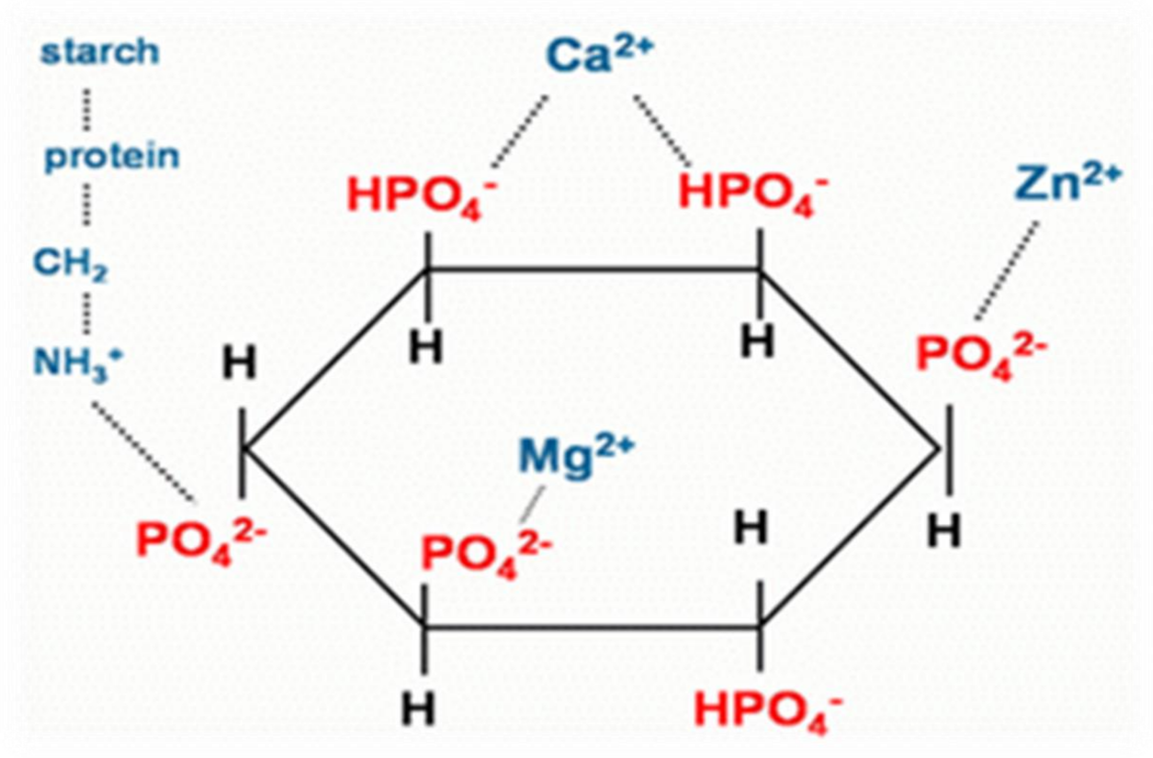
عوامل موثر بر بازدهی آنزیم فیتاز در تغذیه طیور

Speaker: mzaghari@ut.ac.ir

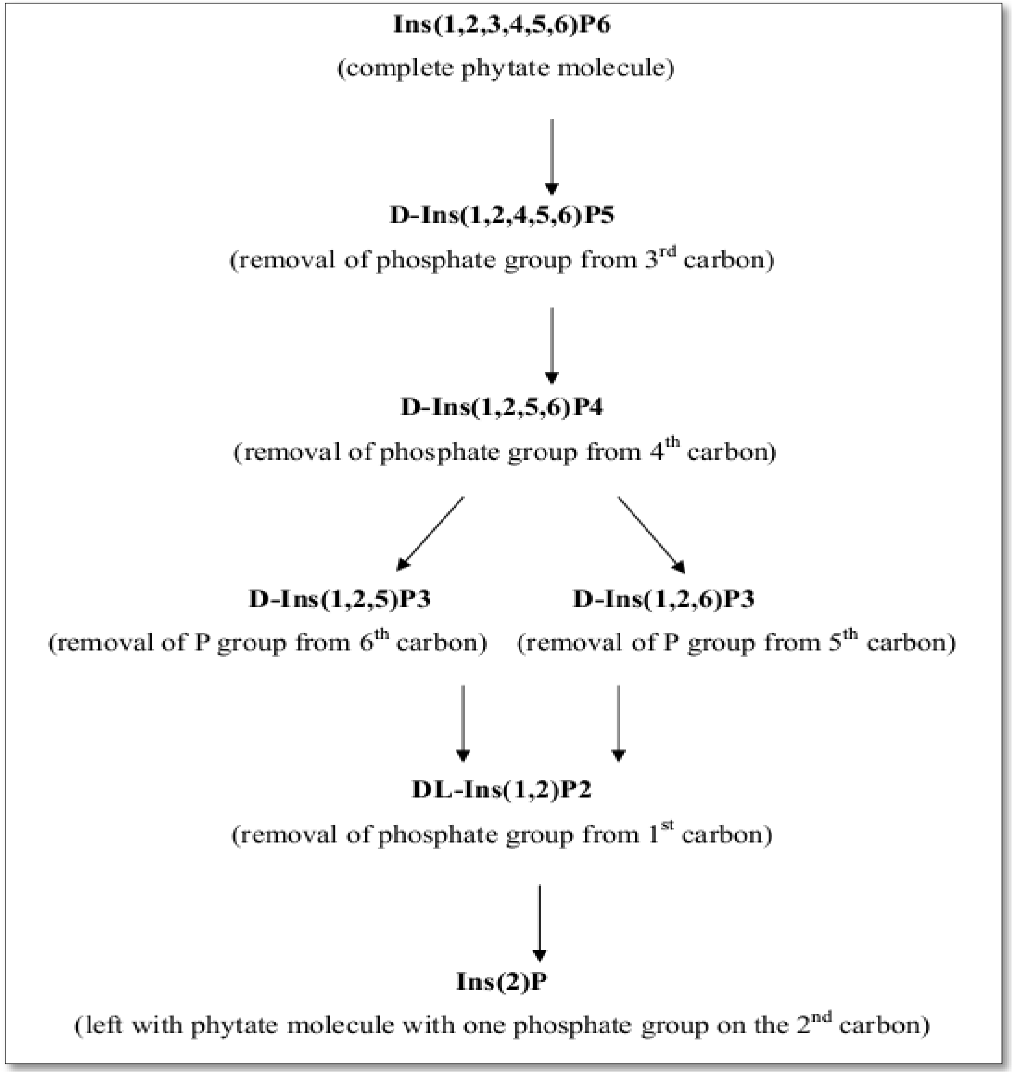
Terminology of Phytate

Phytate: Mixed salt of phytic acid (myo-inositol hexaphosphate; IP6).
Phytin: Deposited complex of IP6 with potassium, magnesium and calcium.
Phytic acid: The free form of IP6.

$Zn^{2+} > Cu^{2+} > Na^{2+} > Co^{2+} > Mn^{2+} > Ca^{2+} > Fe^{2+}$

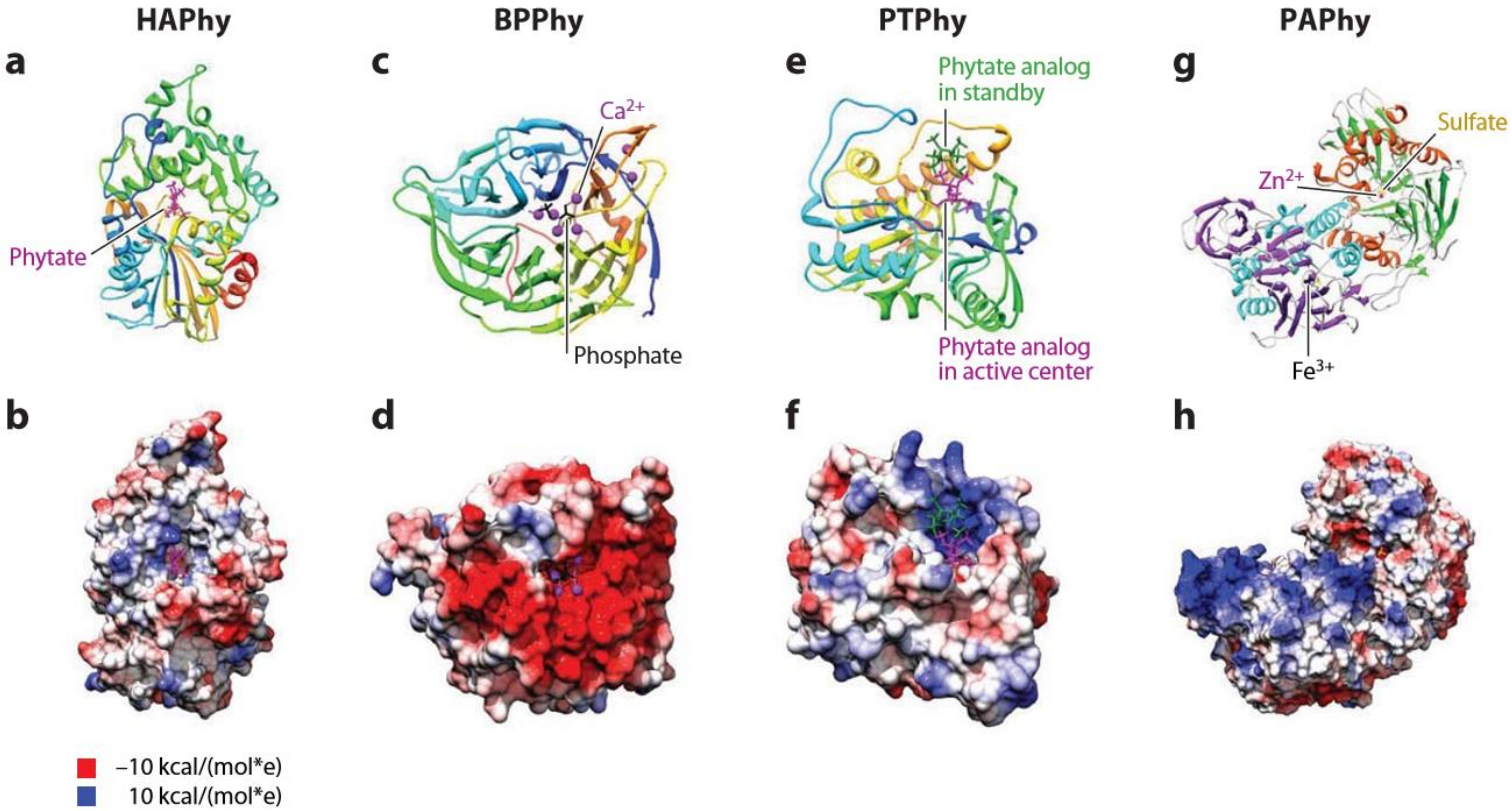


$Zn^{2+} >> Fe^{2+} > Mn^{2+} > Fe^{3+} > Ca^{2+} > Mg^{2+}$



Presently known distribution of representatives of the different catalytic classes of phytate degrading enzymes

