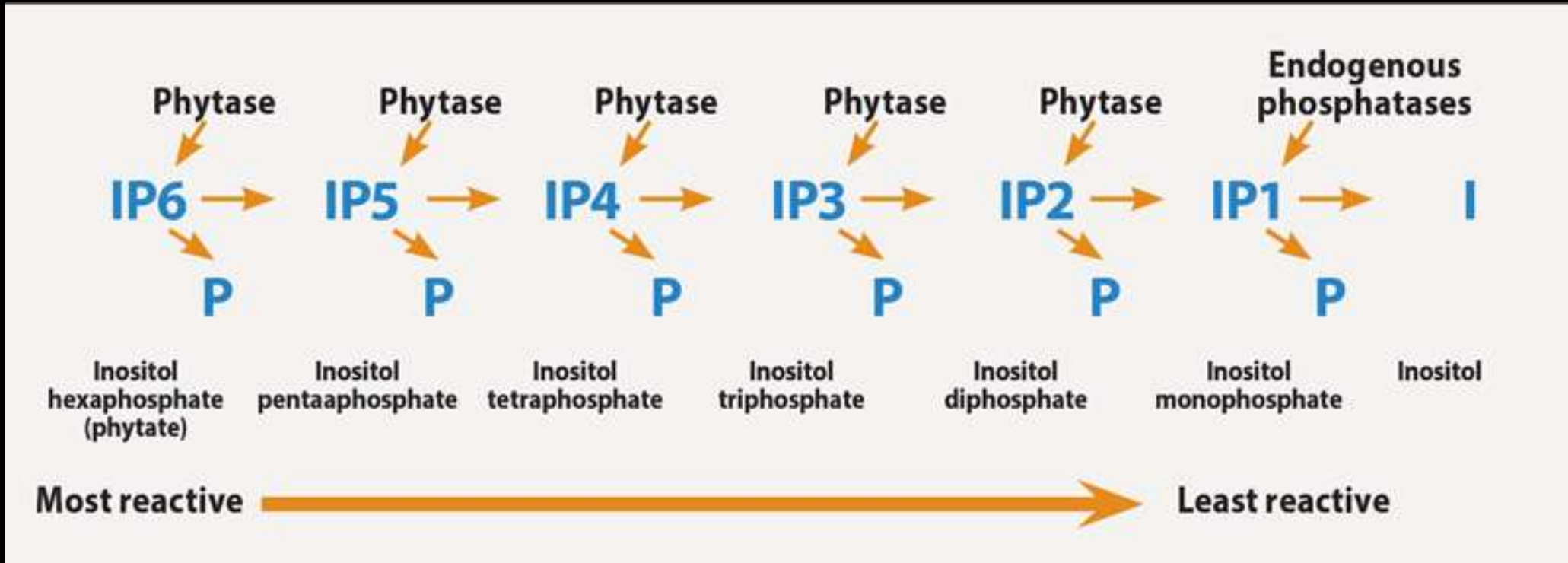
SUBMERGED VS SOLID SUBSTRATE FERMENTATION

Enzyme	Submerged	Surface
Phytase	1,500 PU/g	1,500 PU/g
Fungal Alpha Amylase	ND	240 FAU/g
Beta Glucanase	ND	2,160 BGU/g
Cellulase	ND	310 CMCU/g
Fungal Protease	ND	7,380 HUT/g

Commercially available microbial phytases (Lei *et al.*, 2013)

Product	Company	Origin	Subtype	Expression
Allzyme® SSF	Alltech	<i>Aspergillus niger</i>	3	<i>Aspergillus niger</i>
Finase® EC	AB Vista	<i>Escherichia coli</i>	6	<i>Trichoderma reesei</i>
Finase® P/L	AB Vista	<i>Aspergillus niger</i>	3	<i>Trichoderma reesei</i>
Natuphos®	BASF	<i>Aspergillus niger</i>	3	<i>Aspergillus niger</i>
OptiPhos®	Enzyvia (JBS)	<i>Escherichia coli</i>	6	<i>Pichia pastoris</i>
Phyzyme® XP	Dupont	<i>Escherichia coli</i>	6	<i>Schizosaccharomyces pombe</i>
Quantum™	AB Vista	<i>Escherichia coli</i>	6	<i>Pichia pastoris</i>
Ronozyme® P	Novozyme/DSM	<i>Peniophora lycii</i>	6	<i>Aspergillus oryzae</i>

Phytate degradation by phytase

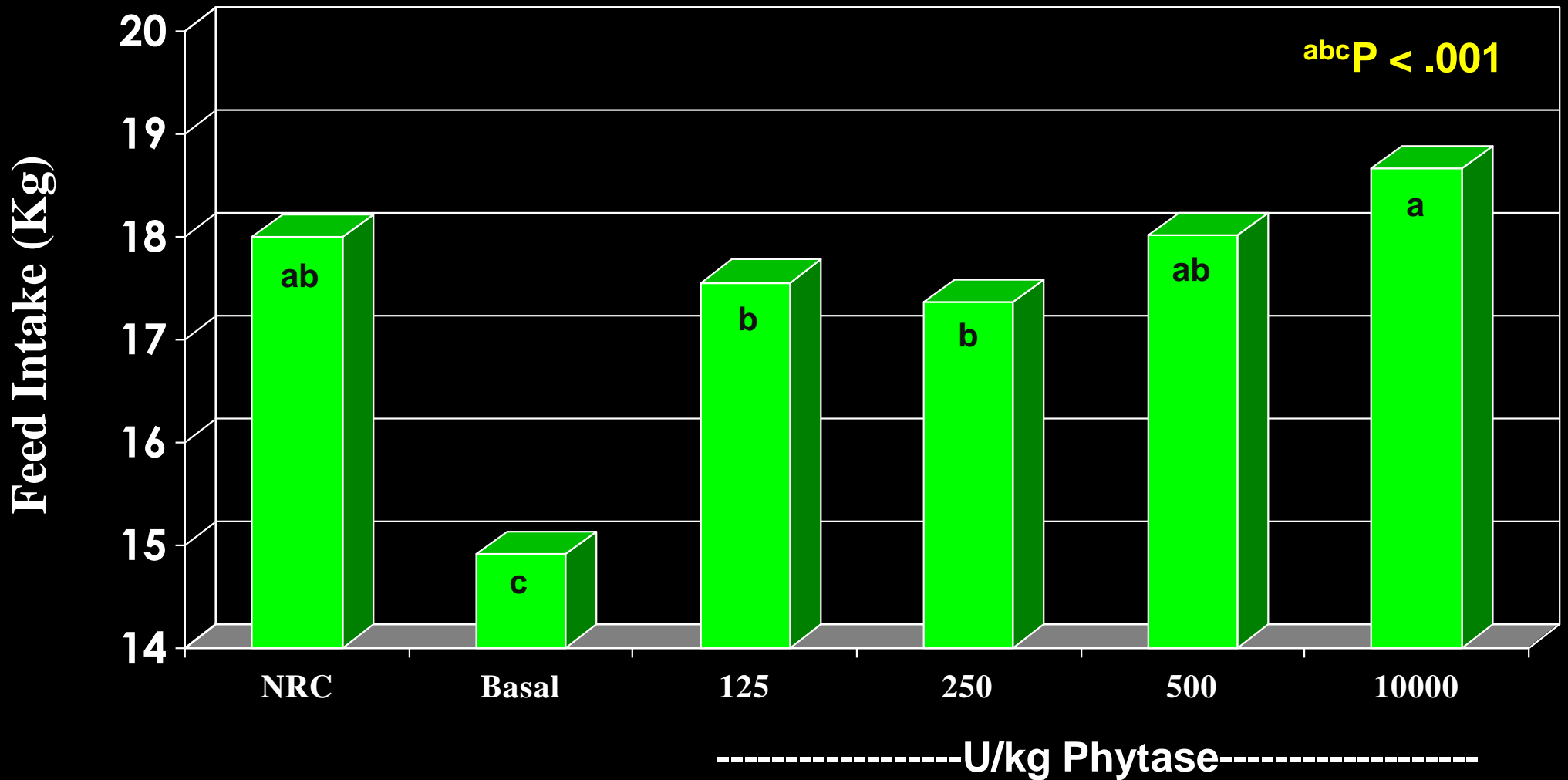


Bedford (2014)

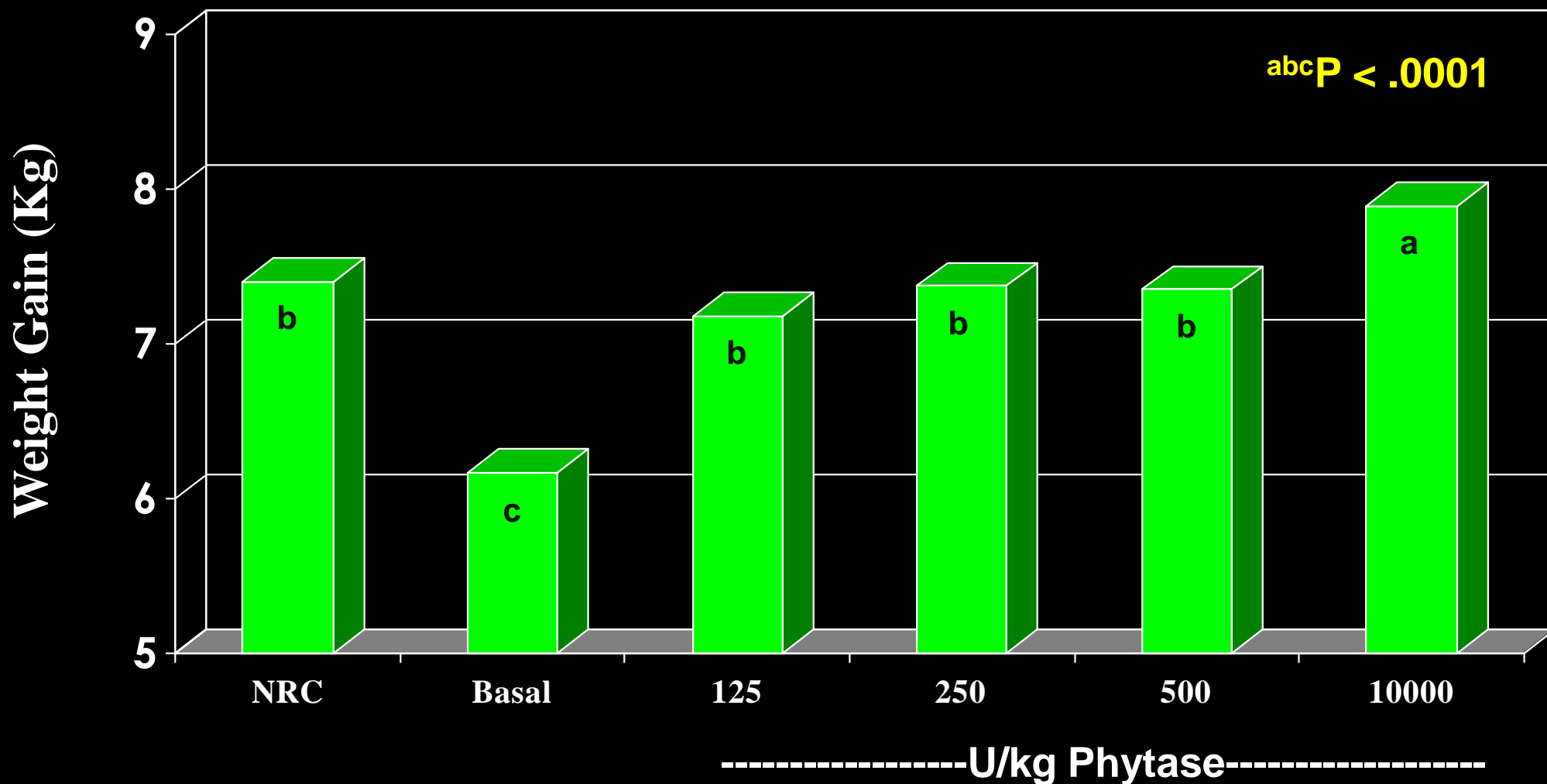
Materials and Methods

- 750 week-old female turkeys
- CRD; 5 reps of 25 turkeys each
- NRC, 0.6% npP, 1.2% Ca
- Negative control, 60% NRC npP, 84% NRC Ca
- 0, 125, 250, 500, or 10,000 U phytase/kg diet
- Bacterial δ phytase
- Diets fed from week 1 to week 14

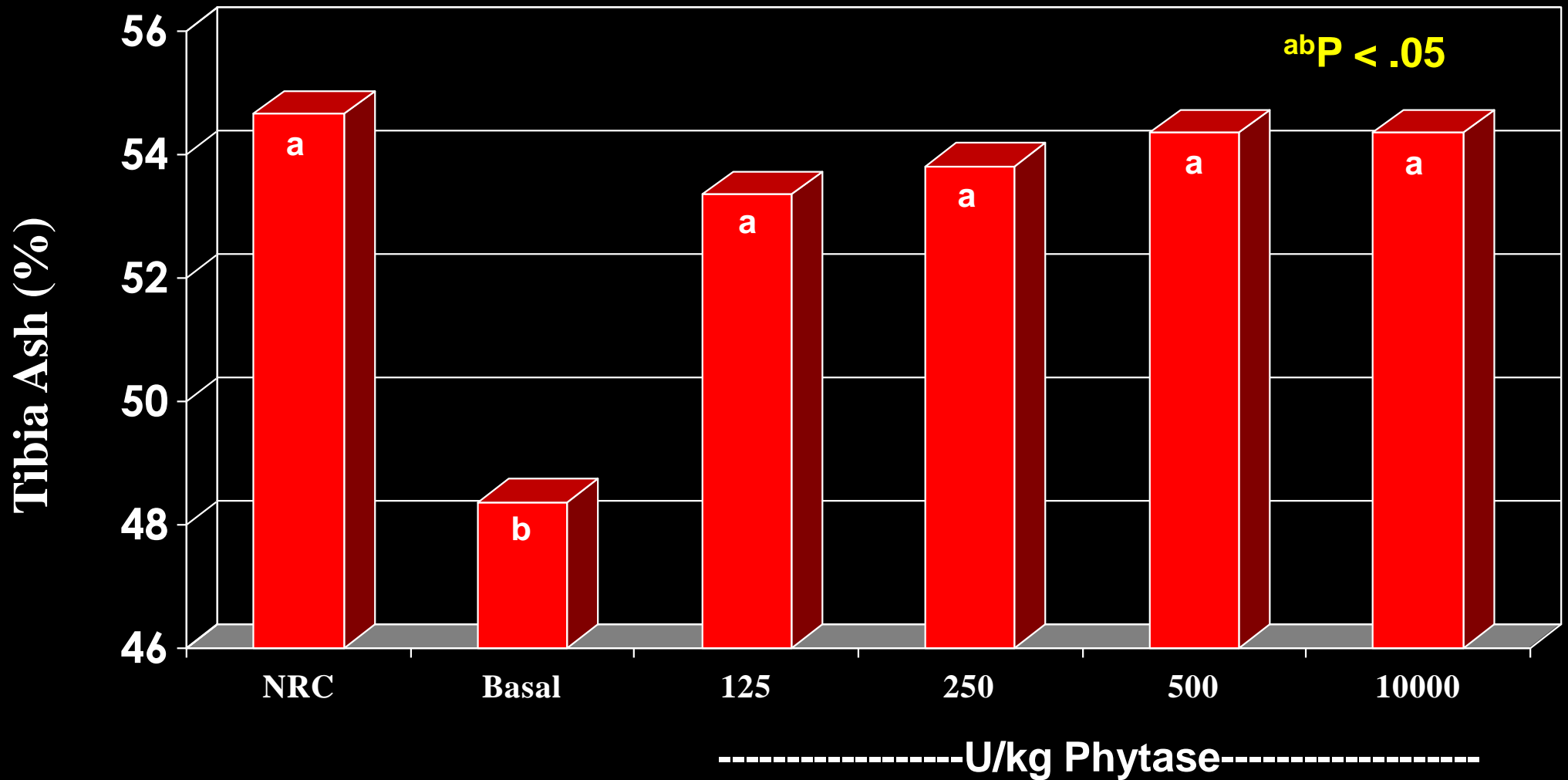
Effect of dietary treatments on FI of turkeys (Ledoux *et al.*, 2005)