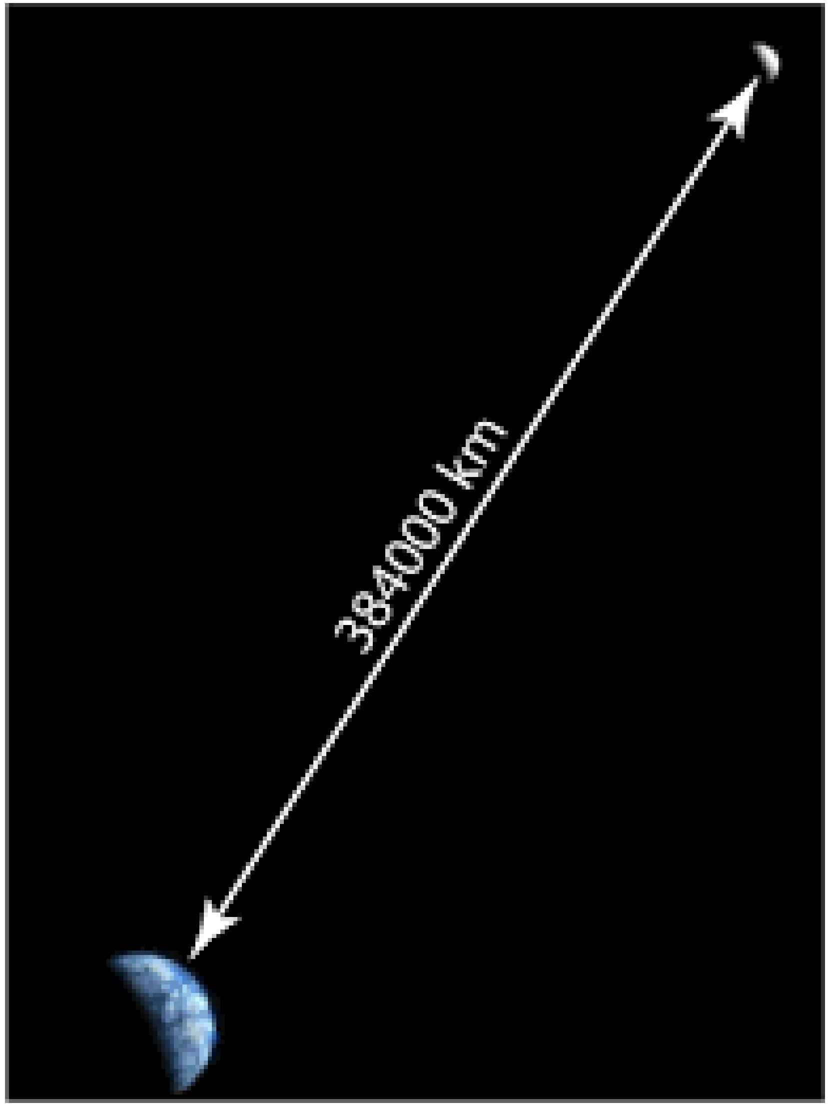
Type	Taxa			Exemplary protein	NCBI accession number	Amino acids[b]	MW kDa[b]	Isoelectric point[b,c]	pH optima	Temp. optimum (°C)	Specific activity (units/mg)	V_{max} (units/mg)	T_m (°C)	K_m (μM)	k_{cat} (s^{-1})
HAPhy	Bacteria	Gram-positive		*Selenomonas ruminantium* Agp	YP_005432715	413[d]	46	(7.9)	Predicted phytase						
		Gram-negative		*Escherichia coli* AppA	M58708	410	47	(6.1)	4.5	55	1,700	—	63.7	—	—
	Fungi	Ascomycetes	Filamentous	*Aspergillus niger* PhyA	CAA78904	448	49	4.8–5.2 (4.8)	2.0, 5–5.5	65	—	120	66.3	34	170
			Yeast	*Candida krusei* WZ-001	—	—	—	5.5	4.6	40	1,210	—	inactivated >50	30	—
		Basidiomycetes		*Peniophora lycii* PhyA (mushroom)	CAC48195	410	45	3.6 (4.4)	4–4.5	50–55	1,080	—	60	—	—
	Plants	Monocots		*Zea mays* Phy S11 (corn)	CAA11390	369[f]	80 (dimer)	(5.4)	4.8	55	2.3	—	—	117	—
		Dicots		*Arabidopsis thaliana*	AAB60740	449	51	(8.6)	Predicted phytase						
	Animals			Avian (*Gallus gallus*) MINPP (chicken)	NP_989975	430	48	(8.0)	5	—	—	0.7	—	140	—
BBPhy	Bacteria	Gram-positive		*Bacillus amyloliquefaciens* DS11	O66037	356[d]	39	(4.9)	7–8	70	—	—	inactivated >70	138	17
		Gram-negative		*Sphingomonas sp.* SKA58	EAT09404	336[d]	35	(4.7)	Predicted phytase						
		Cyanobacteria		*Nostoc sp.* PCC 7120	NP_488278	1,821	193	(4.2)	Predicted phytase						
PAPhy	Fungi	Ascomycetes	Filamentous	*Aspergillus niger* pH 6.0 optimum acid phosphatase (*APase*)	AAB31768	583	64	(5.1)	—	—	—	—	—	315	2.6
	Plants	Monocots		*Triticum aestivum* (wheat) phytase	AX298209	520[d]	58	7.4 (6.1)	6.0	45	137	—	—	—	—
		Dicots		*Glycine max* (soybean) GmPhy	AAK49438	519[d]	59	(5.1)	4.5–5	58	—	—	inactivated >60	61	—
PTPhy	Bacteria	Gram-positive		*Clostridium acetobutylicum* ATCC 824	NP_149178	319	36	(9.7)	Predicted phytase						
		Gram-negative		*Selenomonas ruminantium* PhyAsr	AAQ13669	319	37	(8.4)	4.5–5.5	50–55	—	—	inactivated >60	425	264
Unknown	Protozoa			*Paramecium tetraurelia* 51s	—	—	240 (hexamer)	—	7.0	—	10	—	—	250	—


HAPhy
BPPhy
PTPhy
PAPhy
a
Phytate
c
Ca2+
Phosphate
e
Phytate analog in standby
Phytate analog in active center
g
Sulfate
Zn2+
Fe3+
b
d
f
h
−10 kcal/(mol*e)
10 kcal/(mol*e)

Commercial Sources of Phytase

- **A. Niger:** **Initiate from 3c (3-Phytase)**
- **Peniophera lycii:** **Initiate from 6c (6-Phytase)**
- **E Coli:** **Initiate from 6c (6-Phytase)**


wiseGEEK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Summary of microbial phytase phosphorus equivalency studies in poultry

Reference	Basal diet				Inorganic P source	Response criteria	P equivalence (FTU = g P)	Phytate-P released (%)	Phytase source
	Type	Total P (g kg^{-1})	Phytate-P (g kg^{-1})	Ca:P ratio					
Broilers									
Schoner et al. (1991)	Maize–soy	4.5	2.3	1.33	MCP	P retention	700 = 1.000	43.5	*A. niger*
Schoner et al. (1993)	Maize–soy	3.5	2.3	1.71	MCP	Weight gain, P retention	850 = 1.000	43.5	*A. niger*
Denbow et al. (1995)	Soybean meal	3.8	1.8	2.00	DFP	Weight gain, toe ash	821 = 1.000	55.6	*A. niger*
Kornegay et al. (1996)	Maize–soy	4.4	2.4	2.00	DFP	Weight gain, toe ash	939 = 1.000	41.7	*A. niger*
Yi et al. (1996b), Expt. 1	Soybean meal	4.5	1.8	2.00	DFP	Weight gain, toe ash	1146 = 1.000	55.6	*A. niger*
Yi et al. (1996b), Expt. 2	Maize–soy	5.1	2.4	2.00	DFP	Weight gain, toe ash	785 = 1.000	41.7	*A. niger*
Yonemochi et al. (2000)	Maize–soy	6.0	3.0	1.50	DFP	Gain, intake, tibia ash and P, plasma P	500 = 1.172	39.1	*A. niger*
Augspurger et al. (2003)	Maize–soy	3.6	2.6	2.08	KH_2PO_4	Weight gain, tibia ash	500 = 1.250	48.1	*E. coli*
Adedokun et al. (2004)	Maize–soy	3.9	2.7	1.95	MSP	Gain, feed intake, toe and tibia ash,	1000 = 1.031	38.2	*E. coli*
Turkeys									
Ravindran et al. (1995b)	Soybean meal	4.9	2.2	2.00	DFP	Weight gain, toe ash	652 = 1.000	45.5	*A. niger*
Applegate et al. (2003a,b,c)	Maize–soy	7.2	2.5	1.85	MCP	Weight gain, toe ash	500 = 2.125	85.0	*E. coli*
Esteve-Garcia et al. (2005)	Maize–soy	6.1	3.6	1.97	DCP	Weight, toe and tibia ash	413 = 1.000	27.8	*H. polymorpha*
Ducks									
Orban et al. (1999)	Maize–soy	4.8	3.0	1.75	MSP	Weight gain, plasma P	750 = 0.600	20.0	*E. coli*

Product	Company	Protein origin	Type	Subtype[b]	Expression	NCBI accession number	Amino acids[c]	MW kDa[c]	Isoelectric point[c,d]	pH optima	Temp. optimum (°C)	Specific activity (units/mg)	V_{max} (units/mg)	T_m (°C)	K_m (μM)	k_{cat} (s^{-1})
Allzyme® SSF	Alltech	*Aspergillus niger*	HAPhy	3	*Aspergillus niger*, nonrecombinant[e]	*A. niger* naturally secretes PhyA, PhyB, and pH 6.0–optimum acid phosphatase.										
Finase® EC	AB Vista	*Escherichia coli* AppA	HAPhy	6	*Trichoderma reesei*	M58708	410	47	(6.1)	4.5	55	1,700	—	63.7	—	—
Finase® P/L	AB Vista	*Aspergillus niger* PhyB	HAPhy	3	*Trichoderma reesei*	L20567	460[f]	51	(4.6)	2.5	—	—	—	> 80	103	628
Natuphos®	BASF	*Aspergillus niger* PhyA	HAPhy	3	*Aspergillus niger*	CAA78904	448	49	4.8–5.2 (4.8)	2.0, 5–5.5	65	—	120	66.3	34	170
OptiPhos®	Enzyvia (JBS United)	*Escherichia coli* AppA2	HAPhy	6	*Pichia pastoris*	AAR87658	410[g]	45	(5.8)	3.4, 5.0	58	—	1,070	62.1	74	840
Phyzyme® XP	Dupont Industrial Biosciences	*Escherichia coli* AppA	HAPhy	6	*Schizosaccharomyces pombe* (ATCC 5233)	M58708	410	47	(6.1)	4.5	55	1,700	—	63.7	—	—
Quantum™	AB Vista	*Escherichia coli* Phy9X[h]	HAPhy	6	*Pichia pastoris* DSM 15927	DD141515[i]	410[g]	45	(5.5)	4.5		1,700	—	75.7	—	—
Ronozyme® P (Bio-Feed® phytase, ZY® Phytase)	Novozyme and DSM	*Peniophora lycii* PhyA	HAPhy	6	*Aspergillus oryzae* DSM 14223	CAC48195	410	45	3.6 (4.4)	4–4.5	50–55	1,080	—	60	—	—