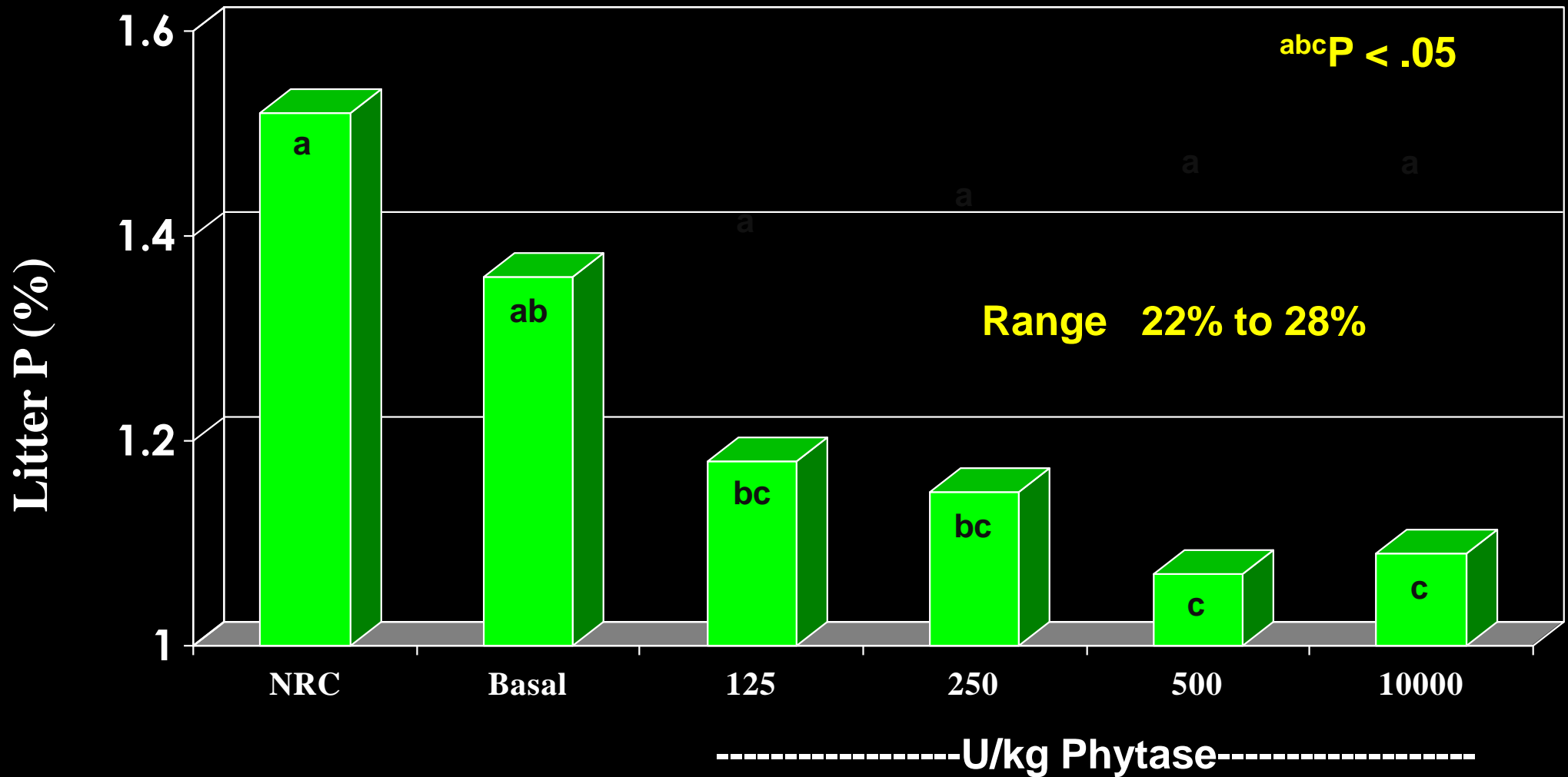
Effect of dietary treatments on WG of turkeys (Ledoux *et al.*, 2005)



Effect of dietary treatments on tibia ash of turkeys (Ledoux *et al.*, 2005)



Effect of dietary treatments on litter P (Ledoux *et al.*, 2005)



EFFECTS OF AVAILABLE P AND PHYTASE (300 U/kg) ON PERCENT HEN-DAY EGG PRODUCTION (Boling *et al.*, 2000)

Treatment	25	30	35	42	70
	----- Age (Weeks) -----				
0.10% aP	95 ^{ab}	84 ^b	61 ^b	55 ^c	---
0.15% aP	96 ^{ab}	95 ^a	95 ^a	84 ^b	73 ^a
0.20% aP	92 ^b	96 ^a	94 ^a	90 ^{ab}	75 ^a
0.25% aP	93 ^{ab}	96 ^a	94 ^a	88 ^{ab}	78 ^a
0.45% aP	94 ^{ab}	93 ^a	93 ^a	90 ^{ab}	74 ^a
0.10% aP+Phyt	97 ^a	96 ^a	94 ^a	87 ^{ab}	79 ^a
0.15% aP+Phyt	94 ^{ab}	94 ^a	95 ^a	88 ^{ab}	78 ^a
0.20% aP+ Phyt	94 ^{ab}	94 ^a	95 ^a	94 ^a	80 ^a

^{a-c}Within a column, values with no common superscript differ (P < 0.05)

**EFFECTS OF AVAILABLE P AND PHYTASE (300 U/kg)
ON EGG YIELD (g/hen/d; Boling *et al.*, 2000)**

Treatment	21-30	31-40	41-50	51-60	61-70
	----- Age (Weeks) -----				
0.10% aP	53.6 ^a	42.0 ^b	----	----	---
0.15% aP	53.6 ^a	58.0 ^a	54.0 ^a	52.7 ^a	47.3 ^a
0.20% aP	53.2 ^a	57.5 ^a	57.0 ^a	55.7 ^a	50.3 ^a
0.25% aP	63.8 ^a	58.5 ^a	56.5 ^a	53.0 ^a	50.0 ^a
0.45% aP	53.0 ^a	56.2 ^a	57.0 ^a	52.7 ^a	48.0 ^a
0.10% aP+Phyt	54.4 ^a	57.2 ^a	56.0 ^a	54.7 ^a	52.0 ^a
0.15% aP+Phyt	54.2 ^a	58.5 ^a	56.0 ^a	55.3 ^a	51.7 ^a
0.20% aP+ Phyt	54.8 ^a	58.0 ^a	58.0 ^a	53.0 ^a	52.3 ^a

^{a-b}Within a column, values with no common superscript differ (P<0.05)

Effect of P level and phytase on performance of broiler breeders 29-64 weeks of age (Plumstead et al., 2007)

TRT	NPP (%)	Phyt (FTU/kg)	Eggs per hen housed (n)	Feed per dozen eggs (g)	Hen Day egg prod. (%)	Fertility (%)	Chicks per hen housed (n)
A	0.37	0	158	2,999 ^{xy}	62.1 ^b	97.5 ^a	144
B	0.27	500	165	3,038 ^x	62.1 ^b	95.0 ^b	145
C	0.19	0	164	3,068 ^x	61.2 ^b	95.5 ^b	145
D	0.09	500	171	2,875 ^y	65.2 ^a	95.3 ^b	152
SEM			3.7	46.7	0.89	-----	3.26
P Value			0.178	0.059	0.041	<0.001	0.269

Total P in manure (%): A = 3.23^a ; B = 2.79^a ; C = 1.97^b ; D = 1.87^b

Plant phytase

PHYTASE ACTIVITY (U/KG) OF SELECTED FEEDSTUFFS (Nys *et al.*, 1996)

Ingredient	Phytase activity (U/kg)
------------	-------------------------

Cereals:

Wheat	508 - 1193
Rye	2700 - 5130
Triticale	880 - 1688
Barley	288 - 582
Oats	19 - 42
Corn	15 - 46

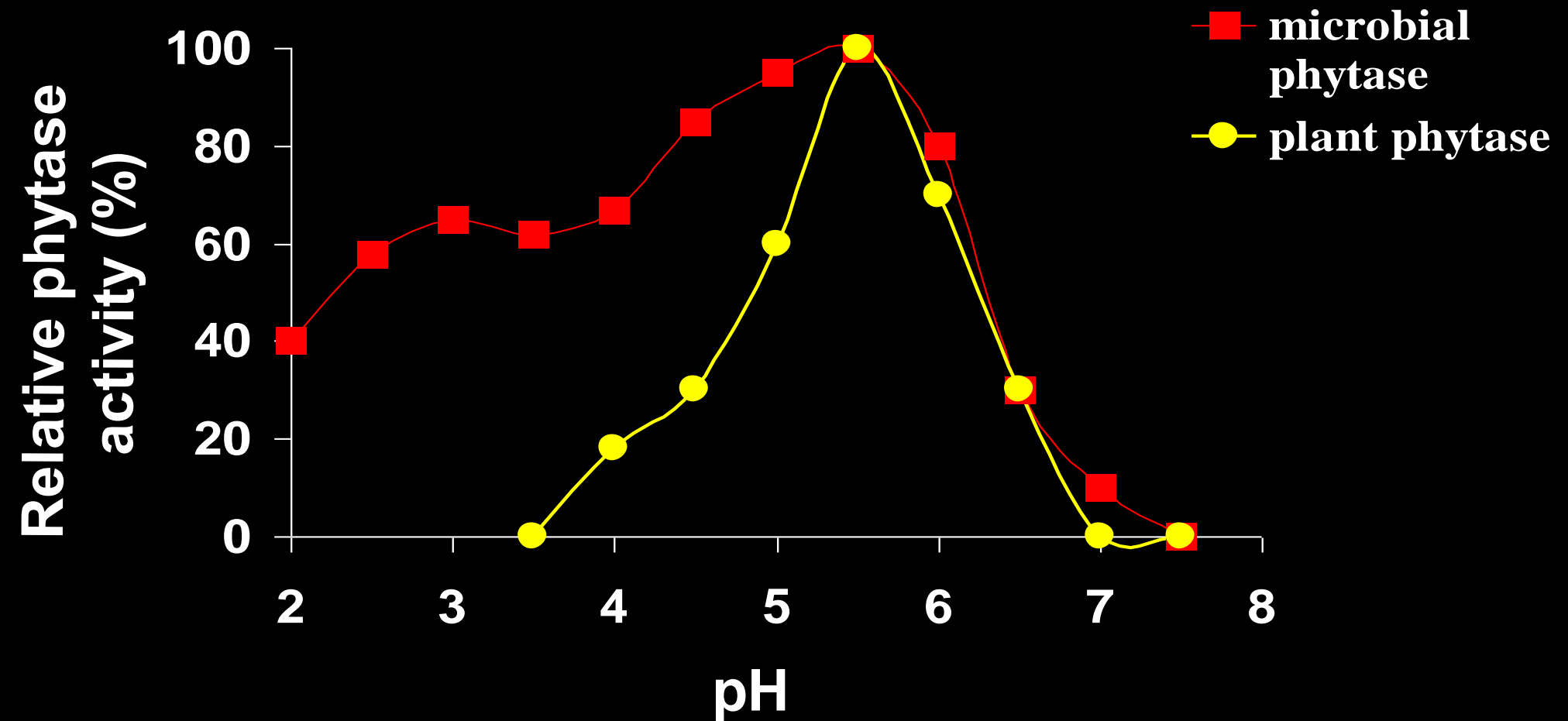
Cereal byproducts:

Wheat bran	1100 - 2857
Wheat bran middlings	1900 - 4381
Rye bran	6190 - 6410
Rice bran	122

Biological Activity of Wheat Phytase Compared with Natuphos[®] in Pigs (Eeckhout and Paepe, 1990)

	Digestibility, %	
	P	Ca
Basal ration	34.9	40.7
+ wheat phytase (500 FTU/kg)	45.6	53.2
+ Natuphos (500 FTU/kg)	53.5	62.6
Relative activity of wheat phytase (Natuphos = 100)	57.5	57.0

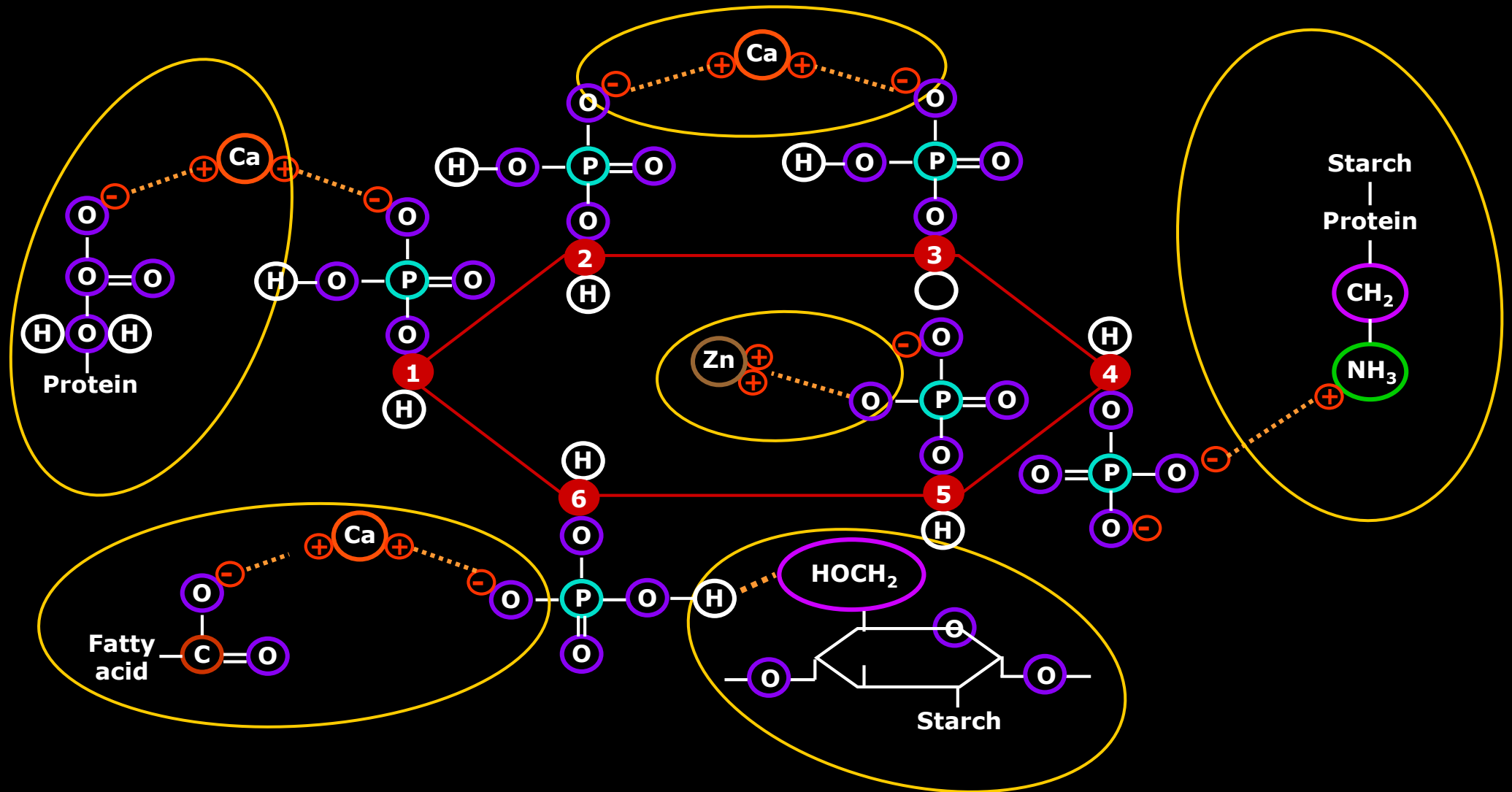
pH Profile of Microbial and Plant Phytase (Heinzl, 1996)



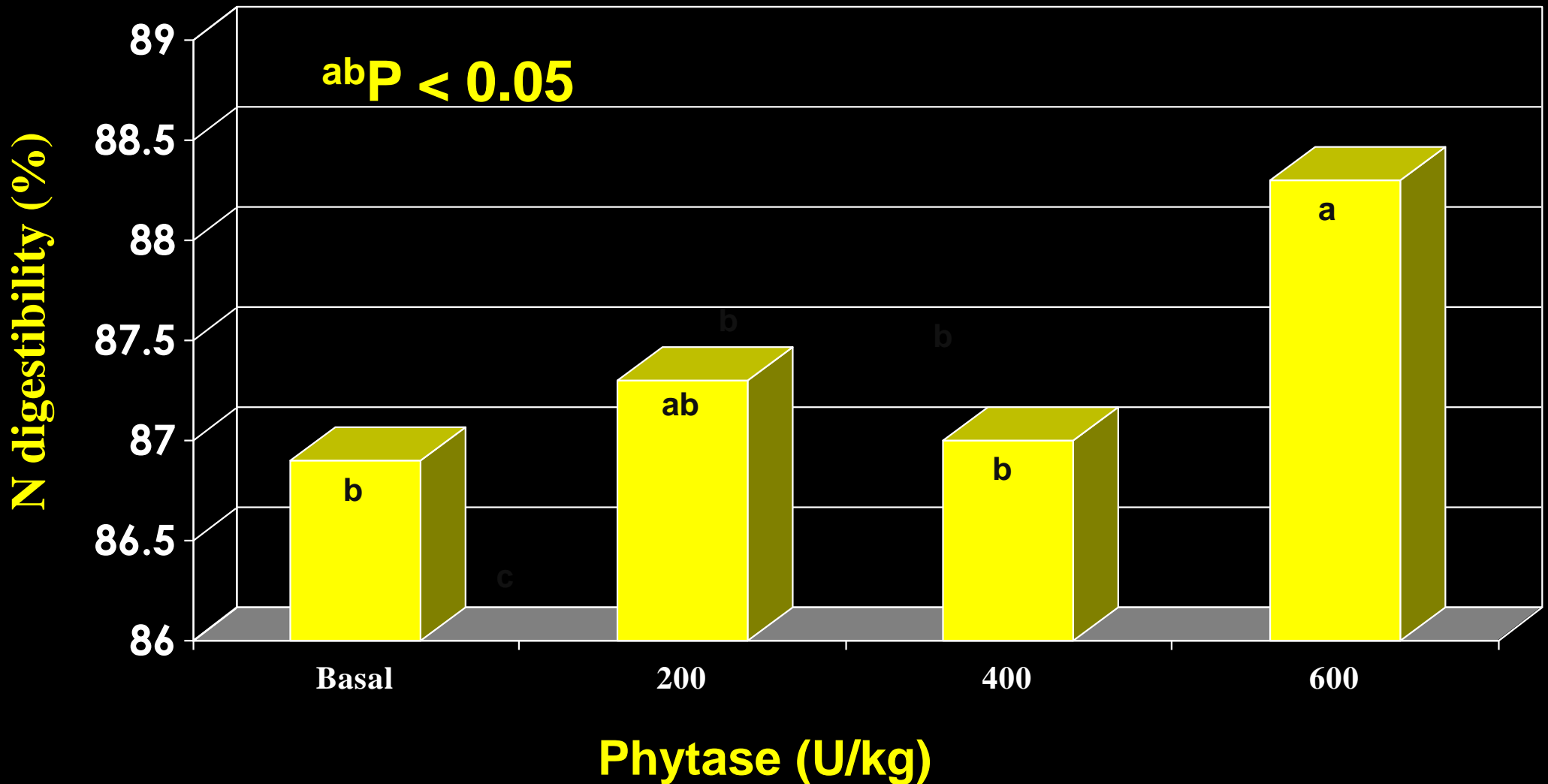
OTHER BENEFITS OF PHYTASE

- **Increased Ca utilization**
- **Improved AA utilization**
- **Improved energy (AME) utilization**
- **Increased trace mineral (Zn, Mn) utilization**