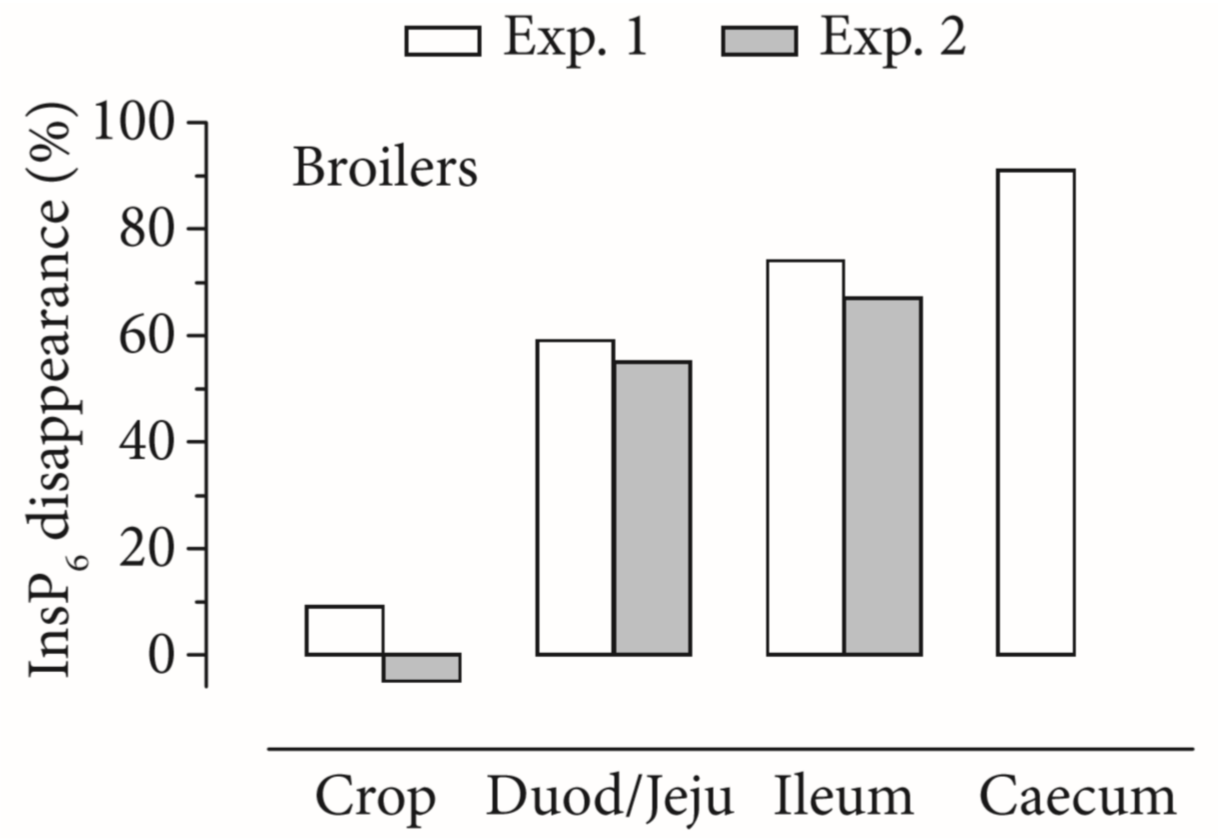
Commercial product	Type	Protein source organism	Producing organism	Matrix value/ 500 FTU/kg diet	Producer
Natuphos®	3 / fungal	A. niger	A. niger	%avP: 0.10 %Ca: 0.10	BASF
Allzyme® SSF	3 / fungal	A. niger	A. niger	%avP: 0.10 %Ca: 0.10	AllTech
Finase®	3 / fungl	A. niger	Trichoderma reesei	%avP: 0.10 %Ca: 0.11	AB Vista
Ronozyme®	6 / fungal	Peniphora lycii	Asperigillus oryzae	%avP: 0.125 %Ca: 0.14	DSM
Finase® EC	6 / bacterial	E. coli	Trichoderma reesei	%avP: 0.12 %Ca: 0.132	AB Vista
Quantum®	6 / bacterial	E. coli	Pichia pastoris	%avP: 0.13 %Ca: 0.143	AB Vista
Hostazyme® P	6 / bacterial	E. coli	Pichia pastoris	%avP: 0.125 %Ca: 0.125	Huvepharma
Phyzyme® XP	6 / bacterial	E. coli	Schizosacch-aromyces pombe	%avP: 0.12 %Ca: 0.11	Dupont
Quantum Blue®	6 / bacterial	E. coli	Trichoderma reesei	%avP: 0.15 %Ca: 0.165	AB Vista
Ronozyme hiphos®	6 / bacterial	Citrobacter braakii	Asperigillus oryzae	%avP: 0.15 %Ca: 0.18	DSM
Axtra® PHY	6 / bacterial	Buttiauxella spp.	Trichoderma reesei	%avP: 0.15 %Ca: 0.134	Dupont

Phytase activity (μmol phytic acid h^{-1}) in the digestive tract of laying hens fed wheat-corn-soybean meal-based diet without microbial phytase supplementation (Marounek et al., *2010).*[1]

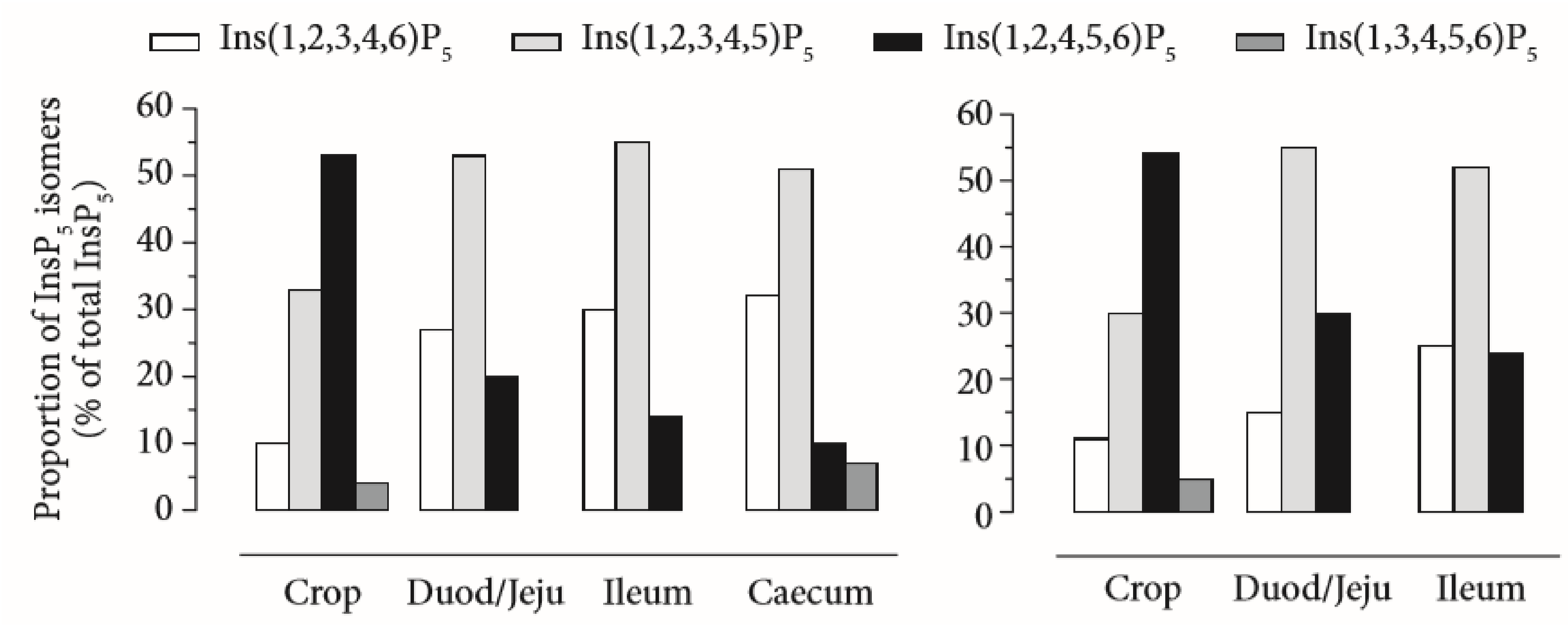
Segment	Specific (per g digesta)	Total (per segment)
Crop	10.2[a]	98[a]
Stomach	9.2[a]	97[a]
Small intestine	14.6[a]	359[b]
Small intestinal mucosa	11.5[a]	227[ab]
Sum pre-caecal		781
Caeca	135.4[b]	663[c]
Total		1,444

[1] Means within a column not sharing a common letter differ significantly ($P<0.05$).

Poultry GIT microbiota can utilize 10-25% of dietary phytate



InsP6 disappearance measured in sections of the digestive tract of broiler chickens fed maize-soybean meal-based diets without a phytase supplement; data from Rutherfurd et al. (2014) and Zeller et al. (2015, 2016).

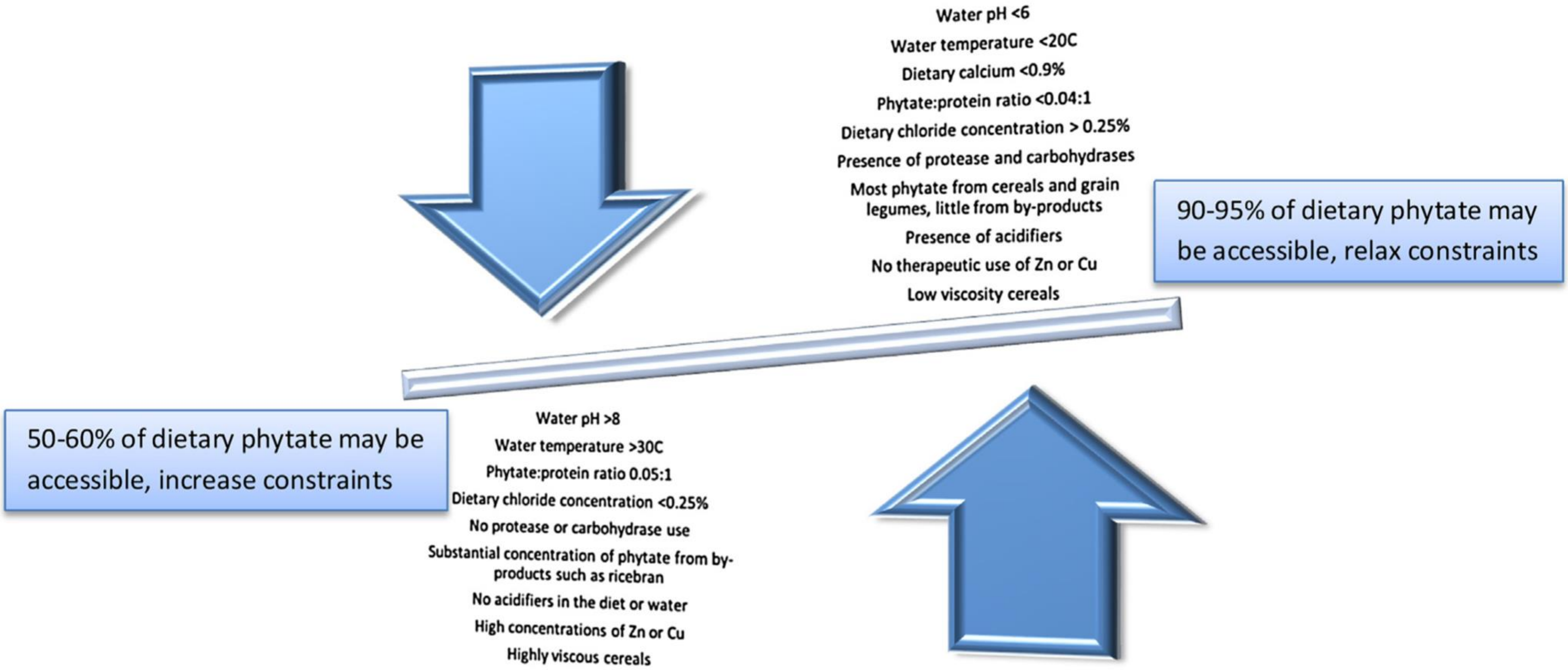


Pattern of InsP5 isomers detected in different sections of the gastrointestinal tract after feeding low-P maize-soybean meal diets without added phytase in two experiments with broiler chickens (Zeller et al., 2015, 2016).

Phytase activity in diet and digesta of broiler chickens fed diets with or without added microbial phytase from 8 to 22 days of age; activity measured at day 22 (Onyango et al.*, 2005).*[1]

	NC: low-P diet	NC +1000 FTU *Escherichia coli* phytase/kg	NC +1000 FTU *Peniophora lycii* phytase/kg
Feed (FTU/kg)	14	825	1,152
Digesta (FTU/kg DM intake)			
Crop	67[c]	649[a]	404[b]
Proventriculus and gizzard	28[b]	406[a]	63[b]
Jejunum	29[b]	554[a]	25[b]
Ileum	16[b]	91[a]	6[b]

[1] Means within a row not sharing a common letter differ significantly ($P<0.05$).