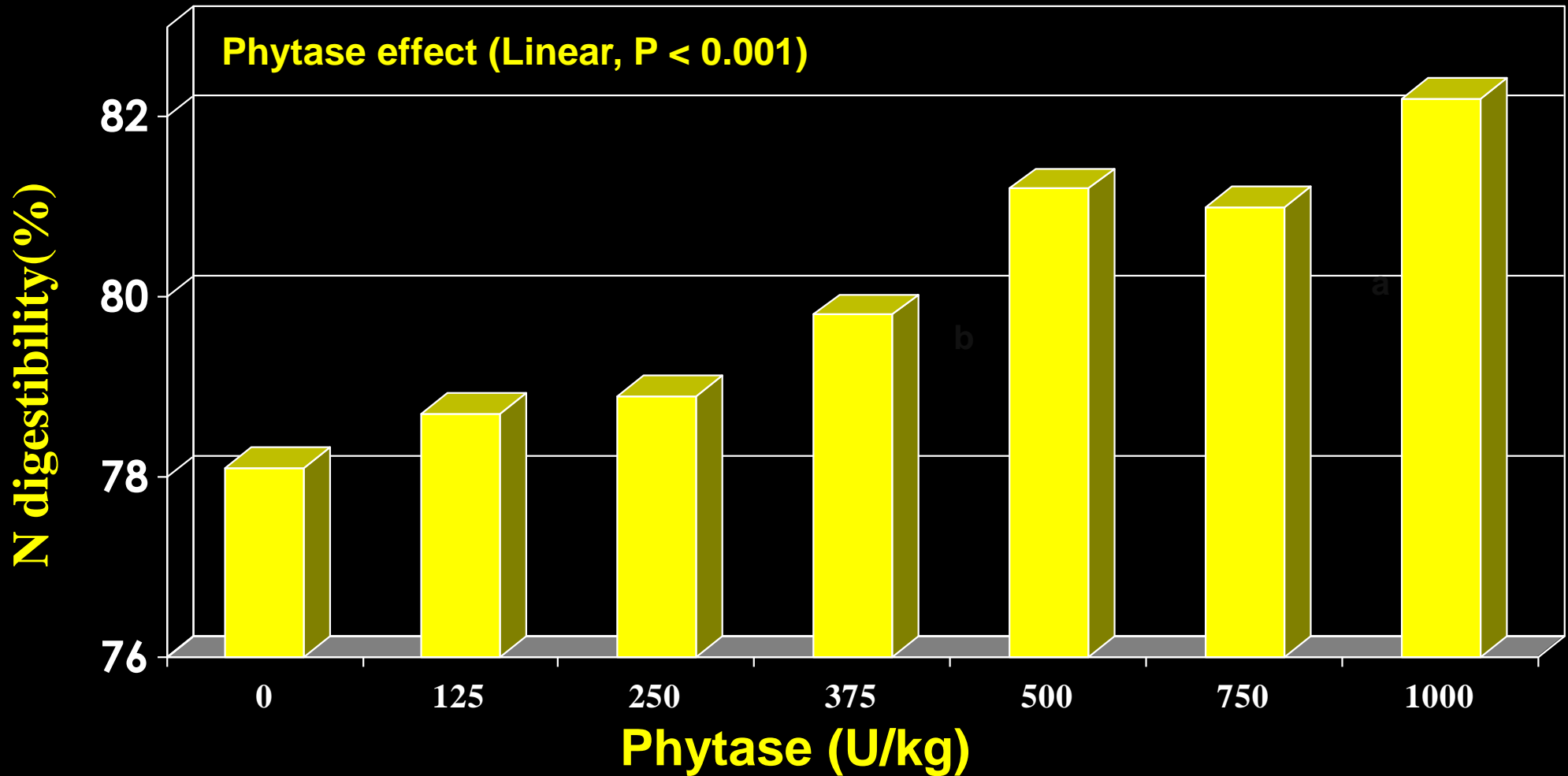
Phytate, P source and anti-nutrient in feed



Effect of phytase on ileal N digestibility in turkeys (Ledoux unpublished)



Effect of phytase on N digestibility in broilers fed a lysine deficient diet (Ravindran *et al.*, 2001)



Average increase from 0 to 1000 FTU/kg = 5.2%

Effects of phytase (0 vs 1,000 FTU/kg) on ileal digestibility of essential AA (Amerah *et al.*, 2014)

AA ¹	0 (%)	1,000 FTU/kg (%)	Increase (%)
Phe	73.7	83.4	13.1*
Leu	72.2	82.6	14.4*
Ile	72.1	82.1	13.8*
Met	88.0	92.8	5.5*
Lys	80.6	88.9	10.3
Val	66.9	77.4	15.7*
Arg	82.3	90.0	9.4*
Hist	73.0	82.1	12.4*
Thr	66.1	76.5	15.7*

¹Averaged across 4 Ca:aP ratios (1.43 – 3.57; aP = 0.28%)

*P < 0.0001

Effects of phytase (0 vs 1,000 FTU/kg) on ileal digestibility of non essential AA (Amerah *et al.*, 2014)

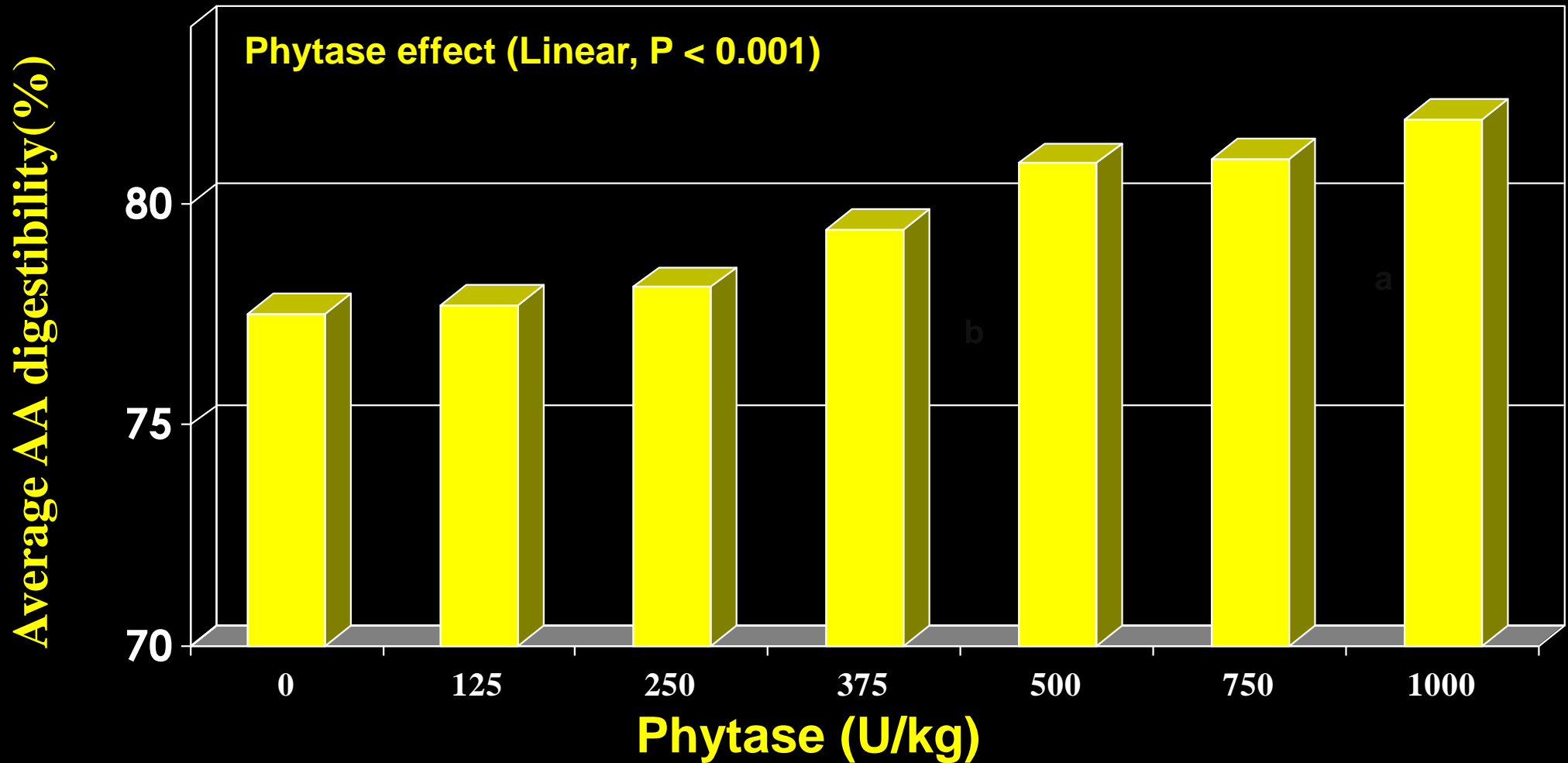
AA ¹	0 (%)	1,000 FTU/kg (%)	Increase (%)
Ser	68.4	80.9	18.2*
Gly	65.8	76.5	16.2*
Asp	75.6	85.0	12.4*
Glu	80.7	88.2	9.3*
Ala	69.9	80.7	15.4*
Pro	72.2	81.2	12.4*
Tyr	75.5	84.4	11.7*
Cyst	54.3	68.5	26.1*

¹Averaged across 4 Ca:aP ratios (1.43 – 3.57; aP = 0.28%)

*P < 0.0001

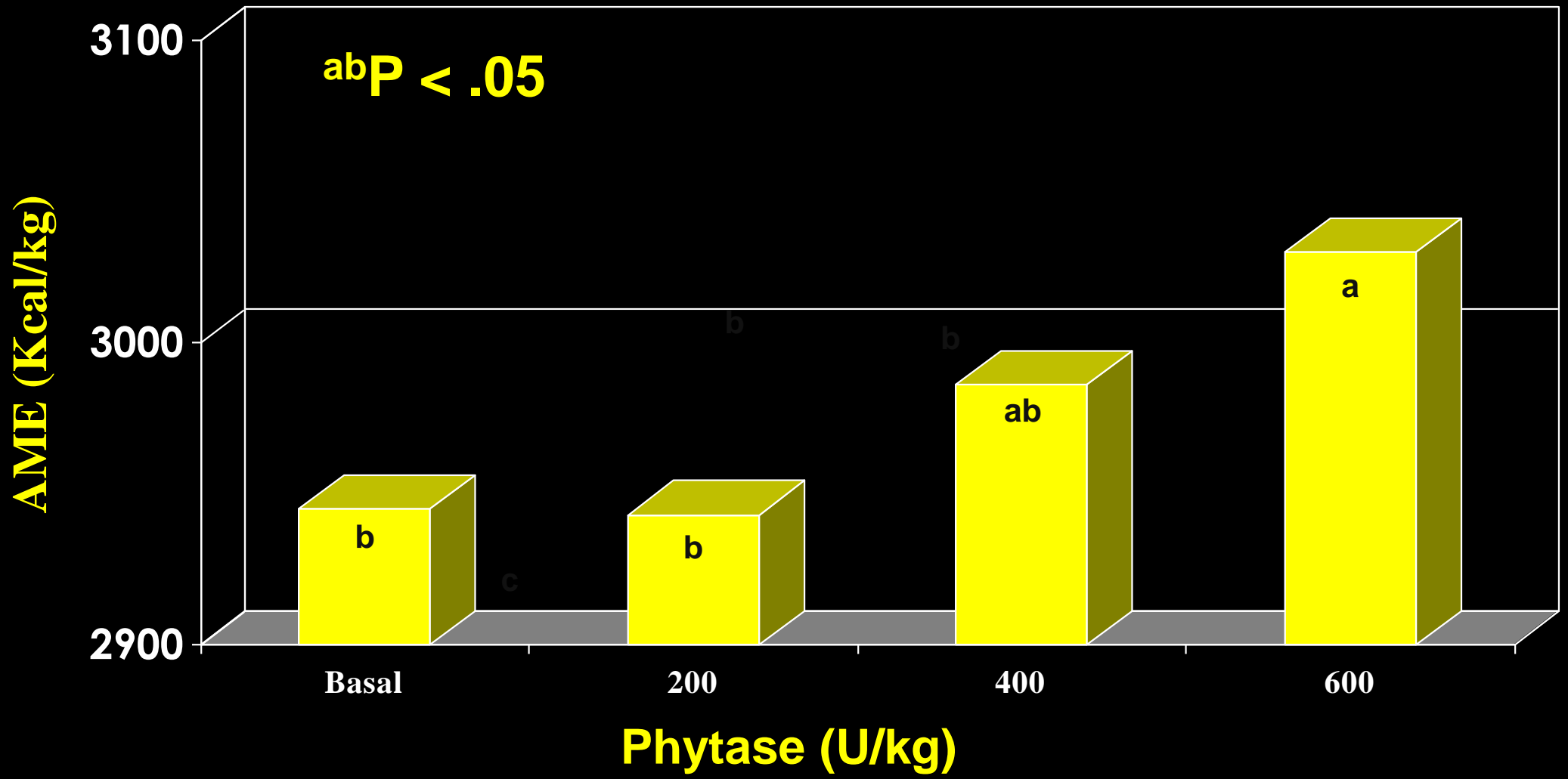
20 studies poultry & pigs 1996-2009: Adeola and Cowieson, 2011
Ranged from no effect to 6 to 7% improvement; TiO₂ & AlA vs Cr₂O₃

Effect of phytase on AA digestibility in broilers fed a lysine deficient diet (Ravindran *et al.*, 2001)

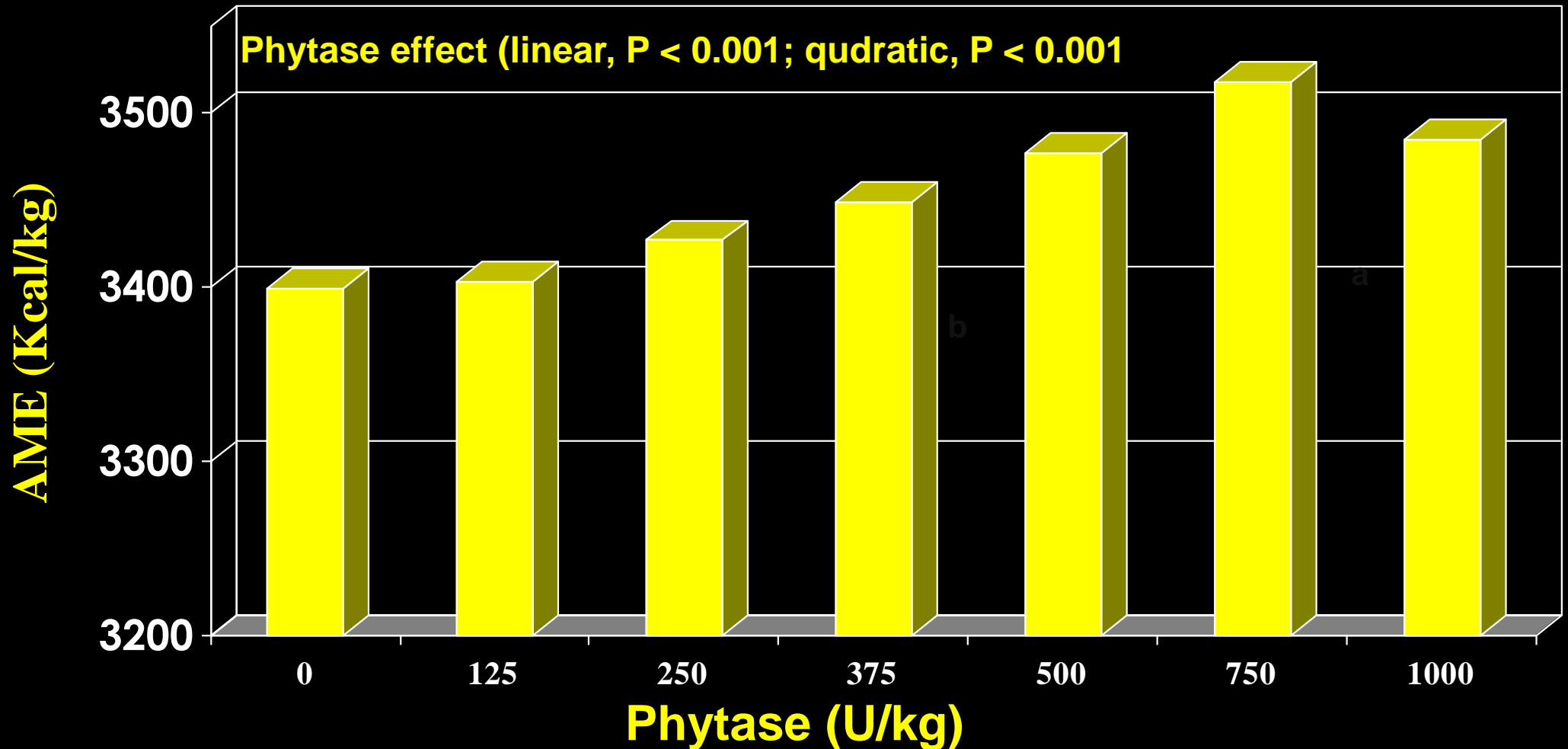


Average increase from 0 to 1000 FTU/kg = 5.6%

Effect of phytase on AME in turkeys (Ledoux unpublished)