Water pH <6
Water temperature <20C
Dietary calcium <0.9%
Phytate:protein ratio <0.04:1
Dietary chloride concentration > 0.25%
Presence of protease and carbohydrases
Most phytate from cereals and grain legumes, little from by-products
Presence of acidifiers
No therapeutic use of Zn or Cu
Low viscosity cereals
90-95% of dietary phytate may be accessible, relax constraints
50-60% of dietary phytate may be accessible, increase constraints
Water pH >8
Water temperature >30C
Phytate:protein ratio 0.05:1
Dietary chloride concentration <0.25%
No protease or carbohydrase use
Substantial concentration of phytate from by-products such as ricebran
No acidifiers in the diet or water
High concentrations of Zn or Cu
Highly viscous cereals

Factors that Affect Phytase Functionality

1. Amount of dietary phytate
2. Source of phytase / phytase catalytic properties
3. Digesta solution pH (Optimum at pH 2.0-4.5)
4. Bio-catalytic reaction (Km, Vmax)
5. Pepsin (Protease) Resistance
6. Heat and moisture stability during feed processing
7. Dietary trace mineral concentration
8. Synergistic effects of other Feed Additives (acidifier)
9. Dietary factors (minerals, vitamin D_3 content)
10. Combination of enzymes
11. Phytase dose
12. Particle size and mixability of commercial phytase
13. Water pH and temperature
14. Functionality of GIT
15. Stability of commercial product during storage

1. Amount of dietary phytate

Weighted mean (and range) of total P and phytate-P concentrations, and proportion of phytate-P of total P, in key poultry feed ingredients

Feed ingredient	Number of data-sets/samples	Total P ($g\,kg^{-1}$)	Phytate-P ($g\,kg^{-1}$)	Proportion (%)
Cereals				
Barley	4/41	3.21 (2.73–3.70)[a]	1.96 (1.86–2.20)[a]	61.0 (59–68)[a]
Maize	7/45	2.62 (2.30–2.90)	1.88 (1.70–2.20)	71.6 (66–85)
Sorghum	5/41	3.01 (2.60–3.09)	2.18 (1.70–2.46)	72.6 (65–83)
Wheat	6/97	3.07 (2.90–4.09)	2.19 (1.80–2.89)	71.6 (55–79)
Oilseed meals				
Canola meal	4/28	9.72 (8.79–11.50)	6.45 (4.00–7.78)	66.4 (36–76)
Cottonseed meal	3/21	10.02 (6.40–11.36)	7.72(4.9–9.11)	77.1 (70–80)
Soyabean meal	6/89	6.49 (5.70–6.94)	3.88 (3.54–4.53)	59.9 (53–68)
By-products				
Rice bran	6/37	17.82 (13.40–27.19)	14.17 (7.90–24.20)	79.5 (42–90)
Wheat bran	6/25	10.96 (8.02–13.71)	8.36 (7.00–9.60)	76.3 (50–87)

Derived from studies by Nelson et al. (1968a), Kirby and Nelson (1988), Eeckhout and de Paepe (1994), Ravindran et al. (1994), Viveros et al. (2000), Selle et al. (2003d) and Godoy et al. (2005).

[a] Range of values.

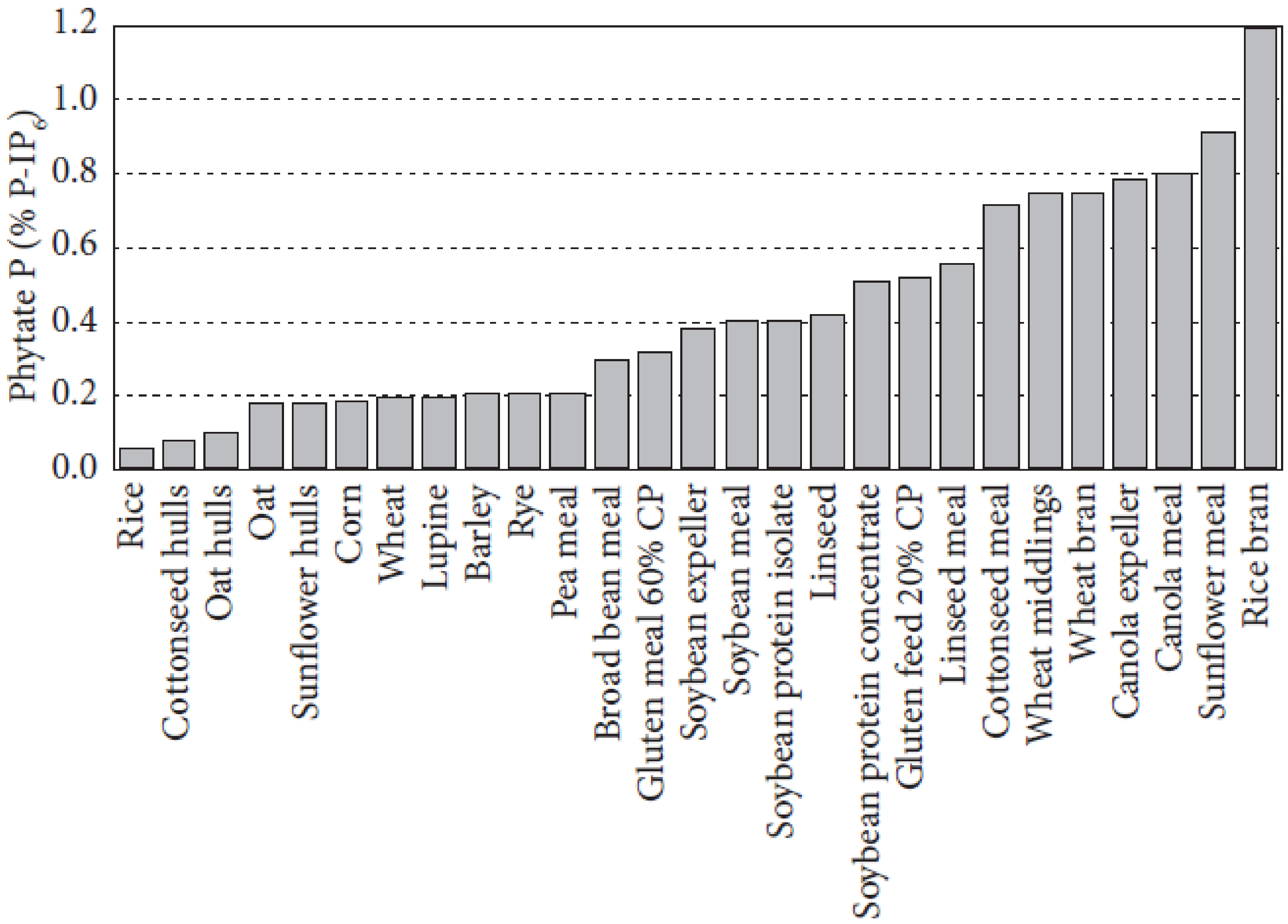
1. Amount of dietary phytate

Phytate Phosphorus Content of Common Feedstuffs

Feedstuff	Total phosphorus (%)	Phytate (% of total phosphorus)
Corn	.26	66
Wheat	.30	67
Grain sorghum	.31	68
Barley	.34	56
Oats	.34	56
Wheat middlings	.47	74
Soybean meal	.61	61
Cottonseed meal	1.07	70
Sesame meal	1.27	81
Wheat bran	1.37	70
Alfalfa meal	1.40	0

[a] Adapted from Nelson et al. (1968).