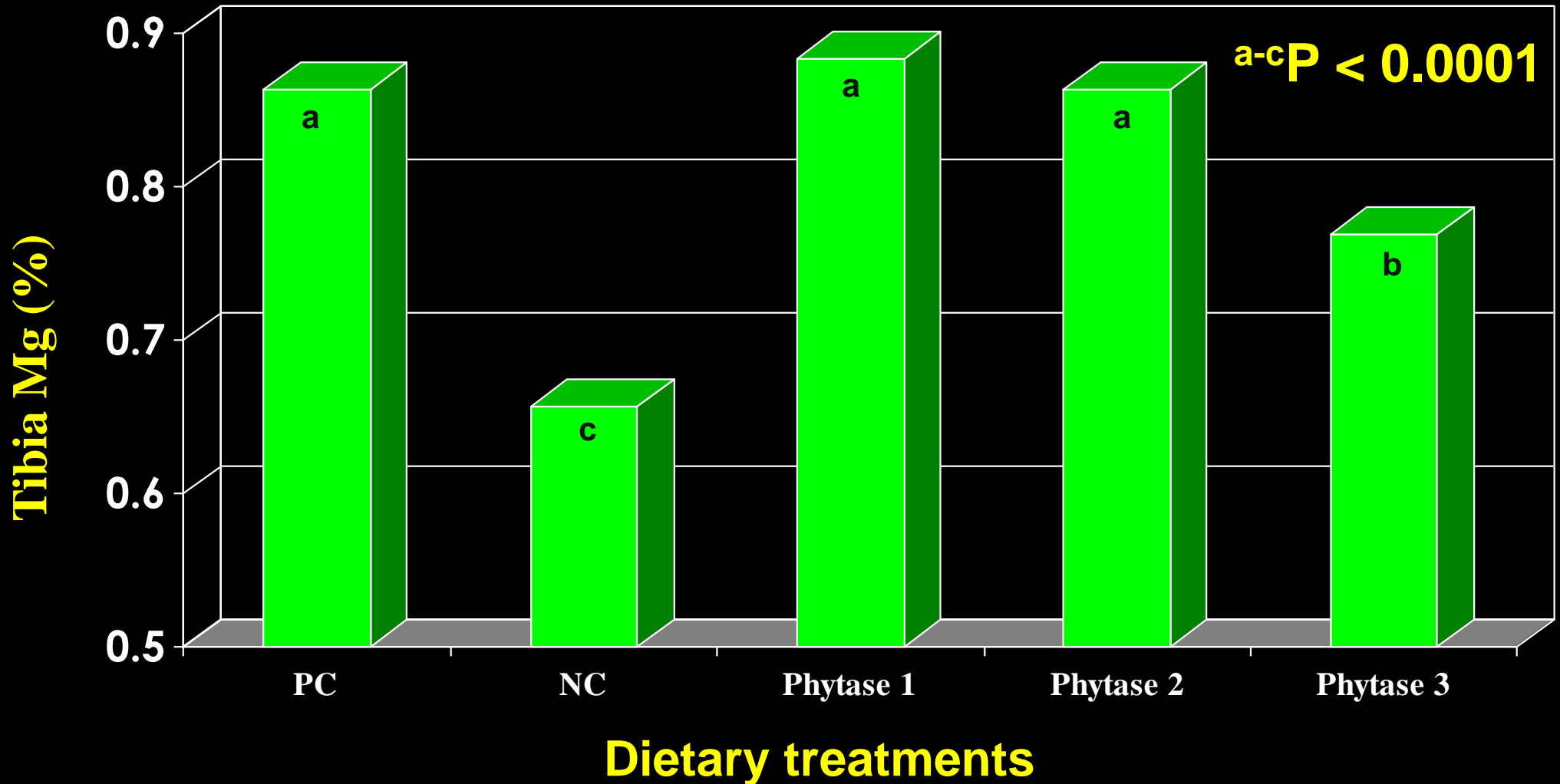


Effect of phytase on AME in broilers fed a lysine deficient diet (Ravindran *et al.*, 2001)



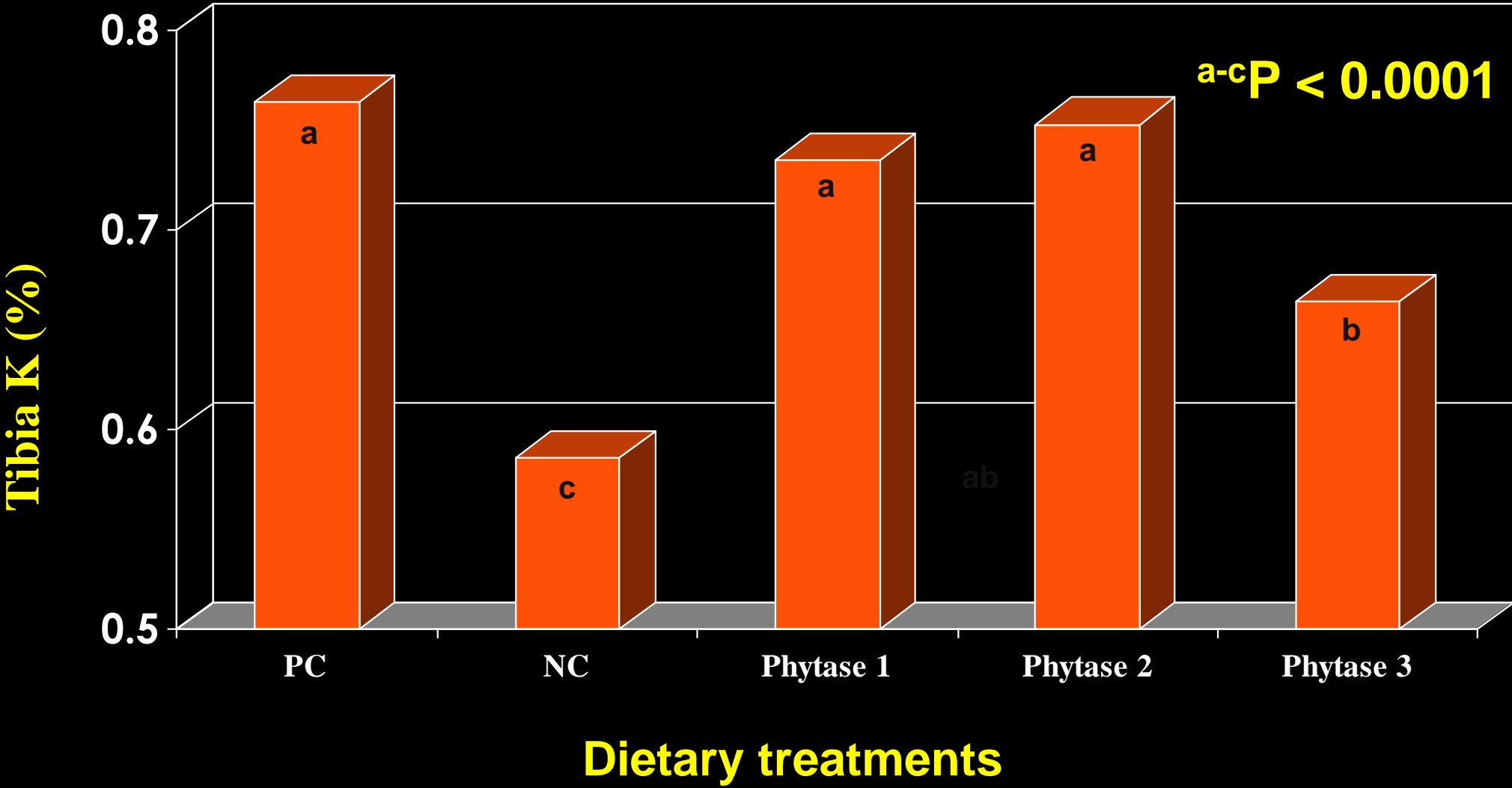
Phytase effect ranged 0 to 120 kcal/kg; Adeola and Cowieson, 2011

Effect of phytase on tibia Mg concentration of broilers at day 41 (Ptak *et al.* 2013)



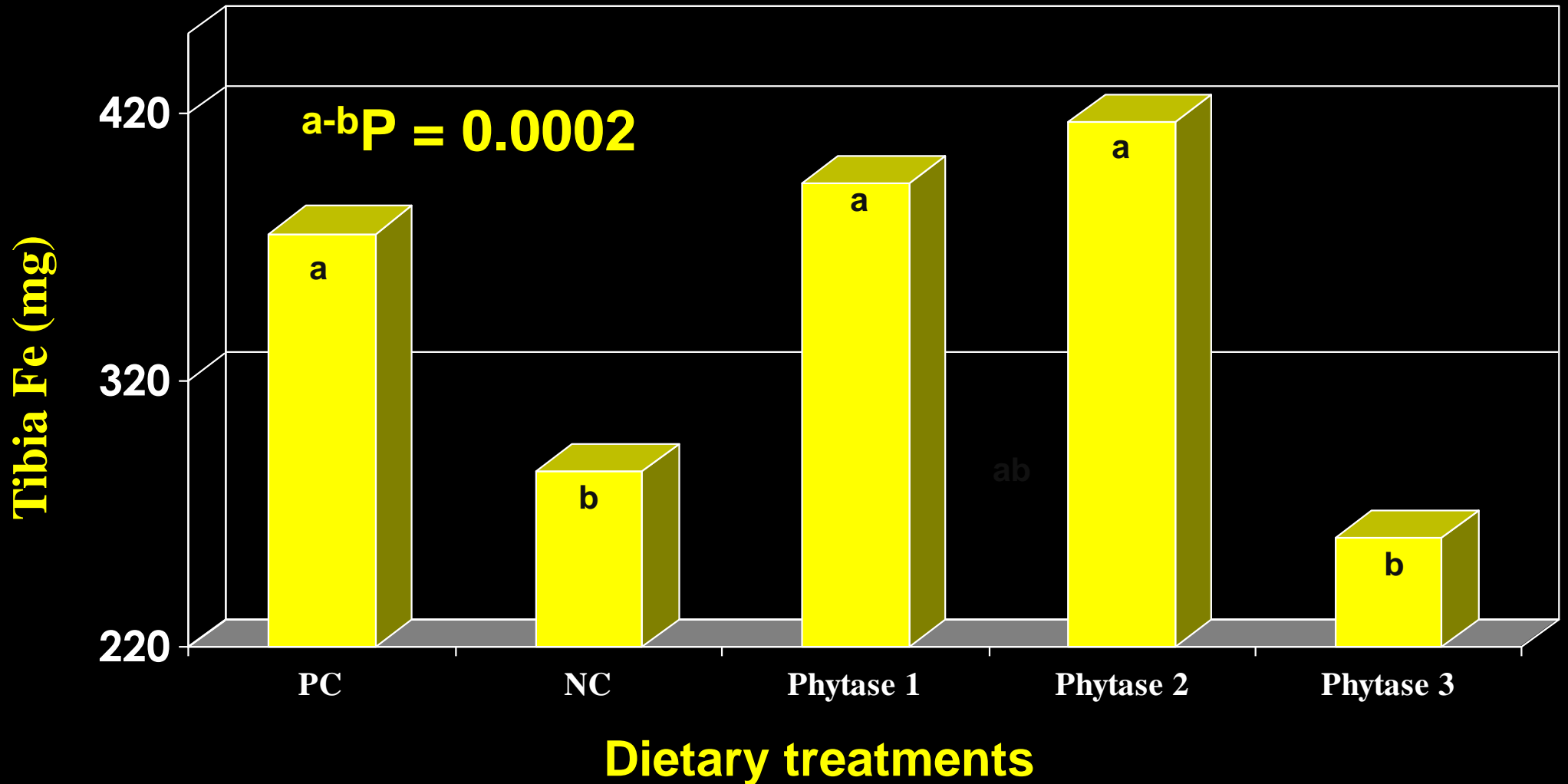
NC diet formulated to meet mineral requirements except for Ca and P

Effect of phytase on tibia K concentration of broilers at day 41 (Ptak et al. 2013)



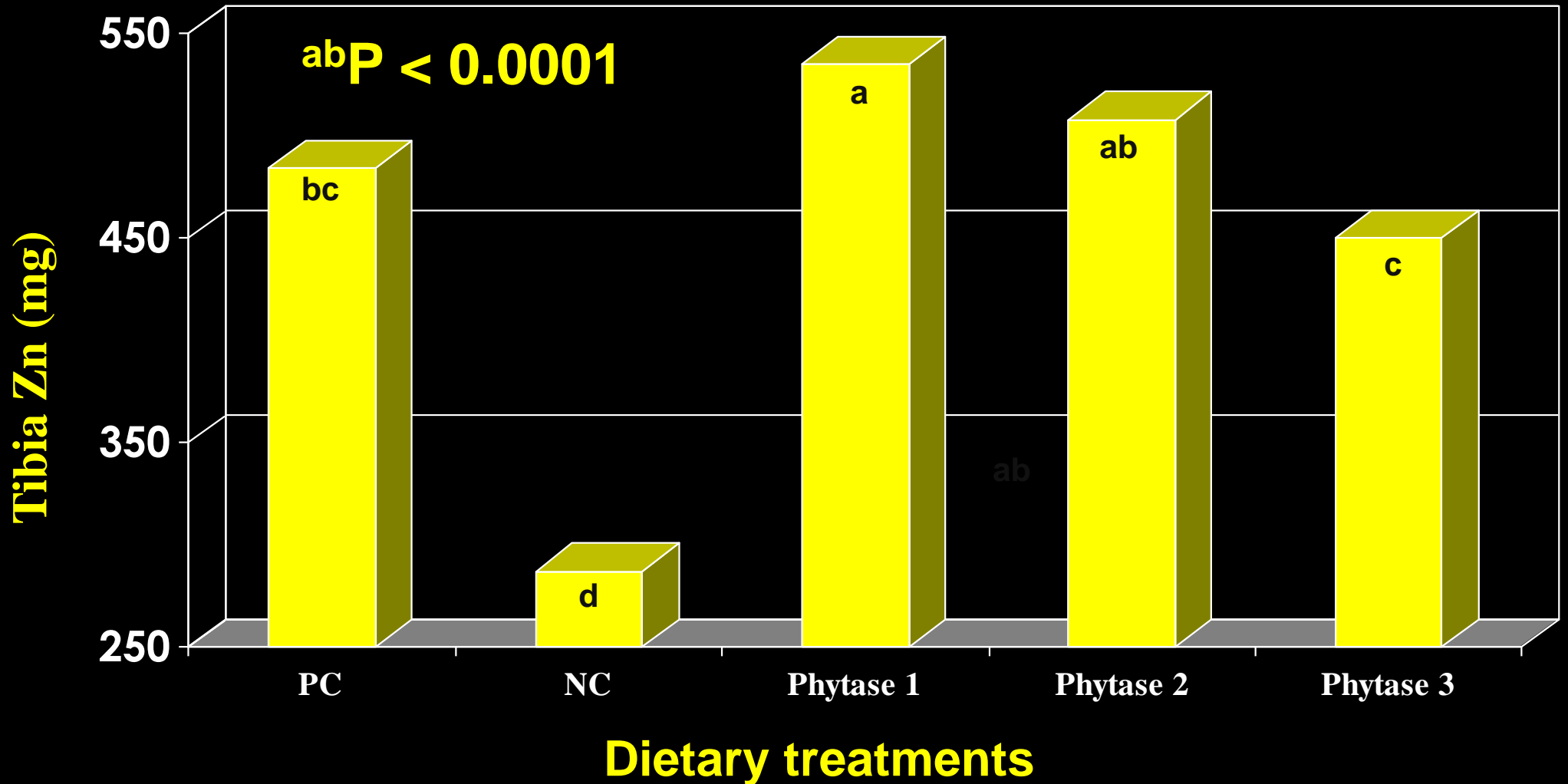
NC diet formulated to meet mineral requirements except for Ca and P

Effect of phytase on tibia Fe concentration of broilers at day 41 (Ptak *et al.* 2013)

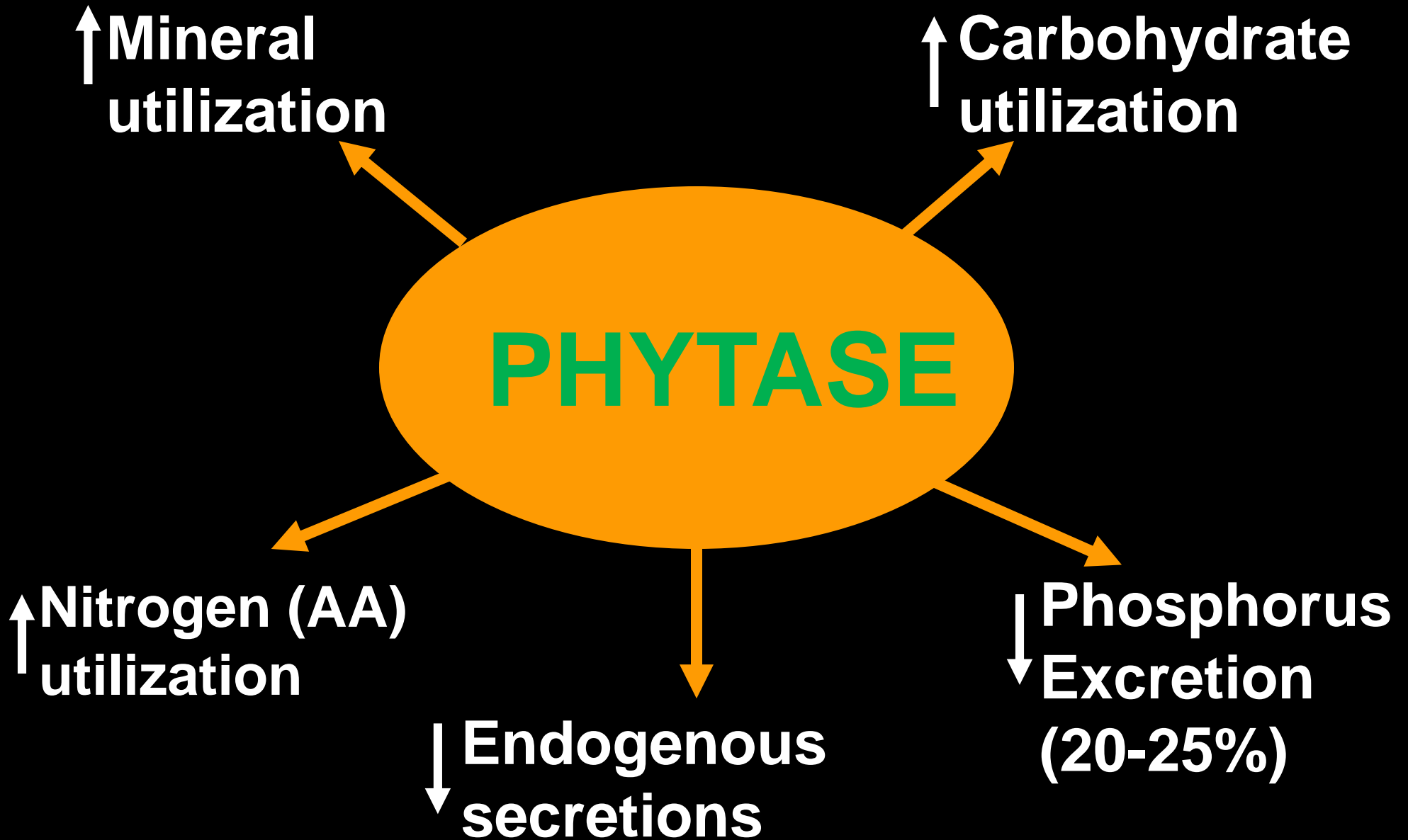


NC diet formulated to meet mineral requirements except for Ca and P

Effect of phytase on tibia Zn concentration of broilers at day 41 (Ptak *et al.* 2013)



NC diet formulated to meet mineral requirements except for Ca and P



Matrix Values for phytase

EFFECTS OF PHYTASE ON PERFORMANCE OF BROILERS FED DIETS DIFFERING IN NUTRIENT CONTENT (Shelton *et al.*, 2004)

Diet	Control	ME	ME+AA	SEM¹
Final weight, g	2,219	2,200	2,188	13.2
ADG, g	51.7	51.3	51.0	0.30
AFI, g	94.1	92.8	92.0	1.0
Mortality, chicks/rep	0.60	1.00	0.80	0.25
Tibia ash, %	57.27	58.02	57.12	0.56
Litter P, %	1.43	1.29	1.24	0.023

Control = C-SBM

¹Diet = NS

ME = C-SBM with 600 FTU/kg and matrix values for Ca, aP, and ME

ME+AA = C-SBM with 600 FTU/kg and matrix values for Ca, aP, ME, and AA

EFFECTS OF PHYTASE ON CARCASS TRAITS OF BROILERS FED DIETS DIFFERING IN NUTRIENT CONTENT (Shelton *et al.*, 2004)

Diet	Control	ME	ME+AA	SEM¹
Live weight, kg	2.20	2.15	2.17	0.03
Eviscerated Wt., kg	1.58	1.53	1.55	0.02
Chill Wt., kg	1.62	1.57	1.58	0.02
Carcass Yield, %	72.1	71.8	71.3	0.30
Breast Wt. PLW, %	13.0	12.7	13.1	0.14
Breast Wt. PCW, %	17.6	17.4	17.9	0.18

Control = C-SBM

¹Diet = NS

ME = C-SBM with 600 FTU/kg and matrix values for Ca, aP, and ME

ME+AA = C-SBM with 600 FTU/k and matrix values for Ca, aP, ME, and AA

EFFECTS OF PHYTASE ON PERFORMANCE OF LAYERS FED DIETS DIFFERING IN NUTRIENT CONTENT (Peron *et al.*, 2010)

Treatment	Egg Prod. (g)	Egg Wt. (%)	Egg Shell Wt. (%)
Control	76.1	57.9	9.5
RN1 + Phytase (300 FTU)	77.2	58.3	9.5
RN2 + Phytase (300 FTU)	76.3	57.6	9.8
RN3 + Phytase (450 FTU)	78.7	57.2	9.5

RN1 = Reduction in aP by 0.115% and Ca by 0.1%

RN2 = Reduction in aP by 0.115%, Ca by 0.1% and ME by 32 kcal/kg

RN3 = Reduction in aP by 0.172%, Ca by 0.15%, and ME by 48 kcal/kg

All RN diets also reduced in AAs

Enzyme Cocktails

Why enzyme cocktails?

- Phytate hydrolysis by phytase (max. 65%)
- Limited access of phytase to phytate
- Phytate occluded by protein, starch, lipids
- Allowing access to phytate should increase phytate hydrolysis
- In cereals: In aleurone layer
- In oil seeds: associated with storage proteins throughout seed

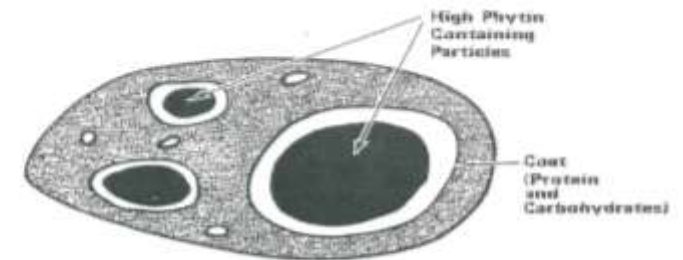
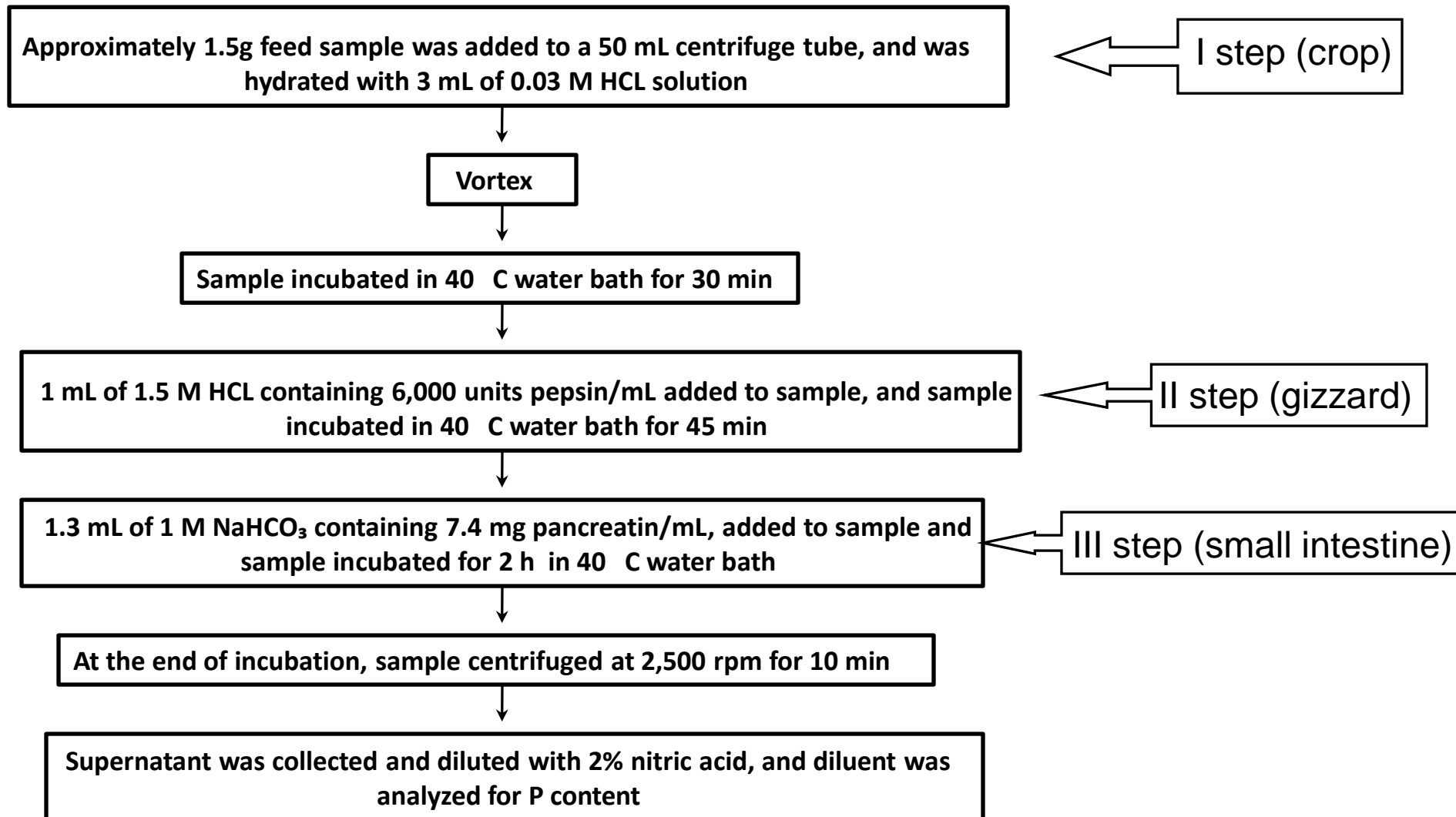


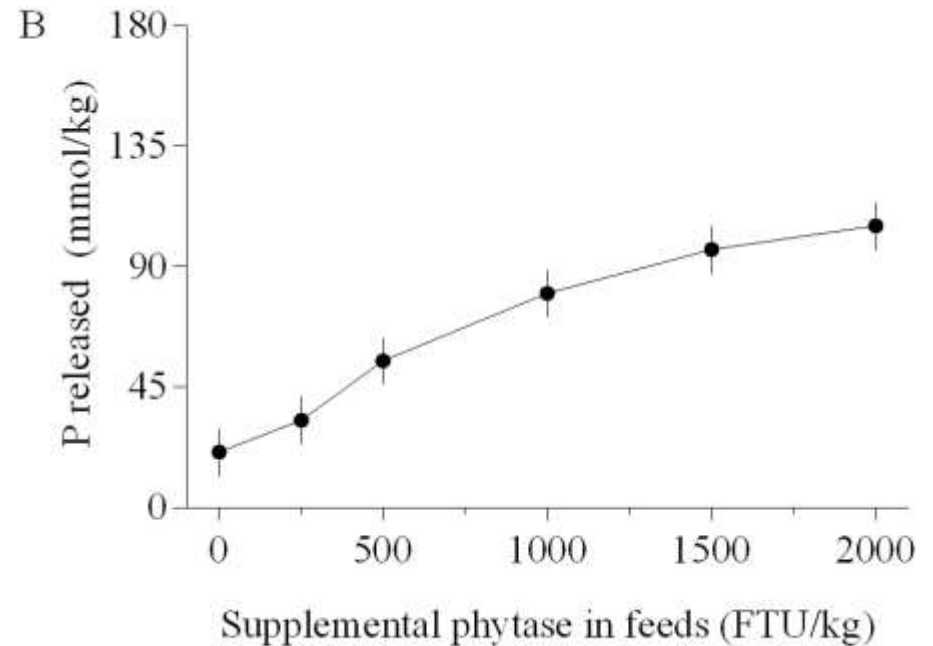
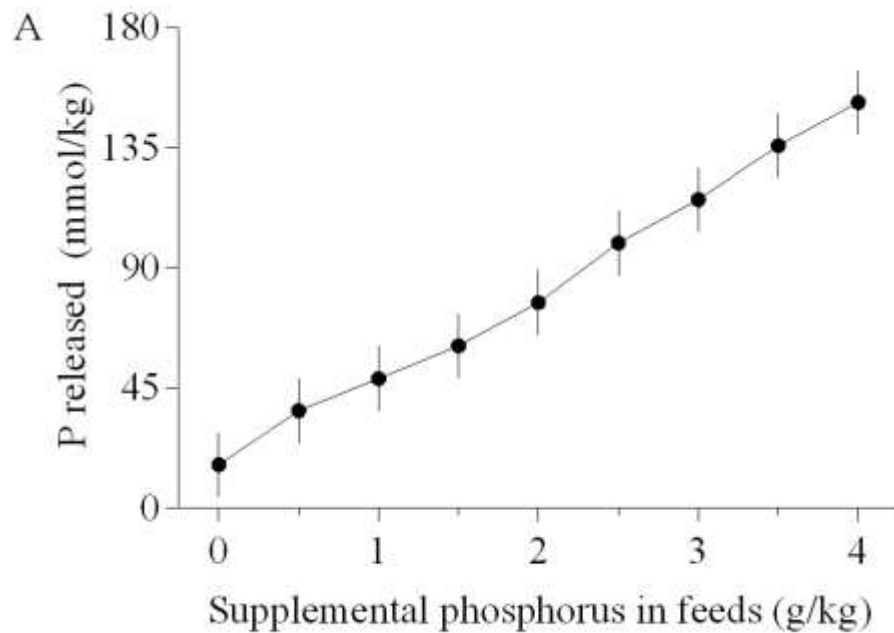
FIGURE 1. Schematic diagram showing an aleurone particle with inclusions, as in rice grains. (From Ogawa, M., Tanaka, K., and Kasai, Z., *Agric. Biol. Chem.*, 39, 695, 1975. With permission.)

In vitro Procedure

(Adapted from Zyla, et al. 1995; Brit. J. of Nutrition, 74, 3-17)



Validation of the *In Vitro* Procedure (Zyla et al., 1995)



Efficacy of an enzyme cocktail on phytate hydrolysis in vitro (Zyla *et al.*, 1995)

Phytase activity (FTU/kg)	Conversion Rate (%)
0	57
231	84
347	91
462	93
694	100

Cocktail = Acid protease, Acid phosphatase, Pectinase, Citric acid

**EFFECTS OF PHYTASE AND ENZYME COCKTAIL ADDITIONS TO A CORN-SBM BASED DIET ON PERFORMANCE AND P RETENTION BY TURKEYS
(ZYLA *et al.*, 1996)**

Treatment	aP (%)	BWG (g)	TBASH (%)	P RET (%)
PC	0.60	381^b	47.6^a	31.0^c
Phytase (1000 U)	0.16	356^c	42.7^c	66.8^b
Cocktail	0.16	393^b	45.2^b	77.0^a
Mycelium (5%)	0.16	420^a	46.8^{ab}	79.5^a

Cocktail: phytase, pectinase, acid phosphatase, acid protease, citric acid, Vit. C

**Mycelium: phytase, acid phosphatase, protease, pectinase, PA, Biotin, myo-
inositol**

**EFFECTS OF PHYTASE AND ENZYME COCKTAIL ADDITIONS TO A WHEAT BASED DIET ON PERFORMANCE AND P RETENTION BY BROILERS
(Zyla *et al.*, 2000)**

Treatment	aP (%)	BWG (g)	TASH (%)	P RET (%)
PC	0.41	443^b	11.94^a	47.24^c
NC	0.17	289^d	8.73^b	48.75^c
Phytase (750 U)	0.17	389^c	9.06^b	58.75^b
Cocktail	0.17	484^a	11.96^a	71.50^a
Mycelium (4%)	0.17	500^a	11.88^a	73.00^a

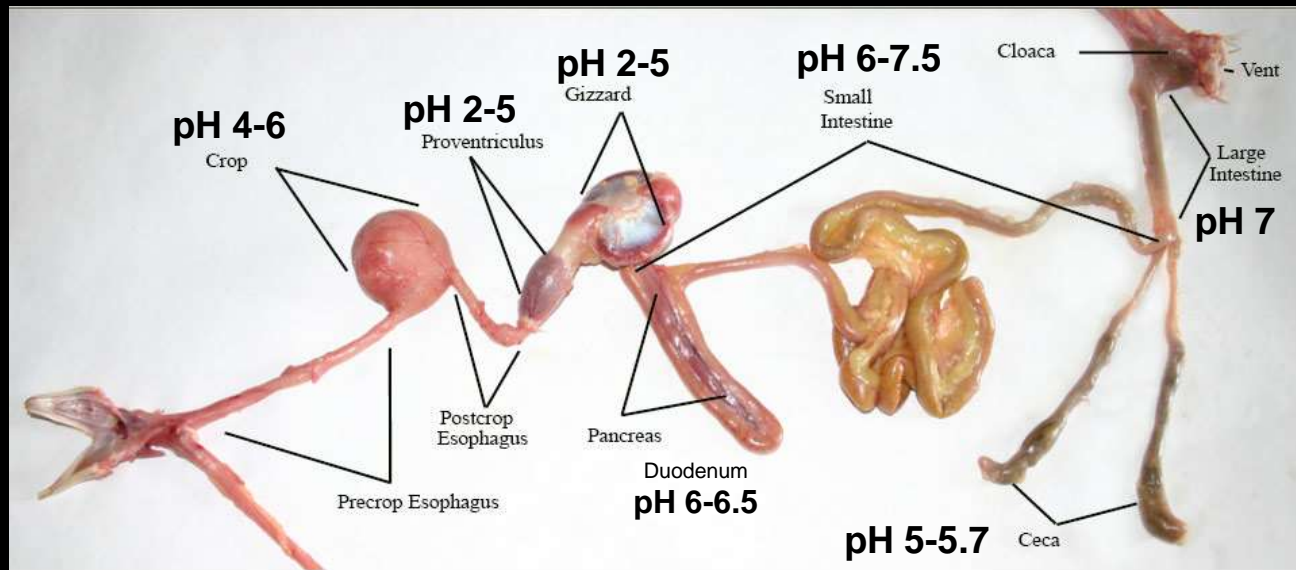
Cocktail: phytase, pectinase, acid phosphatase, citric acid

Mycelium: phytase, acid phosphatase, protease, pectinase, PA, Biotin, myo-inositol

...QUESTION...