1. Amount of dietary phytate



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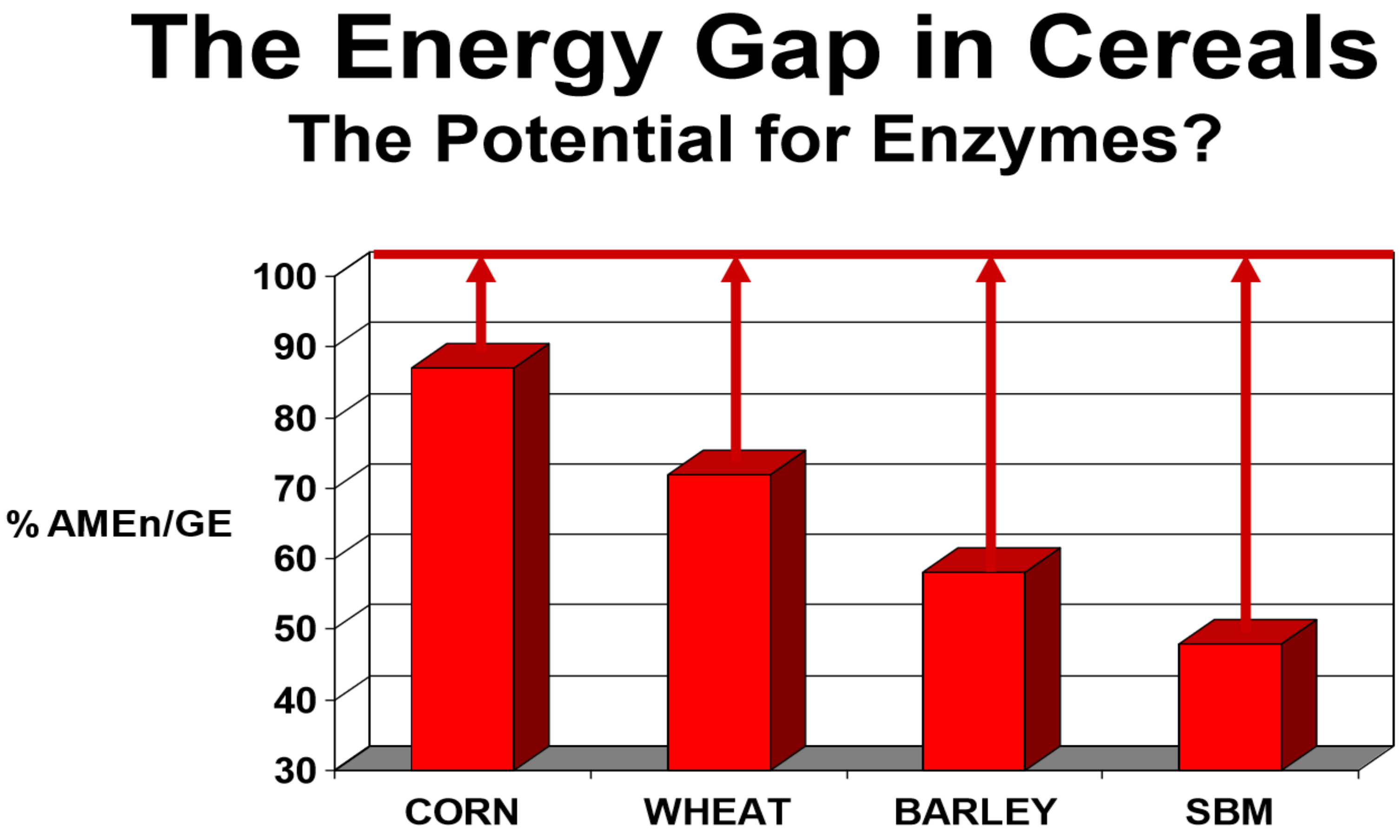
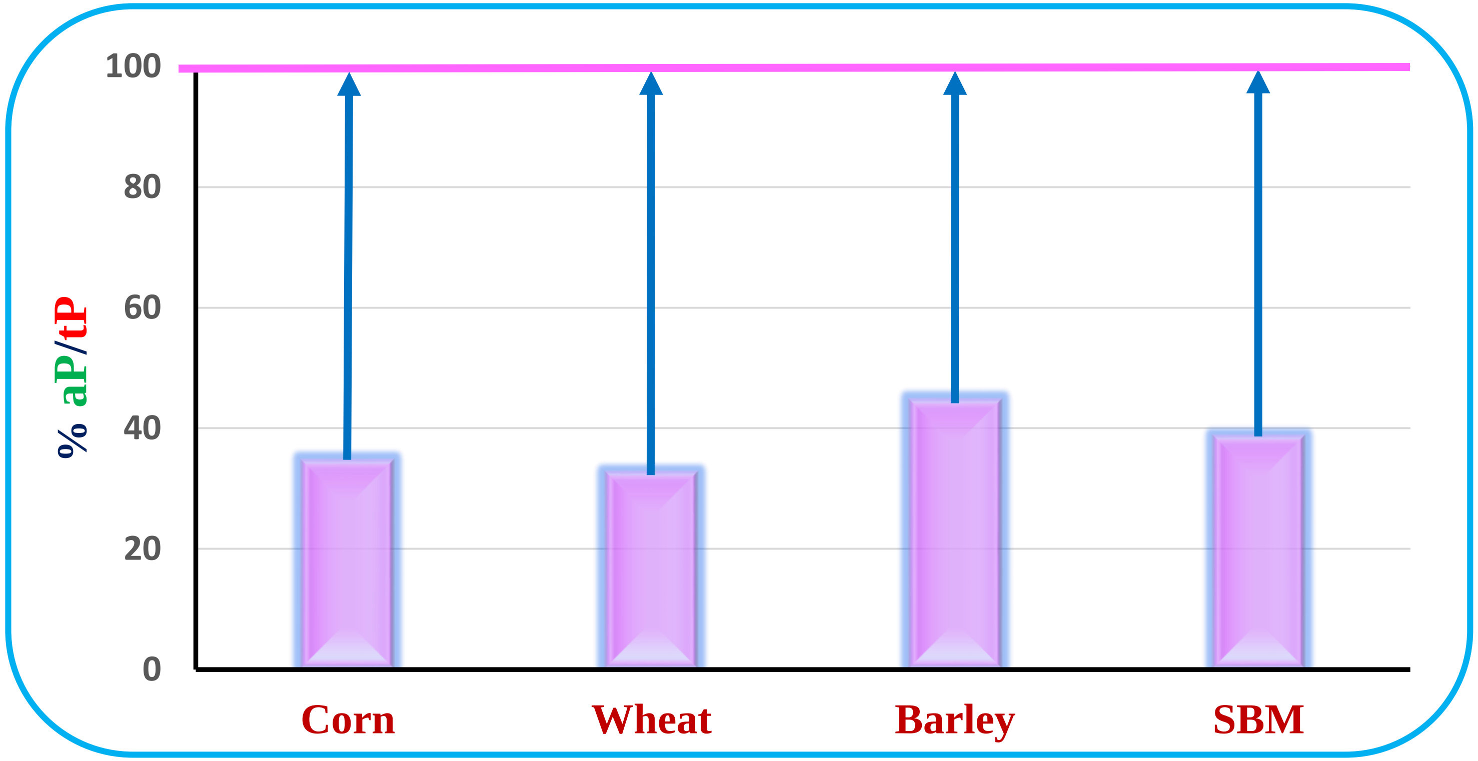
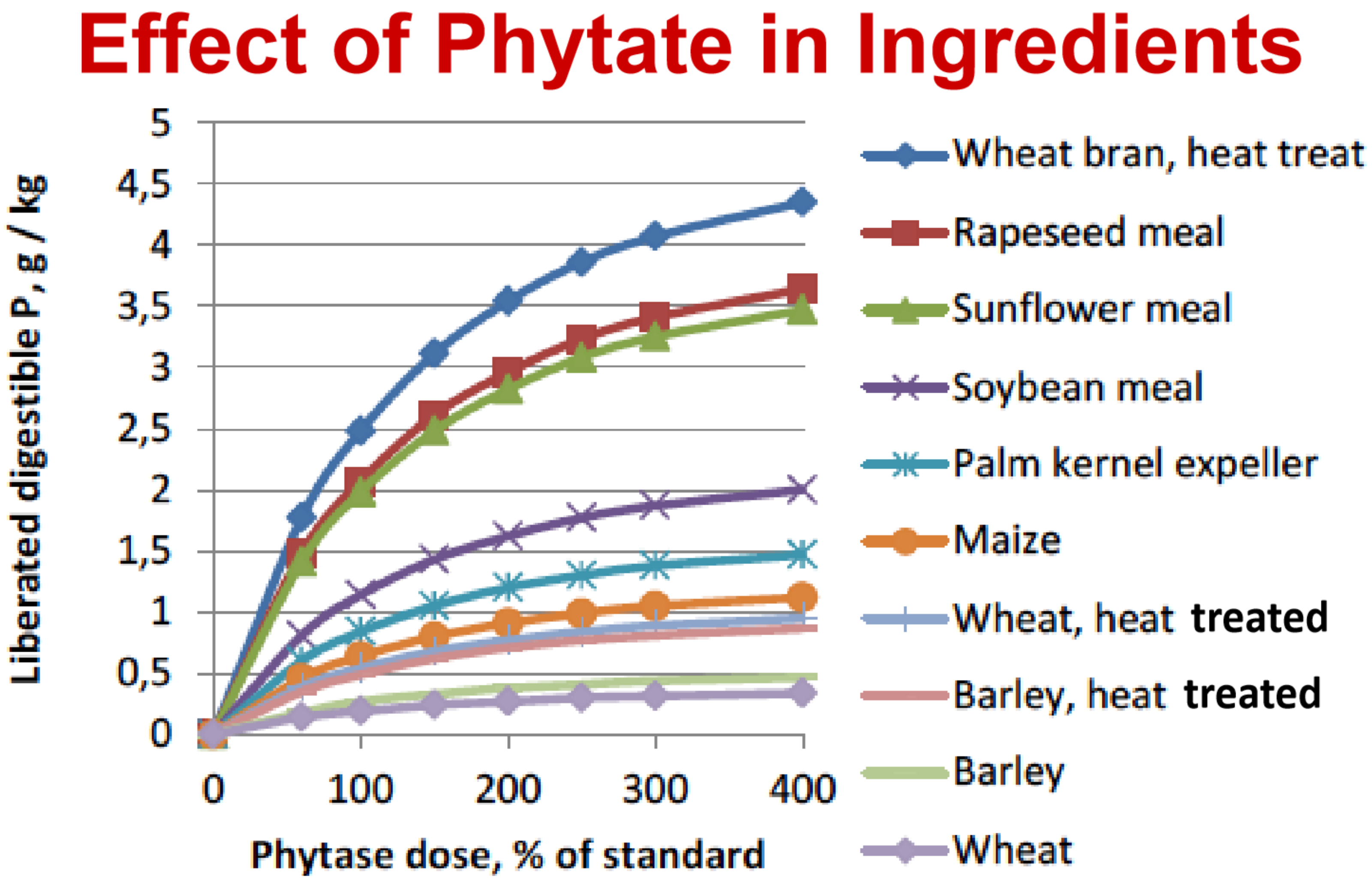


1. Amount of dietary phytate

The available phosphorus gap in cereals
The potential for enzymes?



1. Amount of dietary phytate

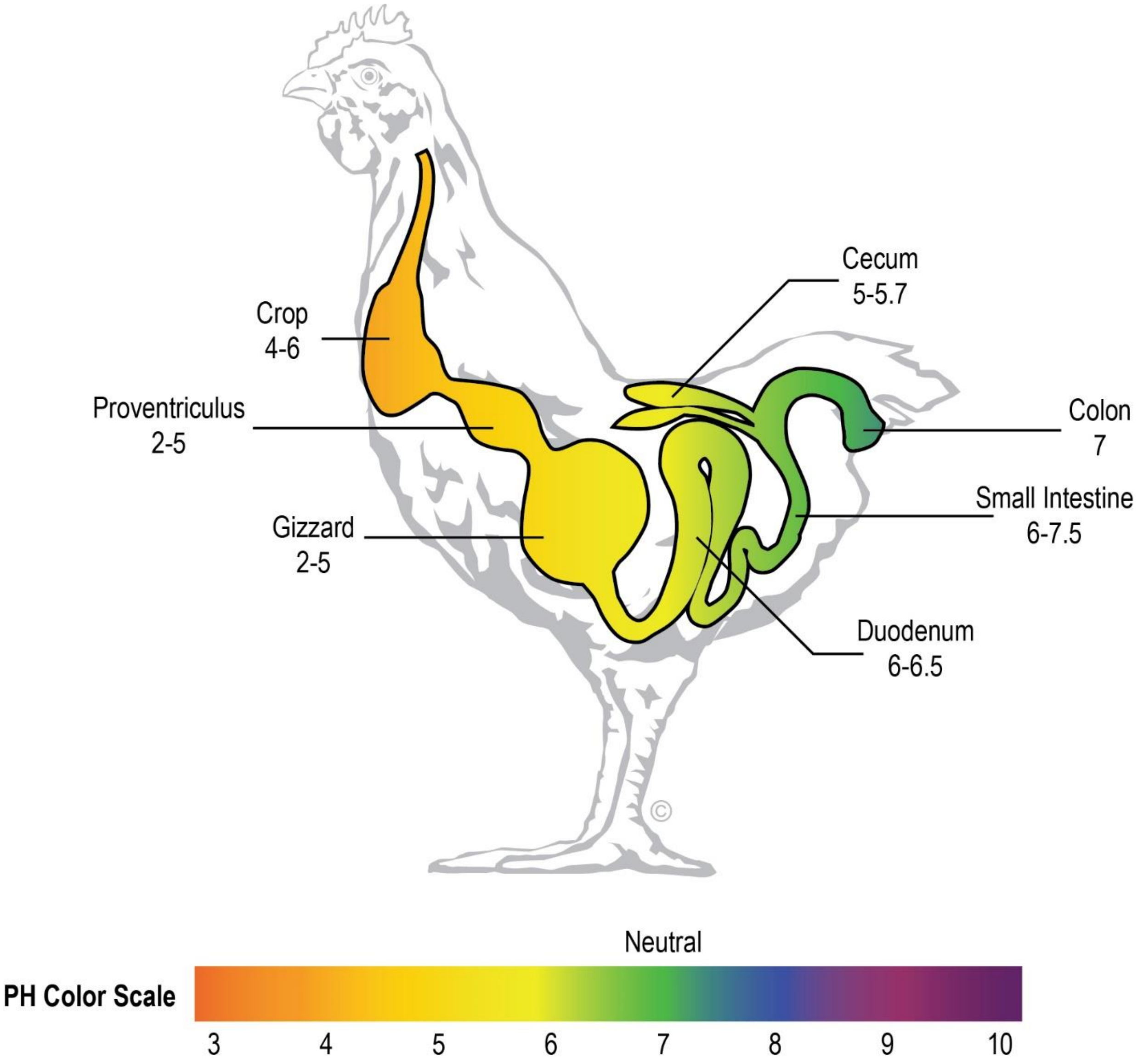


IP6 —— Phytase ——→ IP1

IP6 or IP5 have a much greater chelation capacity for **Ca** than IP4 or IP3.

Indeed, IP3 has only **10%** of the chelation capacity of IP6.

3. Digesta solution pH (Optimum at pH 2.0-4.5)



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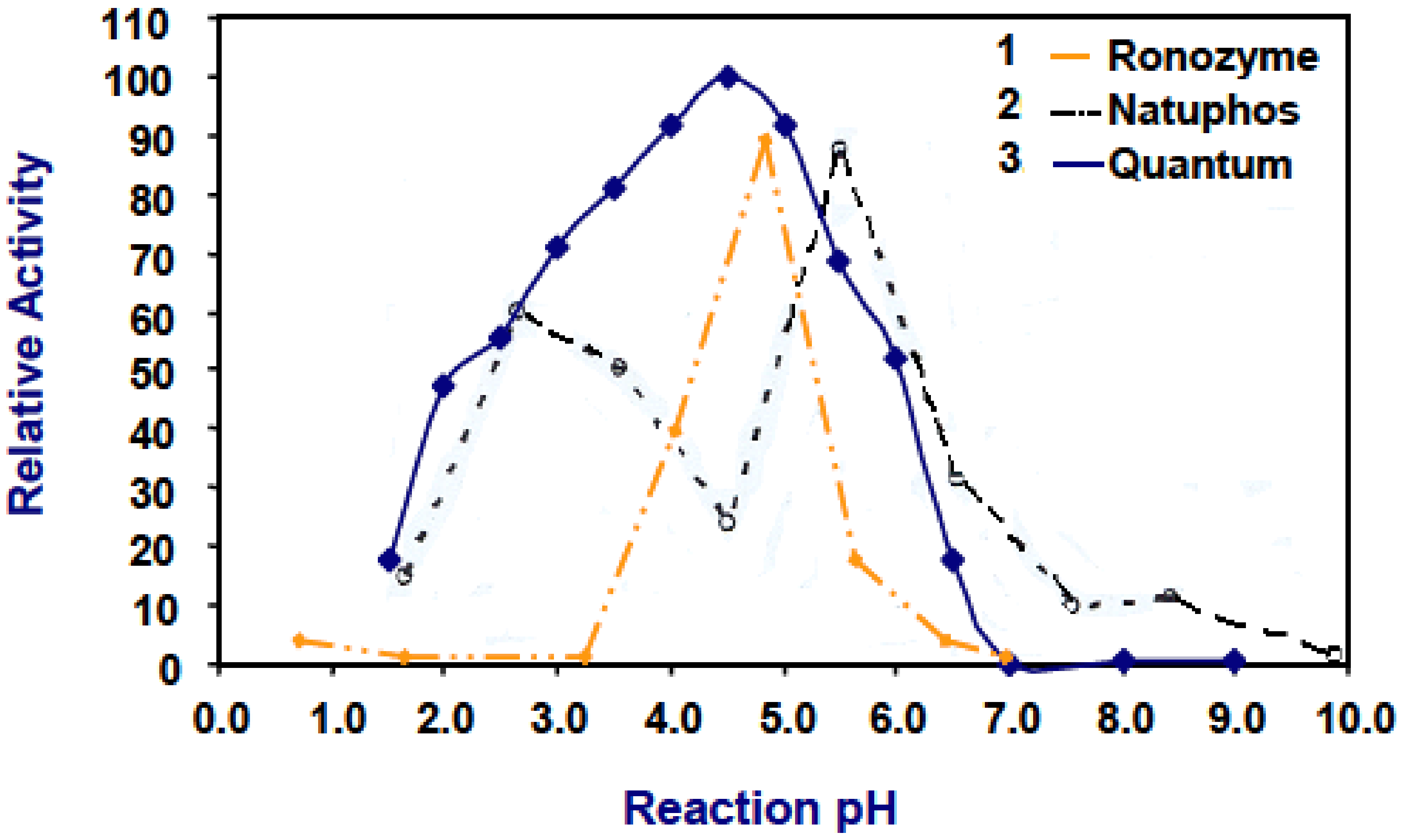

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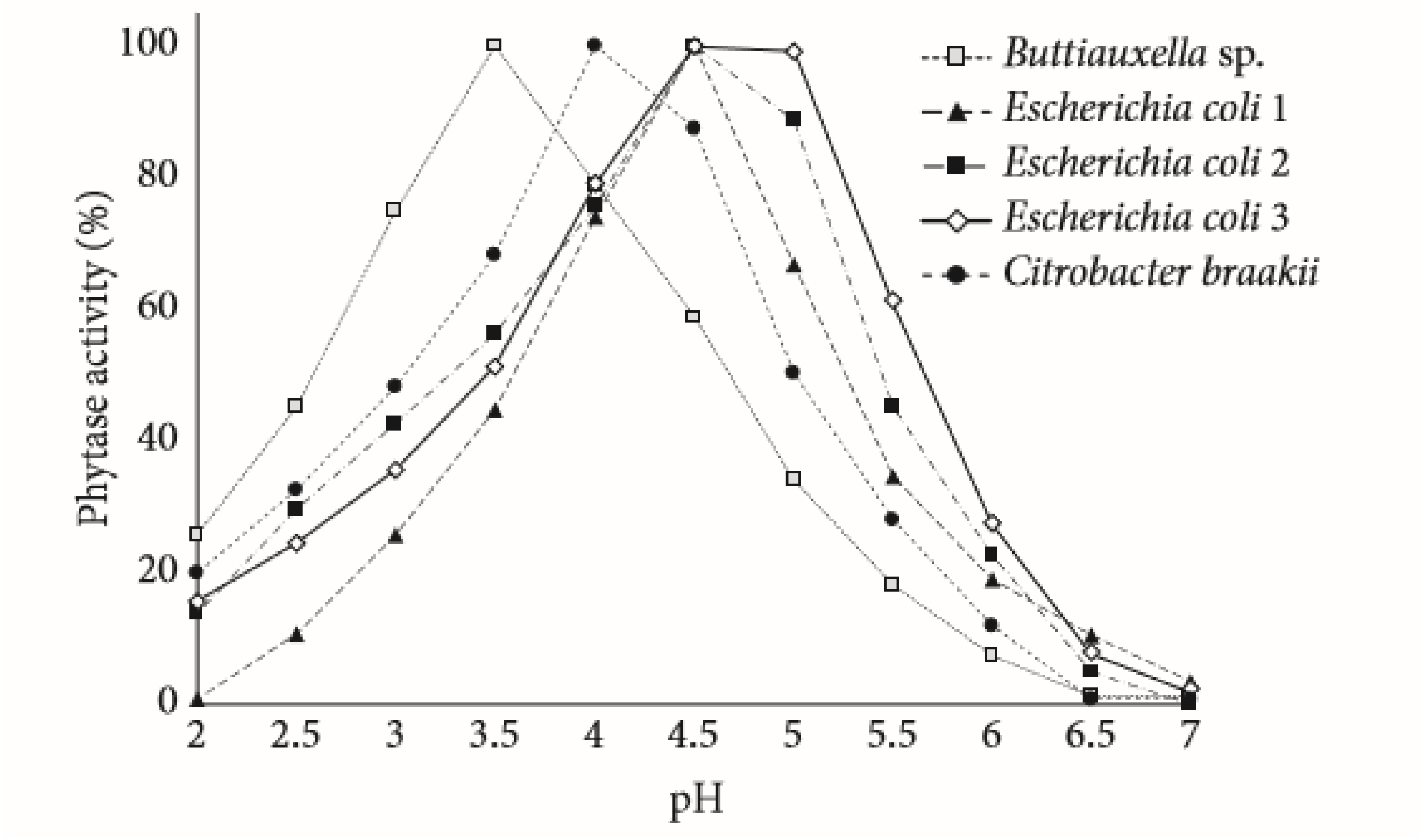

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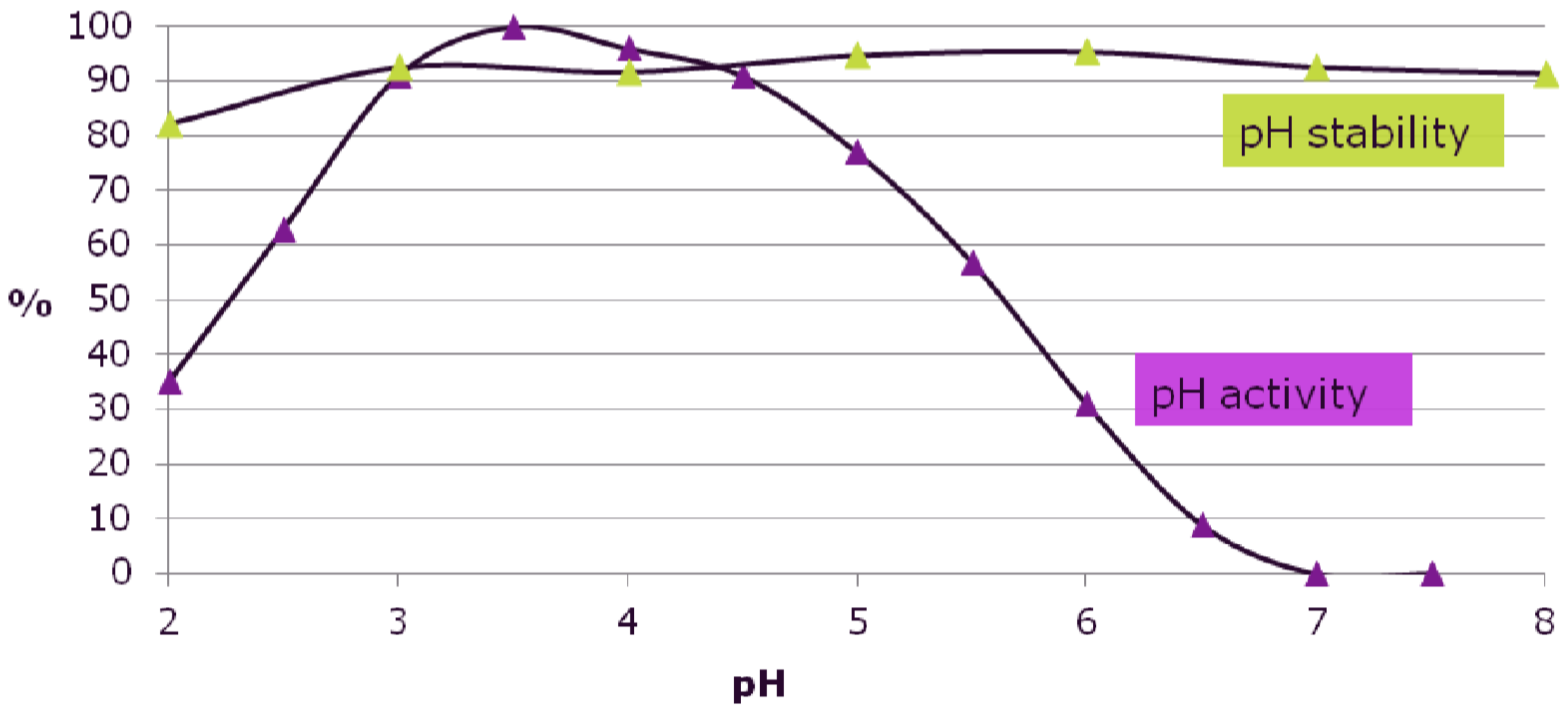
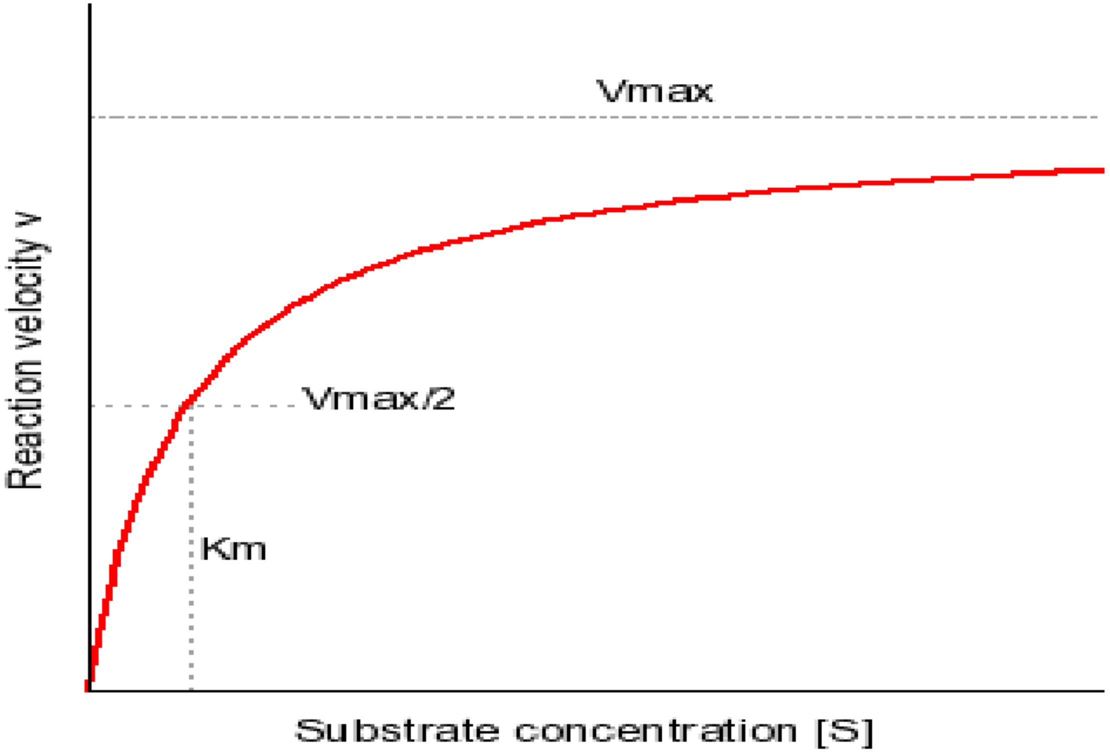