Why not 100% In Vivo?

- Rapid transit time
- pH of intestinal tract
- Availability of substrate (Phytate)
- Solubility of substrate



...RECOMMENDATION...

**THE COCKTAIL STRATEGY IS A FEASIBLE
APPROACH FOR IMPROVING PHOSPHORUS
AVAILABILITY IN POULTRY DIETS**

QUESTION

IS IT BENEFICIAL TO FEED OTHER ENZYMES IN COMBINATION WITH PHYTASE IN THE DIET?

	<u>BWG</u>	<u>FCR</u>
NEGATIVE CONTROL	1067	1.736
XYLANASE ALONE	1079 (+1.12%)	1.690 (-2.66%)
PHYTASE ALONE	1110 (+4.03%)	1.697 (-2.28%)
PHYTASE + XYLANASE	1144 (+7.18%)	1.648 (-5.09%)

*AVERAGE OF 17 PUBLISHED STUDIES AS REVIEWED BY ROSEN (2004)
15 wheat based diets and 2 corn/rice based diets

QUESTION

IS IT BENEFICIAL TO FEED OTHER ENZYMES IN COMBINATION WITH PHYTASE IN THE DIET (NC = corn, rye, SBM)?

	<u>BWG</u>	<u>FCR</u>
NEGATIVE CONTROL	878	1.742
NC + XAP	939 (+7.0%)	1.596 (-8.4%)
NC + PHYTASE	932 (+6.2%)	1.614 (-7.3%)
NC + XAP + PHYTASE	1000 (+14.0)	1.561 (-10.4%)

XAP = XYL+ AMYL+ PROTEASE

Cowieson and Adeola (2005)

QUESTION

IS IT BENEFICIAL TO FEED OTHER ENZYMES IN COMBINATION WITH PHYTASE IN THE DIET (NC = Corn-SBM)?

	<u>BWG</u>	<u>FCR</u>
NEGATIVE CONTROL	553	1.45
NC + XAP	566 (+2.4%)	1.44 (- 0.7%)
NC + PHYTASE	618 (+11.8%)	1.40 (- 3.4%)
NC + XAP + PHYTASE	629 (+13.9)	1.37 (- 5.5%)

XAP = XYL+ AMYL+ PROTEASE

(Olukosi *et al.*, 2007)

Factors affecting the efficacy of phytase

Phytase Activity at Different Pelleting Temperatures (Coelho, 1996)

Pelleting temperature
°F

°C

Phytase activity
%

140

60

91

158

70

66

176

80

24

194

90

7

212

100

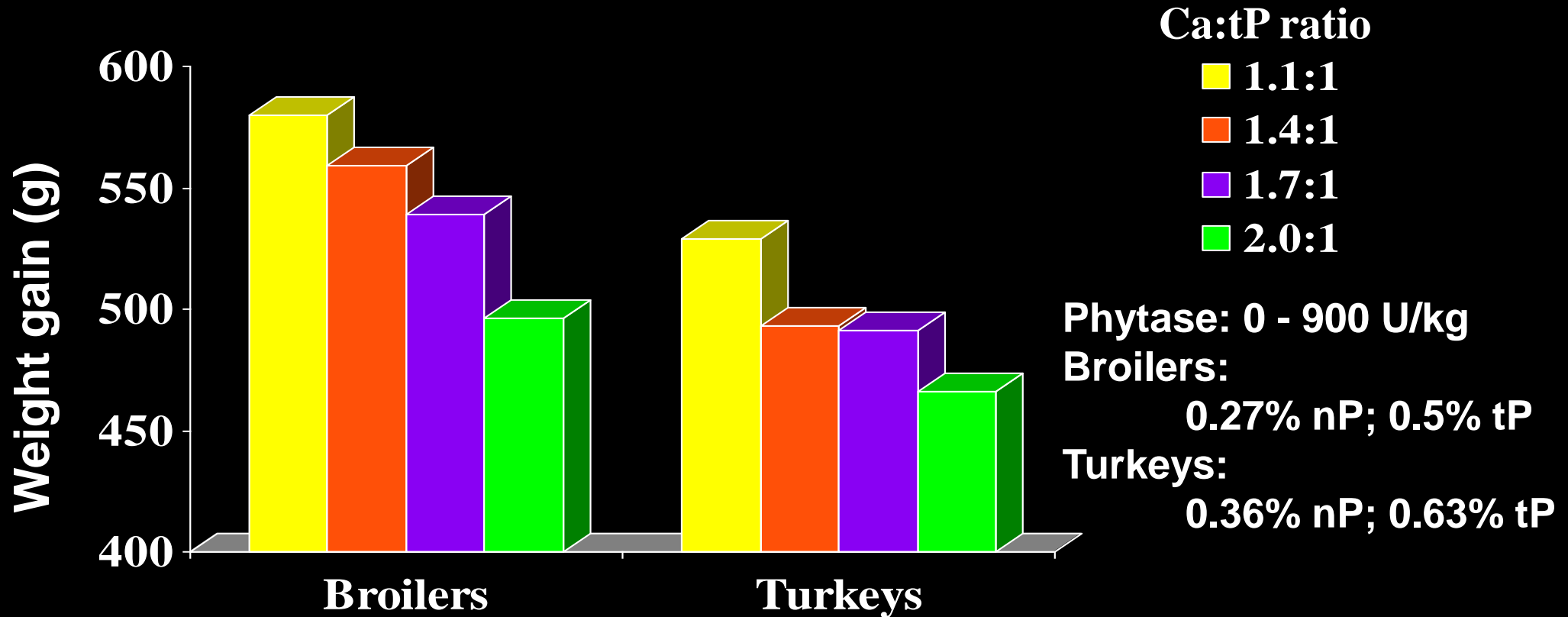
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Approaches for addressing phytase degradation issues

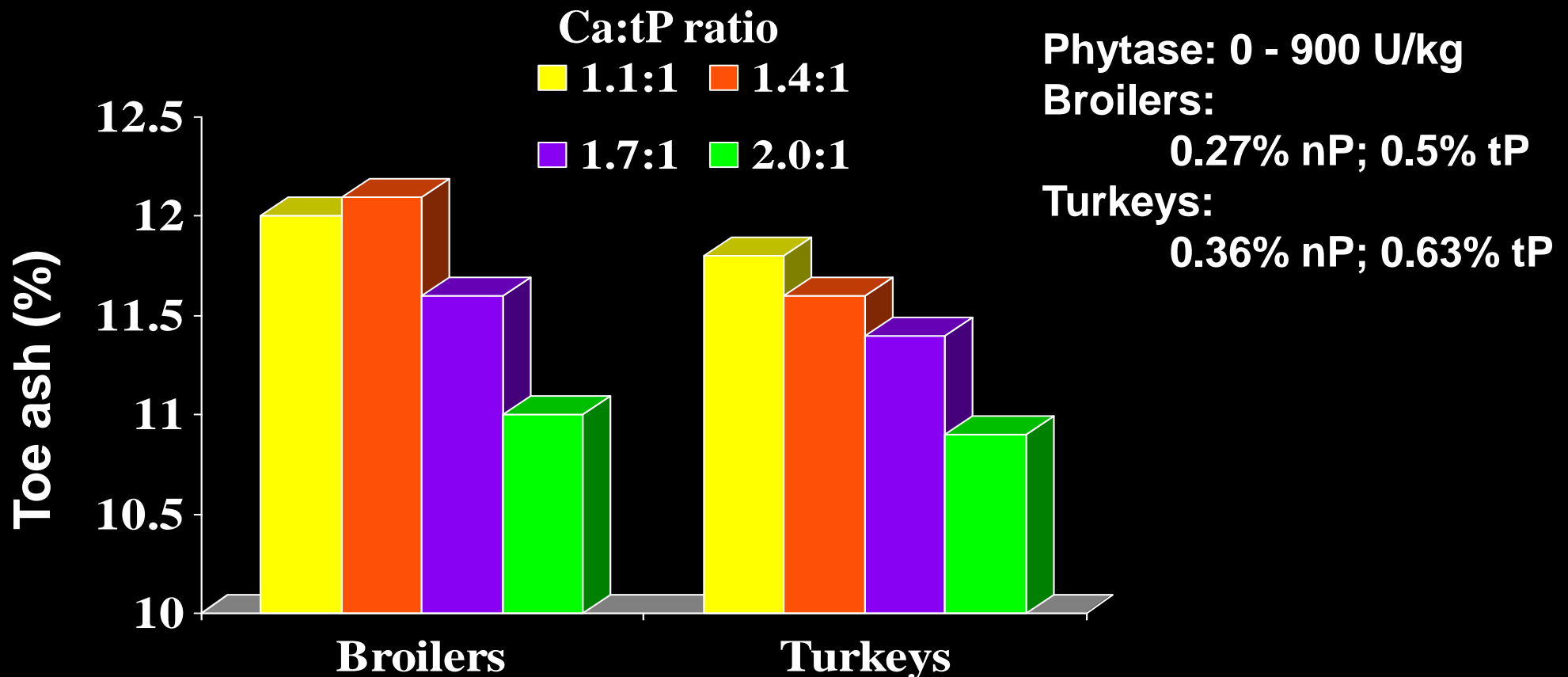
- **Post pelleting applications**
- **Coatings to improve heat stability**
- **Newer phytases more thermostable**
- **More pepsin resistance**

EFFECT OF Ca LEVEL ON THE EFFICACY OF PHYTASE

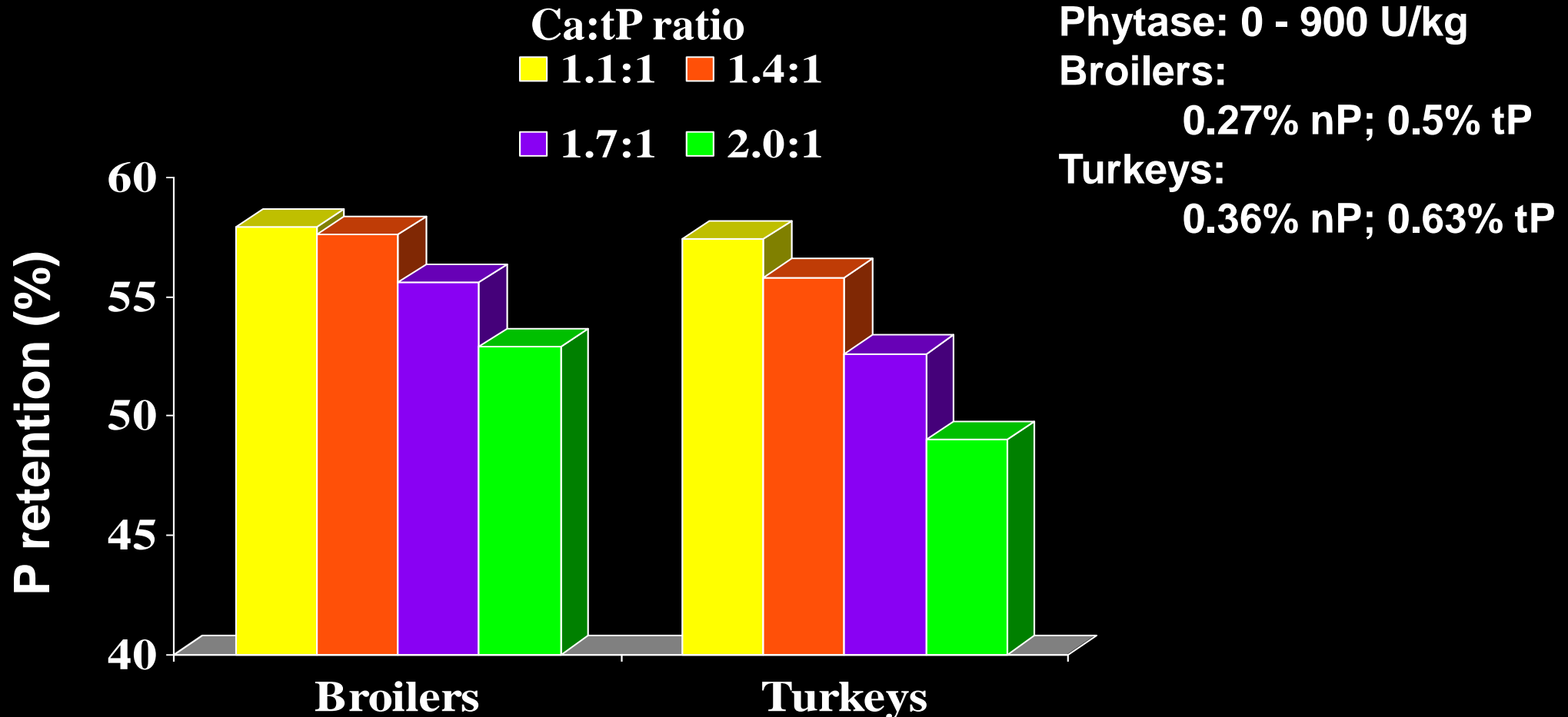
Effect of Ca:tP Ratio on Efficacy of Phytase in Broilers and Turkeys (Qian *et al.*, 1996, 1997)



Effect of Ca:tP Ratio on Efficacy of Phytase in Broilers and Turkeys (Qian *et al.*, 1996, 1997)



Effect of Ca:tP Ratio on Efficacy of Phytase in Broilers and Turkeys (Qian *et al.*, 1996, 1997)



Effects of Formaldehyde on Phytase Efficacy

Effect of formaldehyde treatment of recovered phytase activity (Dos Santos *et al.*, 2013)

Diet	FOR	Phytase Activity	
		Expected	Analyzed
PC	+	0	0
NC	+	0	0
E.coli	-	500	799
E.coli	+	500	116
Fungal	-	500	462
Fungal	+	500	352

Effect of formaldehyde treatment of on performance of broilers (Dos Santos *et al.*, 2013)

Diet	FOR	FI	BWG	FCR
PC	-	1,163	850	1.370
PC	+	1,183	842	1.405
NC	-	1,045	740	1.412
NC	+	1,087	753	1.445
<i>E.coli</i>	-	1,127	816	1.338
<i>E.coli</i>	+	1,133	805	1.408
Fungal	-	1,175	833	1.411
Fungal	+	1,118	800	1.398
FOR Effect		NS	NS	S ¹

¹1.362 (- FOR) vs 1.408 (+ FOR) FOR added at 100% higher than recommended

Superdosing

Super-dosing

- Enough phytase to completely degrade phytate
- Less residual phytate (IP6) and other esters (IP5-IP3)