Leonor Michaelis

Maud Menten

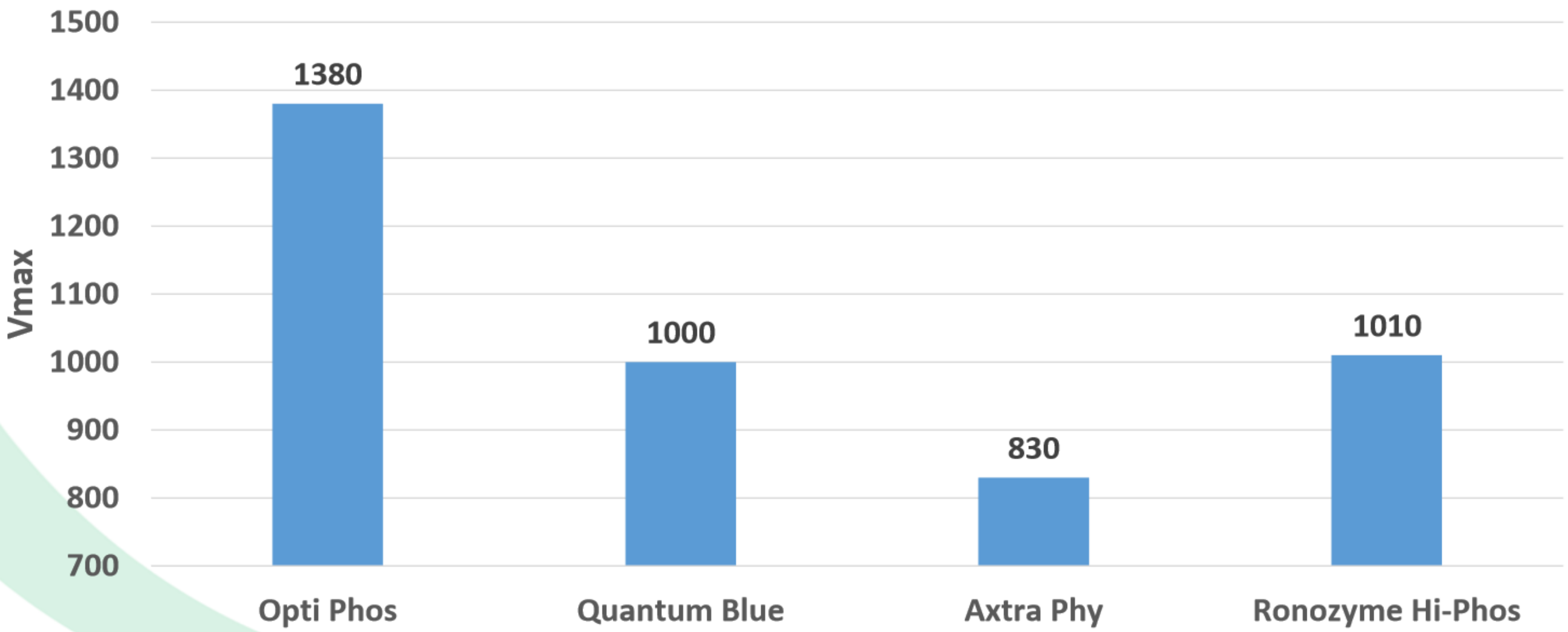
Michaelis Menten kinetics

– Vmax represents the maximum speed rate achieved by the reaction, at maximum (saturating) substrate concentrations.



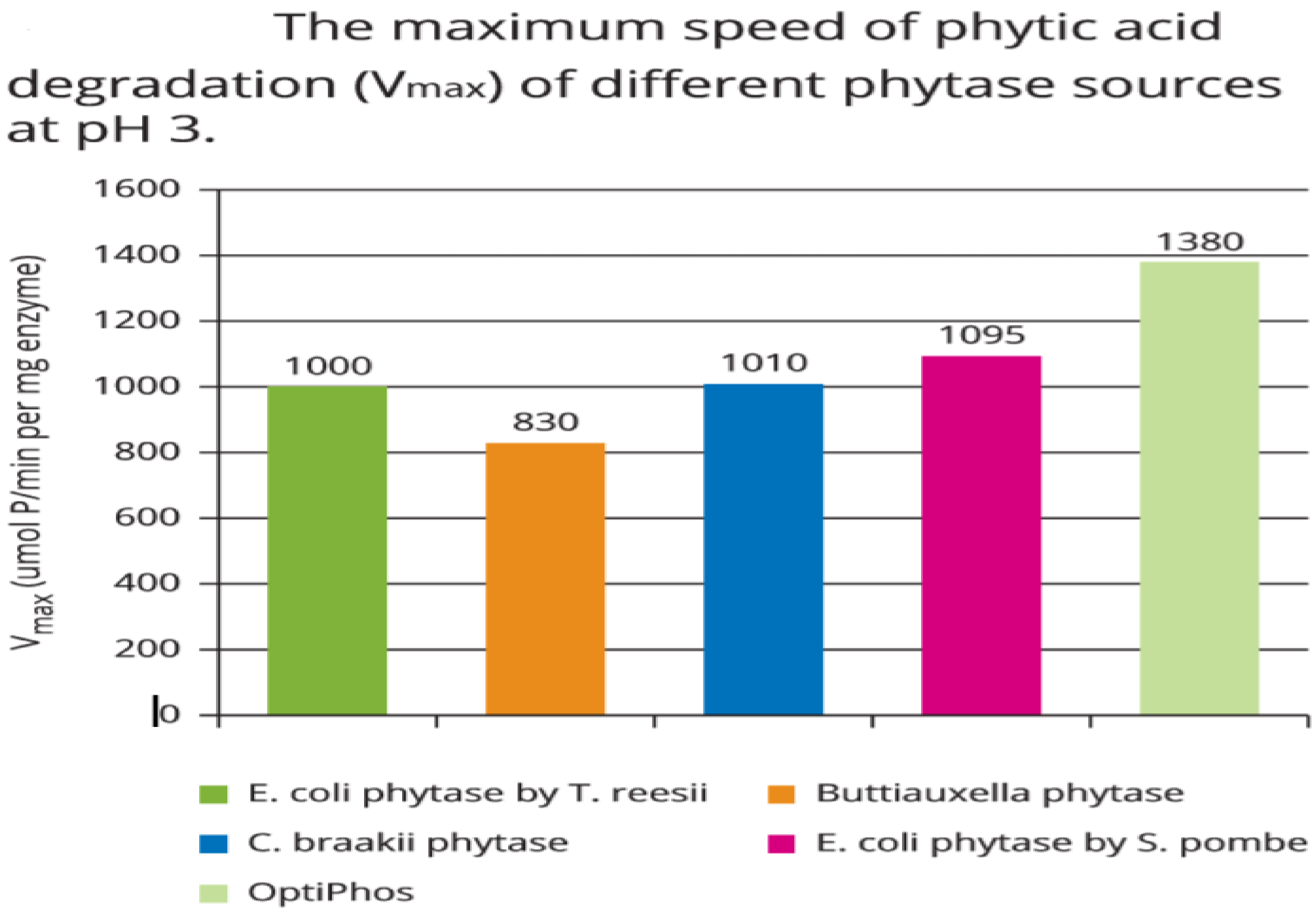
Phytate

Speed of reaction at pH 3



Vmax (velocity maximum) = amount of P (µmol) released in 1 minute by 1 mg pure enzyme and at an overconcentration of phytate.

4. Bio-catalytic reaction (Km, Vmax)



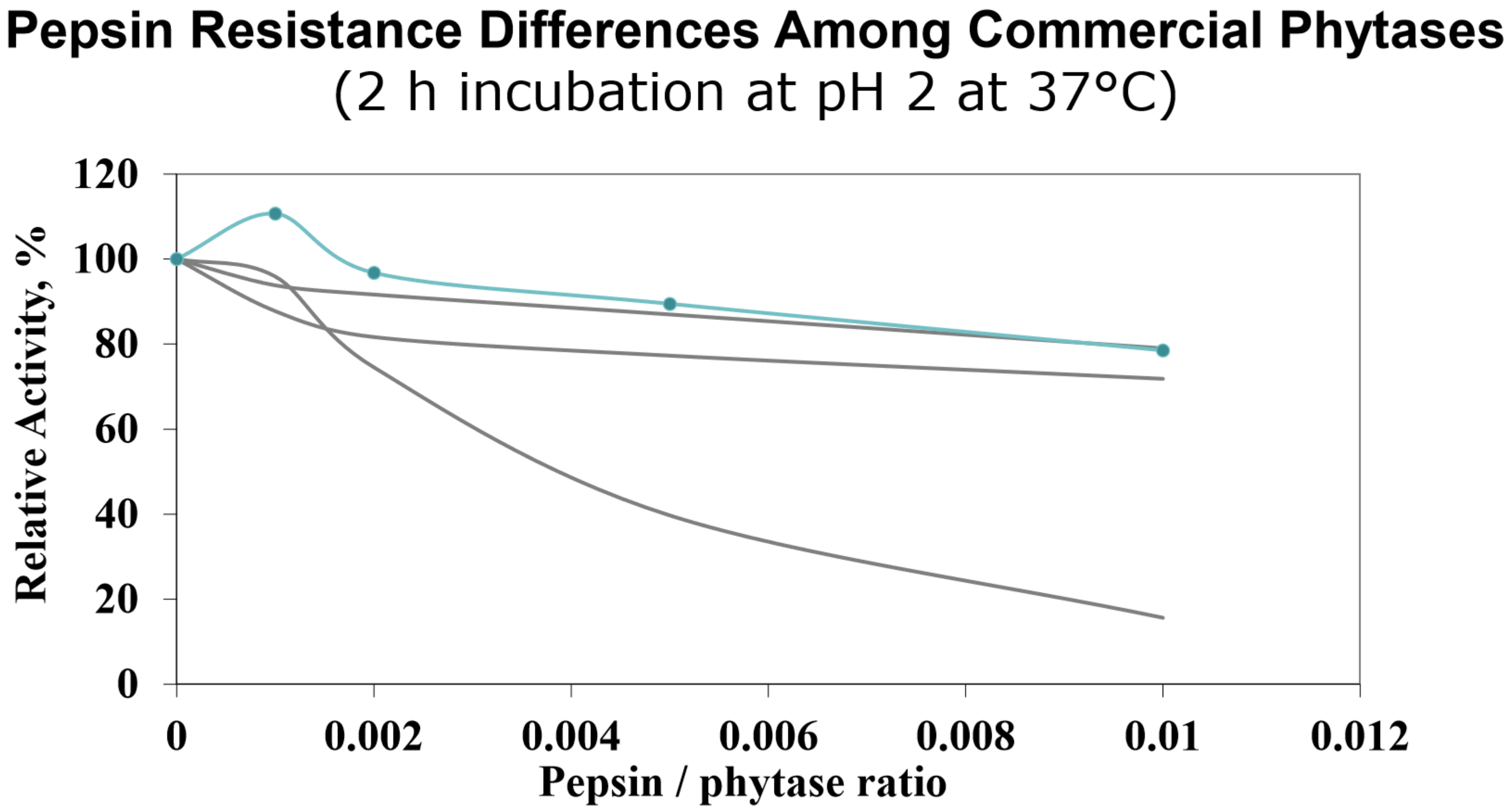
5. Pepsin (Protease) Resistance

Optimal pH range, residual activity to gastric pepsin exposition of several commercial phytases used in animal nutrition.