Less anti-nutritional effects

Less endogenous loss of nutrients

- Generation of *myo*-inositol

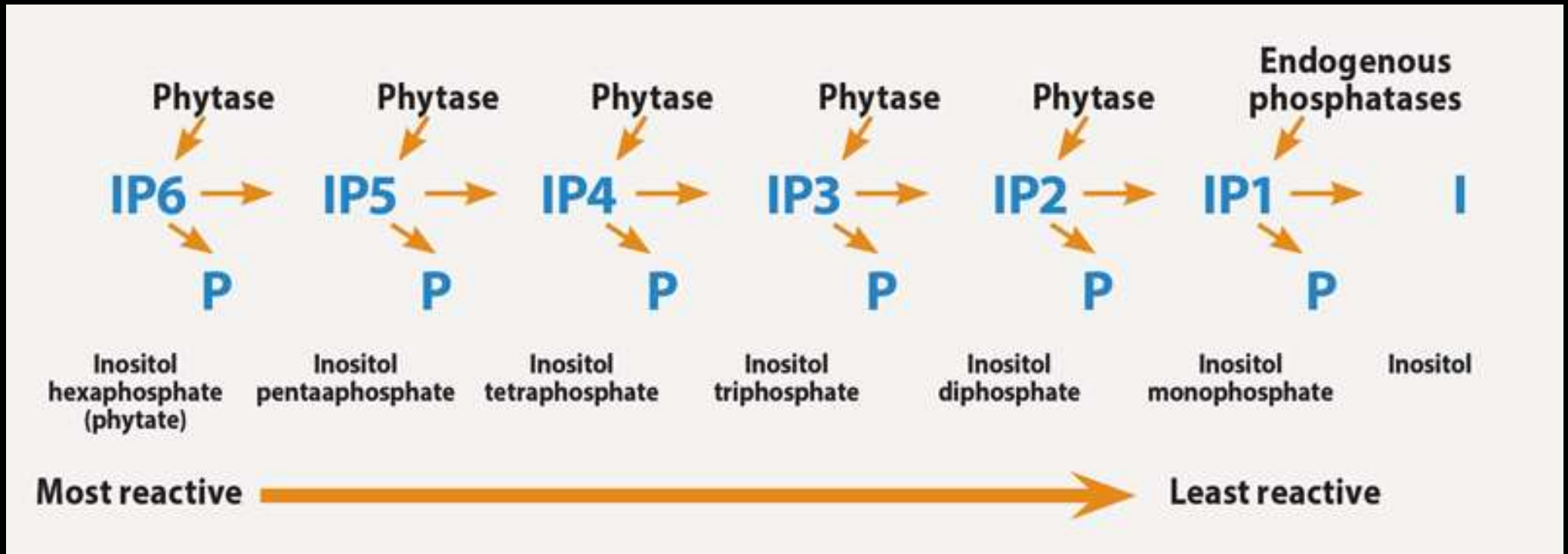
Vitamin like effects

Lipotropic effects

Superdosing of phytase

1) Complete break down of phytate

- Using enough phytase to prevent build up of IP4 and IP3
- IP6 to IP3 can all have anti-nutritional effects



Effects of high concentrations of phytase on performance of broiler chicks from hatch to day 21 (Walk *et al.*, 2014)

TRT	FI	BWG	FCR
PC	1101 ^{ab}	826 ^{bc}	1.332 ^a
NC	1066 ^b	791 ^c	1.348 ^a
NC+500 U/kg	1132 ^a	856 ^{ab}	1.323 ^a
NC+1,000 U/kg	1122 ^a	865 ^a	1.298 ^b
NC+1,500 U/kg	1132 ^a	876 ^a	1.293 ^b

^{a-c}Means in a column with no common superscripts differ $P < 0.05$
NC = 0.30% aP and 0.82% Ca; PC = 0.45% aP and 1.08% Ca

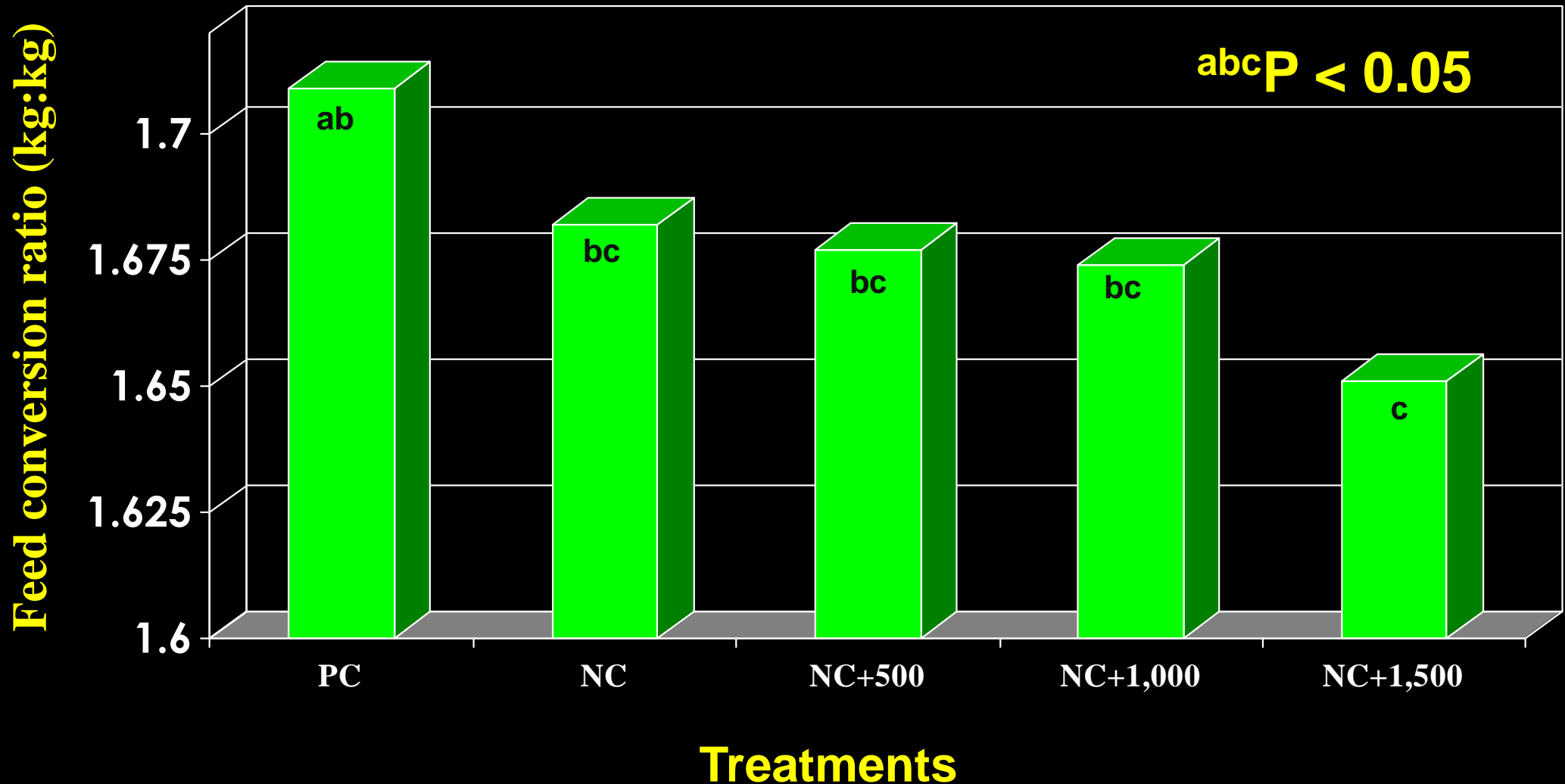
EFFECTS OF PHYTASE ON CONCENTRATIONS OF PHYTATE AND PHYTATE ESTERS IN THE GIZZARD OF BROILERS (Walk *et al.*, 2014)

Treatment	IP6	IP5	IP4	IP3	INOS
	----- $\mu\text{mol/g}$ of dry weight) -----				
PC	2.85 ^{ab}	0.91 ^a	0.75	0.05 ^c	0.91 ^c
NC	1.91 ^b	0.58 ^a	0.67	0.07 ^{bc}	1.21 ^{bc}
NC+500 U/kg	0.04 ^d	0.07 ^b	0.72	0.13 ^{ab}	1.57 ^b
NC+1000 U/kg	0.00 ^d	0.10 ^b	0.55	0.02 ^c	2.12 ^a
NC+1500 U/kg	0.00 ^d	0.11 ^b	0.49	0.02 ^c	2.22 ^a

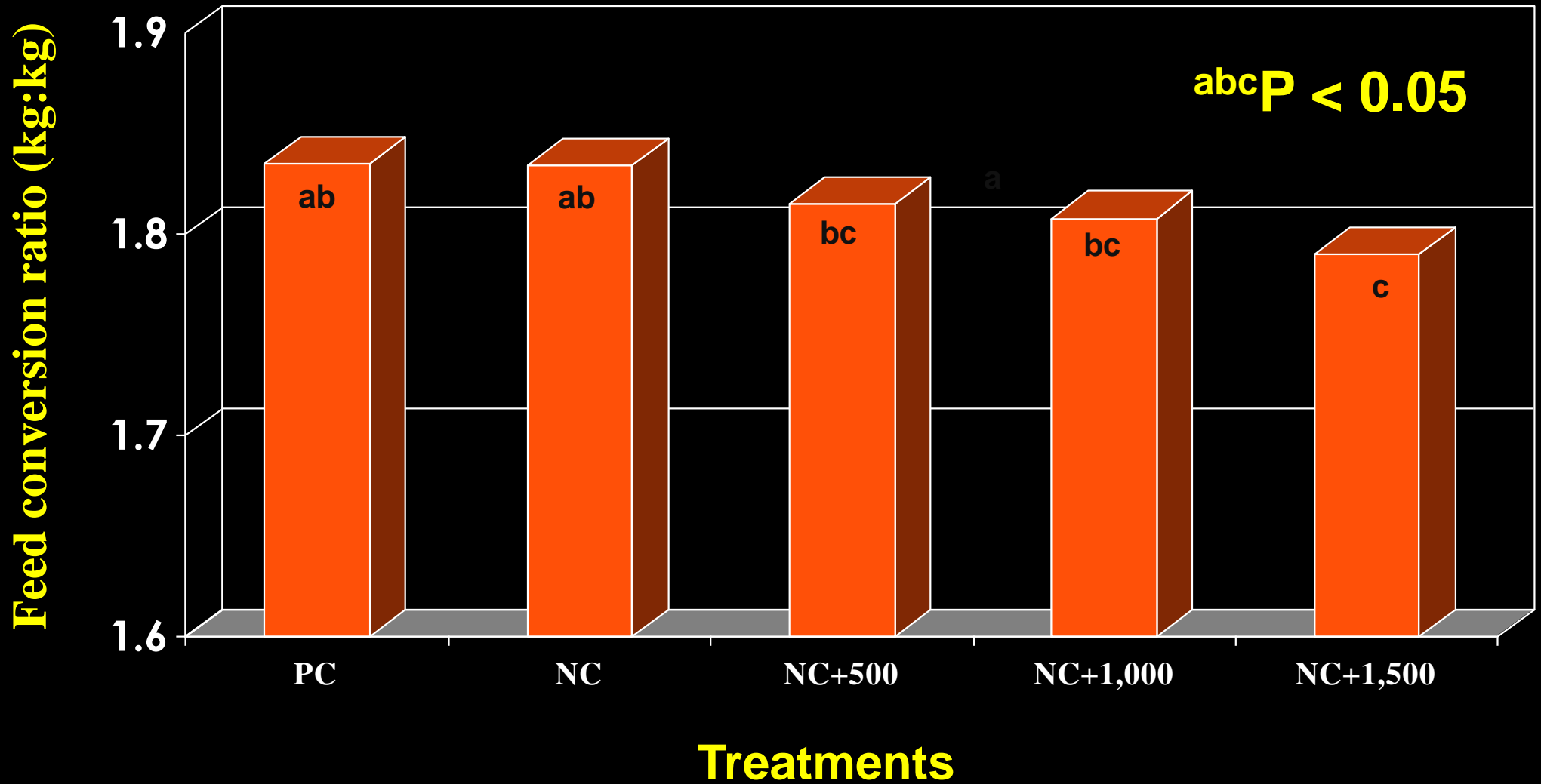
^{a-c}Means in a column with no common superscript differ $P < 0.05$

NC = 0.30% aP and 0.82% Ca; PC = 0.45% aP and 1.08% Ca

Effect of superdosing of phytase on performance of broilers from hatch to day 42 (Walk *et al.*, 2013)



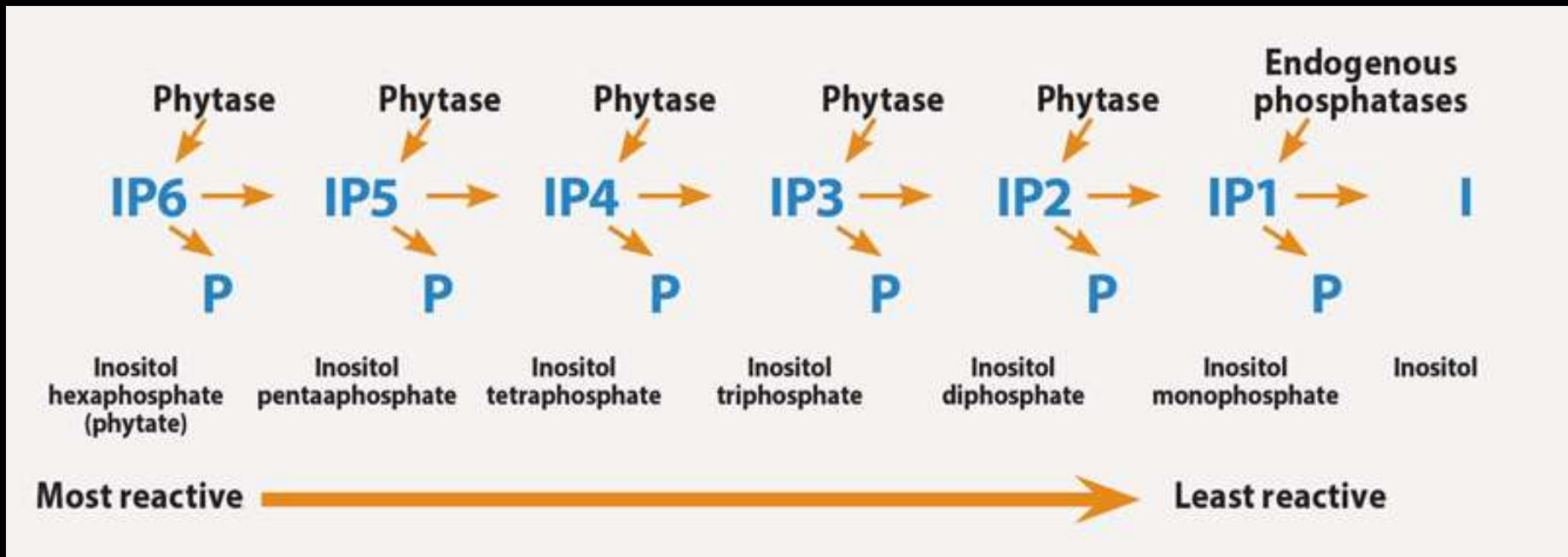
Effect of superdosing of phytase on performance of broilers from hatch to day 49 (Walk *et al.*, 2013)



Superdosing of phytase

2) Release of inositol

- Inositol shown to have growth promoting effects
- Dietary requirement in fish and gerbils
- May involve insulin-like mechanisms



**Effects of inositol on performance of broilers fed a corn-SBM based diet from hatch to day 19
(Zyla *et al.*, 2004)**

Inositol	FI	BWG	FCR
0	838	537^b	1.57^a
0.1%	861	579^a	1.47^b
P Value	NS	0.019	0.057

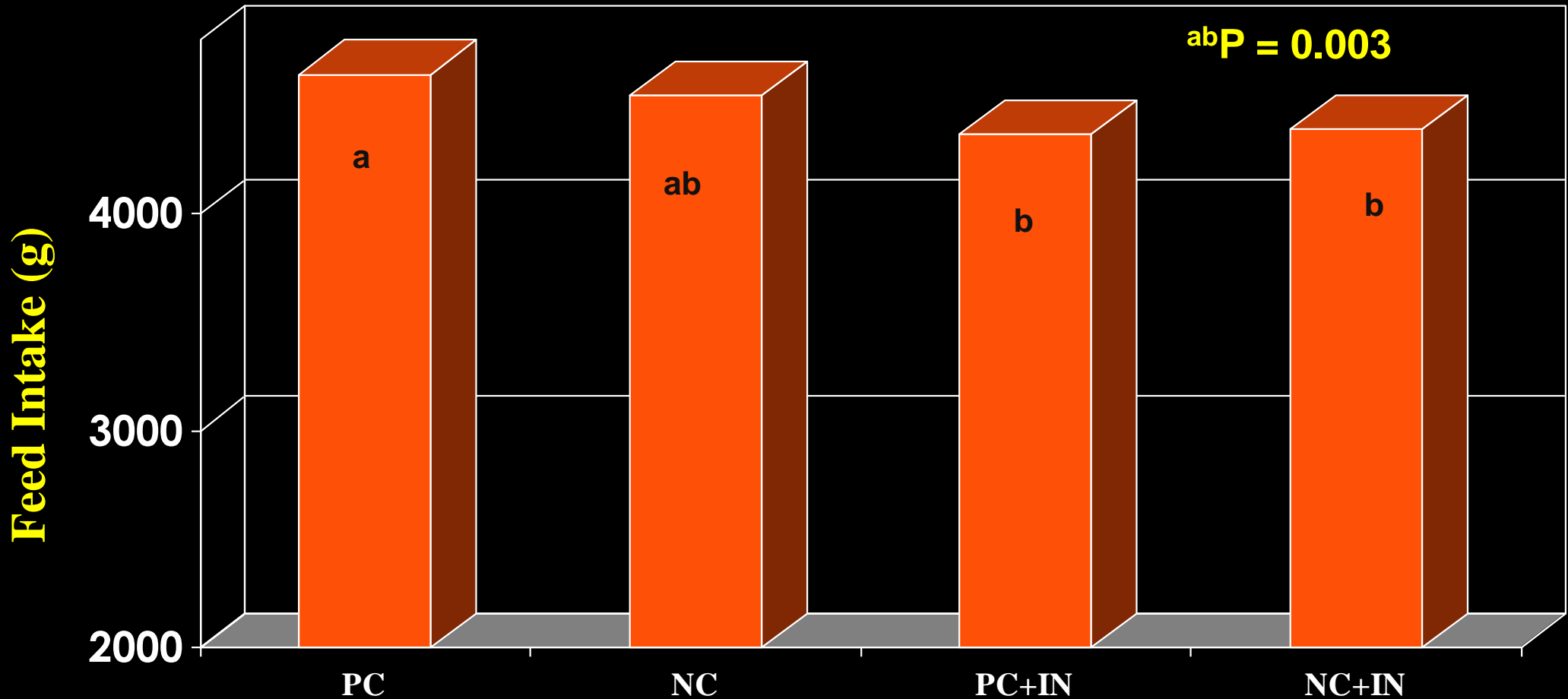
Avg of 2 NPP = 0.27% and 0.47%, and 2 Ca = 0.65% and 0.80%

Effects of inositol on performance of broiler chicks fed corn-SBM and corn-wheat diets from hatch to day 21 (Zyla *et al.*, 2013)

TRT	FI	BWG	FCR
NC	565 ^c	263 ^c	2.195 ^a
INOS (0.1%)	617 ^b	321 ^b	1.977 ^b
Phy B	652 ^{ab}	345 ^{ab}	1.918 ^b
Phy A+B	692 ^a	371 ^a	1.908 ^b
P Values	0.001	0.001	0.007

NC = 0.145% NPP and 0.516% Ca

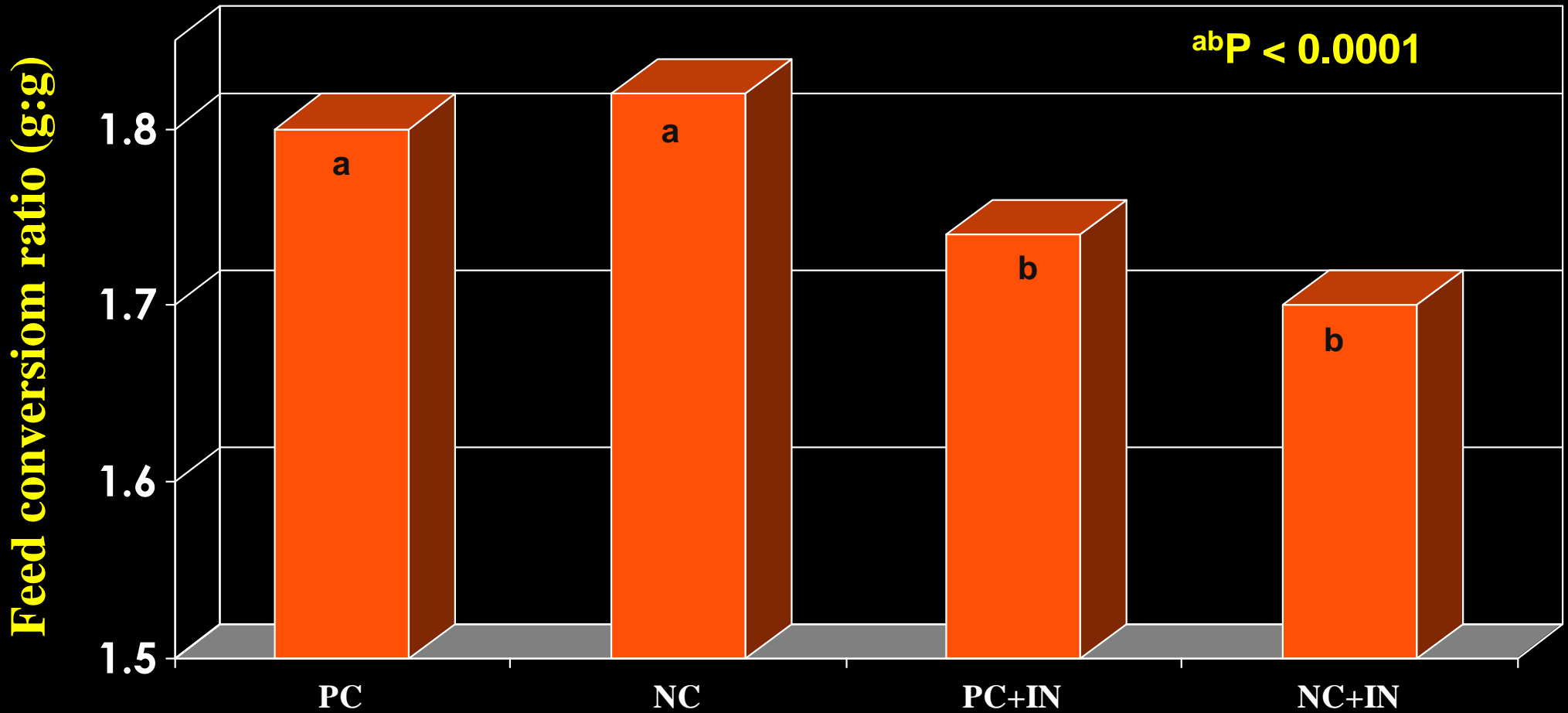
Effect of myo-inositol (0.15%) on feed intake of broilers (Cowieson *et al.*, 2013)



PC - 2590
NC - 2504
PC+IN - 2516
NC+IN - 2579

Treatments

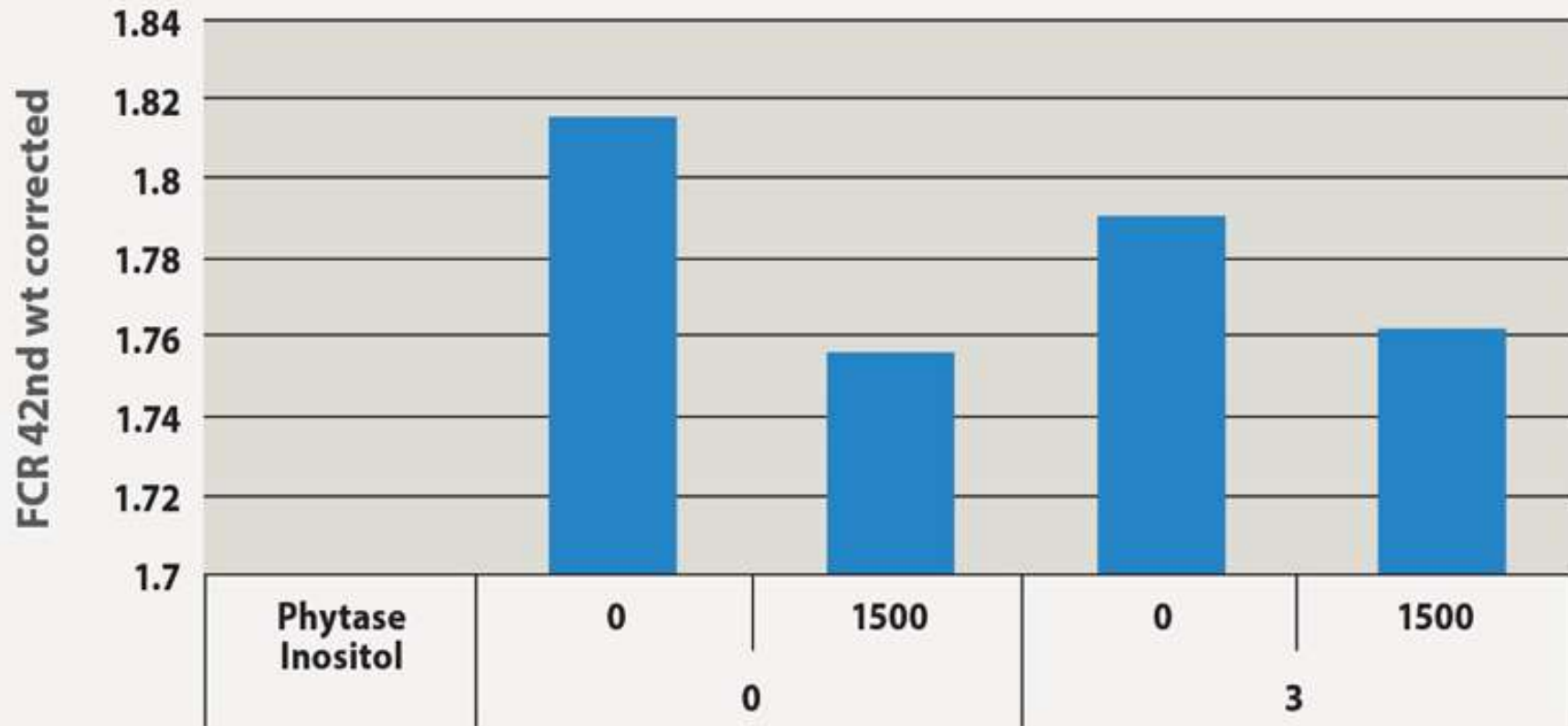
Effect of myo-inositol (0.15%) on feed conversion ratio of broilers (Cowieson *et al.*, 2013)



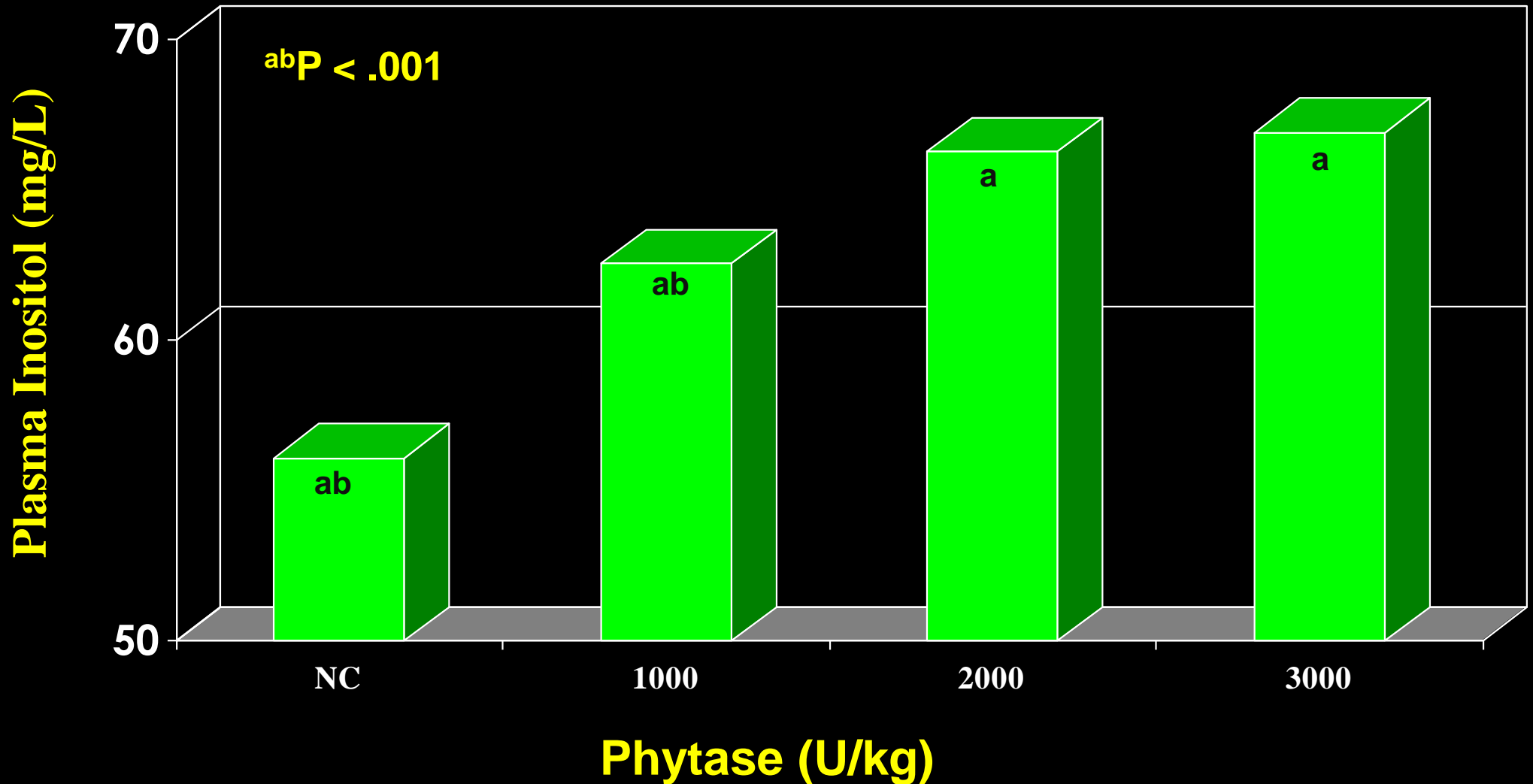
PC - 2590
NC - 2504
PC+IN - 2516
NC+IN - 2579

Treatments

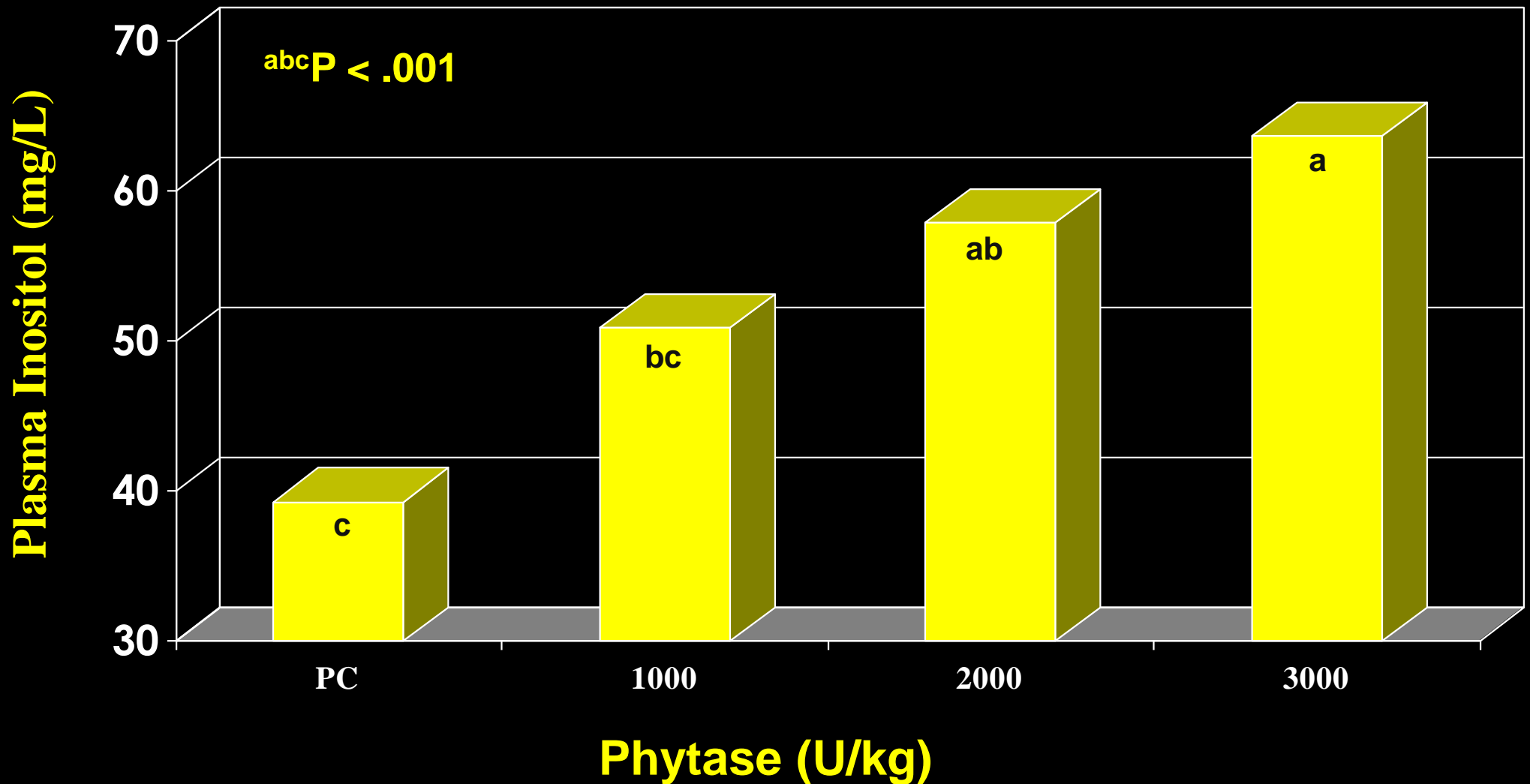
Efficacy of phytase and inositol (Bedford, 2014)



Effect of phytase on plasma inositol concentrations in broilers fed a NC diet (0.13% aP; Cowieson *et al.*, 2014)



Effect of phytase on plasma inositol concentrations in broilers fed a PC diet (0.40 % aP; Cowieson *et al.*, 2014)



Hypothesized mechanism of inositol (Cowieson *et al.*, 2014)

- Phytase at high doses increased plasma inositol
- Inositol has been found to be an insulin mimetic in several species
- This suggests that the beneficial effect of high phytase doses (increased inositol) may be due to insulin-like mechanisms
- Such as insulin-like effects on glucose transport, gluconeogenesis, and protein deposition
- Jozefiak *et al.* (2010) observed no change in insulin in birds fed phytase (500 U) or phytase plus carbohydrase enzymes but did see an increase in liver insulin receptor sensitivity by 9.3% and 12.3%, respectively

Concluding Remarks - 1

- Phytase shown to very effective in improving mineral utilization and decreasing environmental concerns
- Phytase shown to improve AA and energy utilization
- 90% market penetration in poultry diets
- Cost effective with current ingredient prices
- Phytase effective in combination with other enzymes

Concluding Remarks - 2

- Concerns include
 - Dietary Ca concentrations
 - Pelleting
 - Formaldehyde treatment of feed
 - Margins of safety (P equivalency ~ 0.10%)
- Super-dosing appears to be effective
 - Complete prevention of AN effects
 - Inositol growth promoting effects
- Will depend on economics



Thank You ??????



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