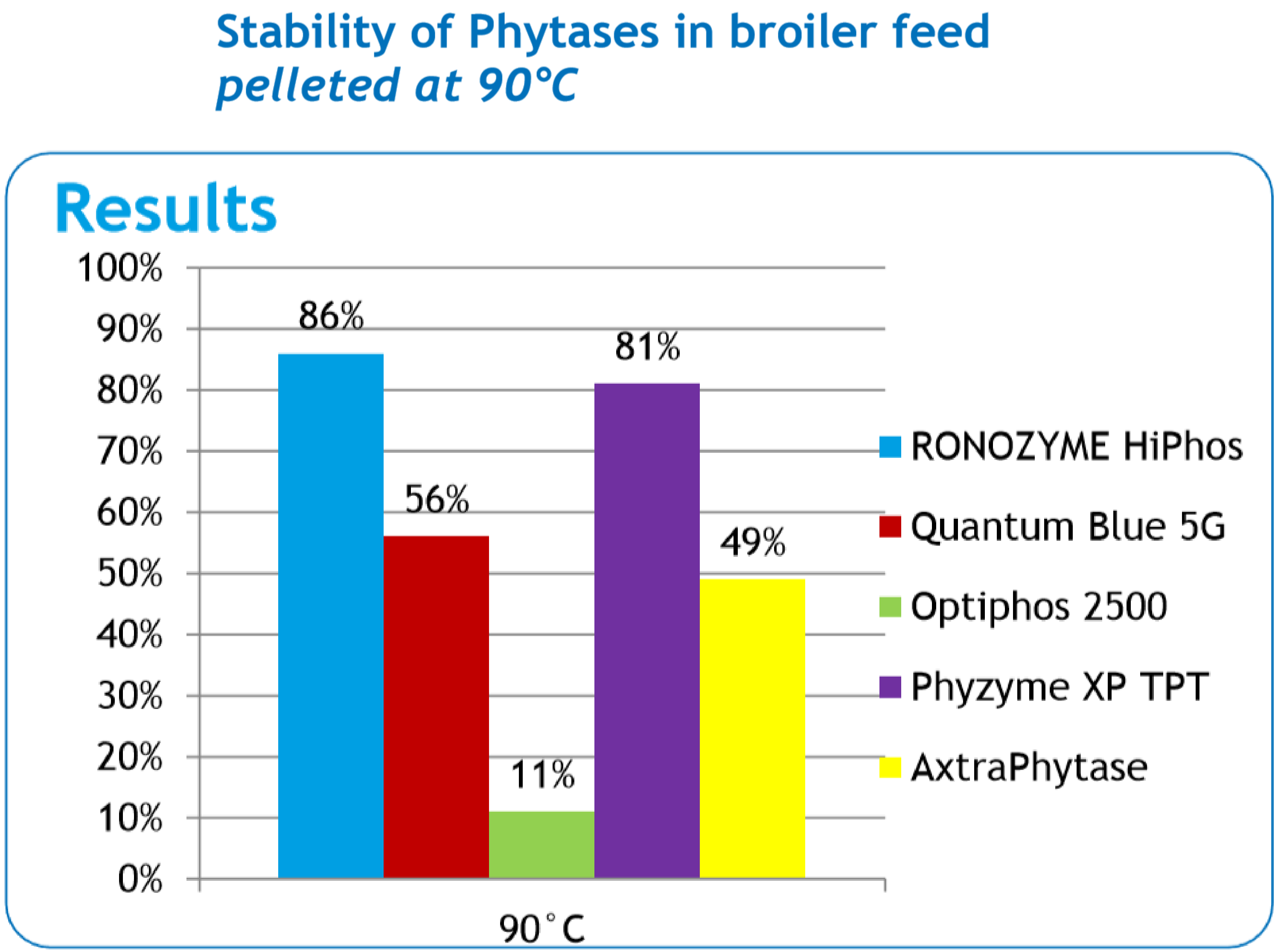
Donor organism	Expression organism	Type (initial cleavage)	Optimal pH range	Residual activity to pepsin (%)	Study[1]
Peniophora lycii	*Aspergillus oryzae*	6-phytase	4.5-5.5	6; 34	1,2
Aspergillus niger	*Aspergillus niger*	3-phytase	4.5-5.5	47	2
Escherichia coli	*Pichia pastoris*	6-phytase	4.0-5.0	90; 93	1,2
Escherichia coli	*Pichia pastoris*	6-phytase	4.0-5.0	95	3
Escherichia coli	*Pichia pastoris*	6-phytase	4.0-5.0	97	3
Escherichia coli	*Trichoderma reesei*	6-phytase	3.5-5.0	98; 91	2
Escherichia coli	*Schizosacch. pombe*	6-phytase	3.0-5.0	92	2
Buttiauxella sp.	*Trichoderma reesei*	6-phytase	3.0-3.5	85; 81	2,3
Citrobacter braakii	*Aspergillus oryzae*	6-phytase	3.0-4.5	92; 64	2,3

1 1 = Morales et al. (2011): pH 2.0, 16 °C, 180 min, trout pepsin:phytase ratio 5,000 PU:FTU. 2 = MenezesBlackburn et al. (2015): pH 3.0, 37 °C, 45 min, porcine pepsin incubating 20 mFTU and 3,000 U of pepsin. 3 = Unpublished data (own elaboration): pH 2.0, 39 °C, 180 min, porcine pepsin:phytase ratio 9,000 PU:FTU.

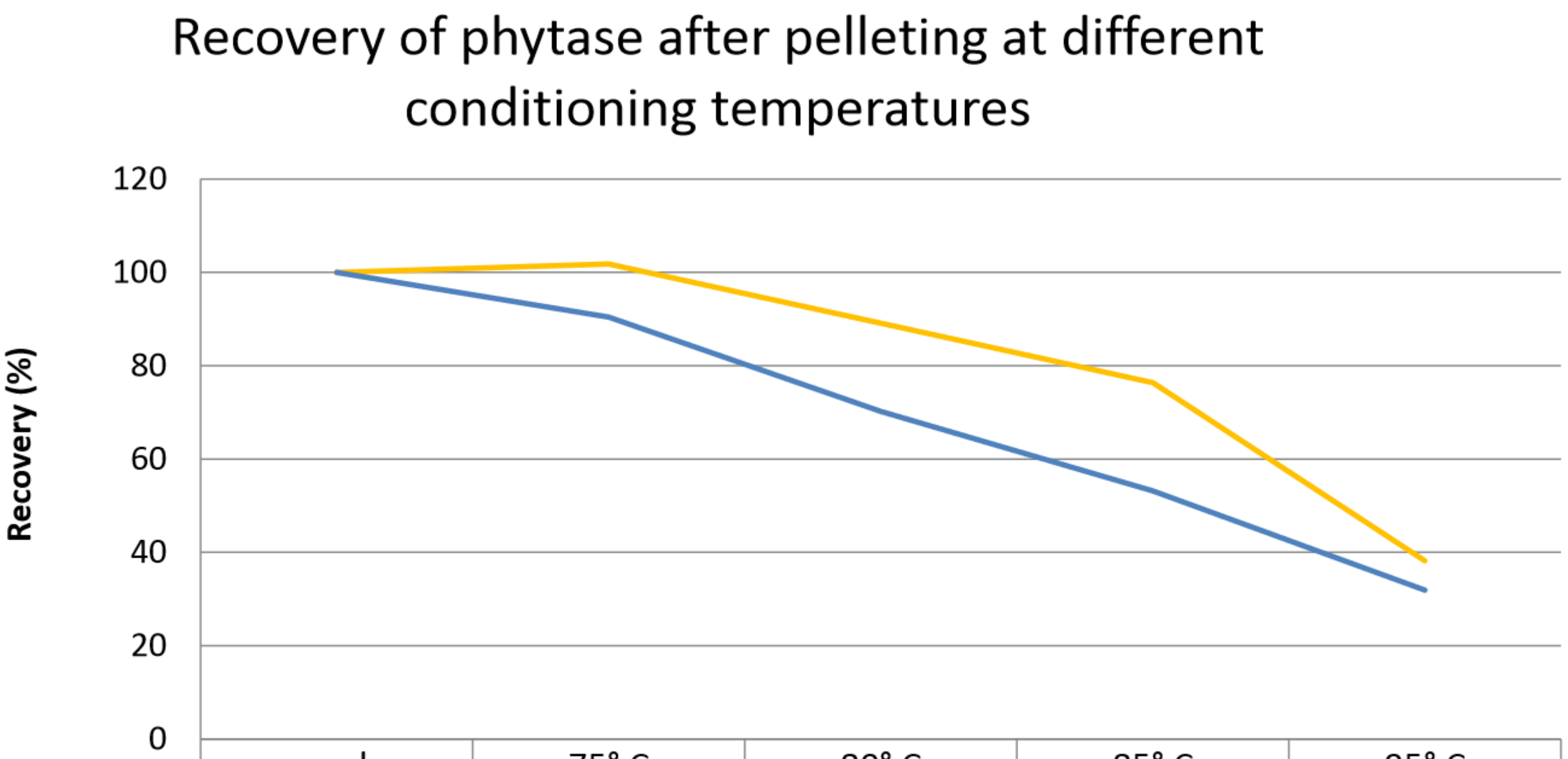
5. Pepsin (Protease) Resistance



6. Heat and moisture stability during feed processing

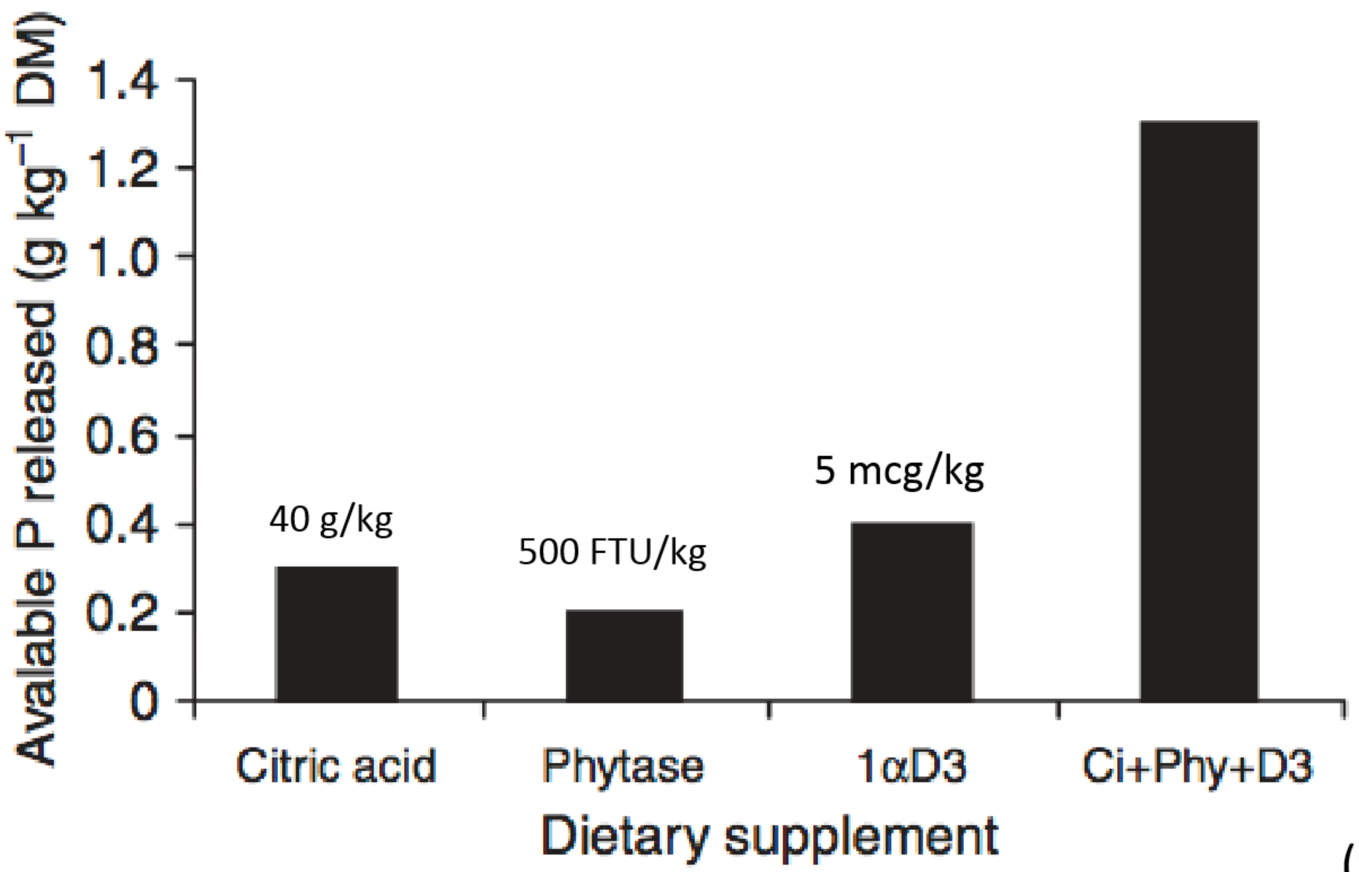


6. Heat and moisture stability during feed processing



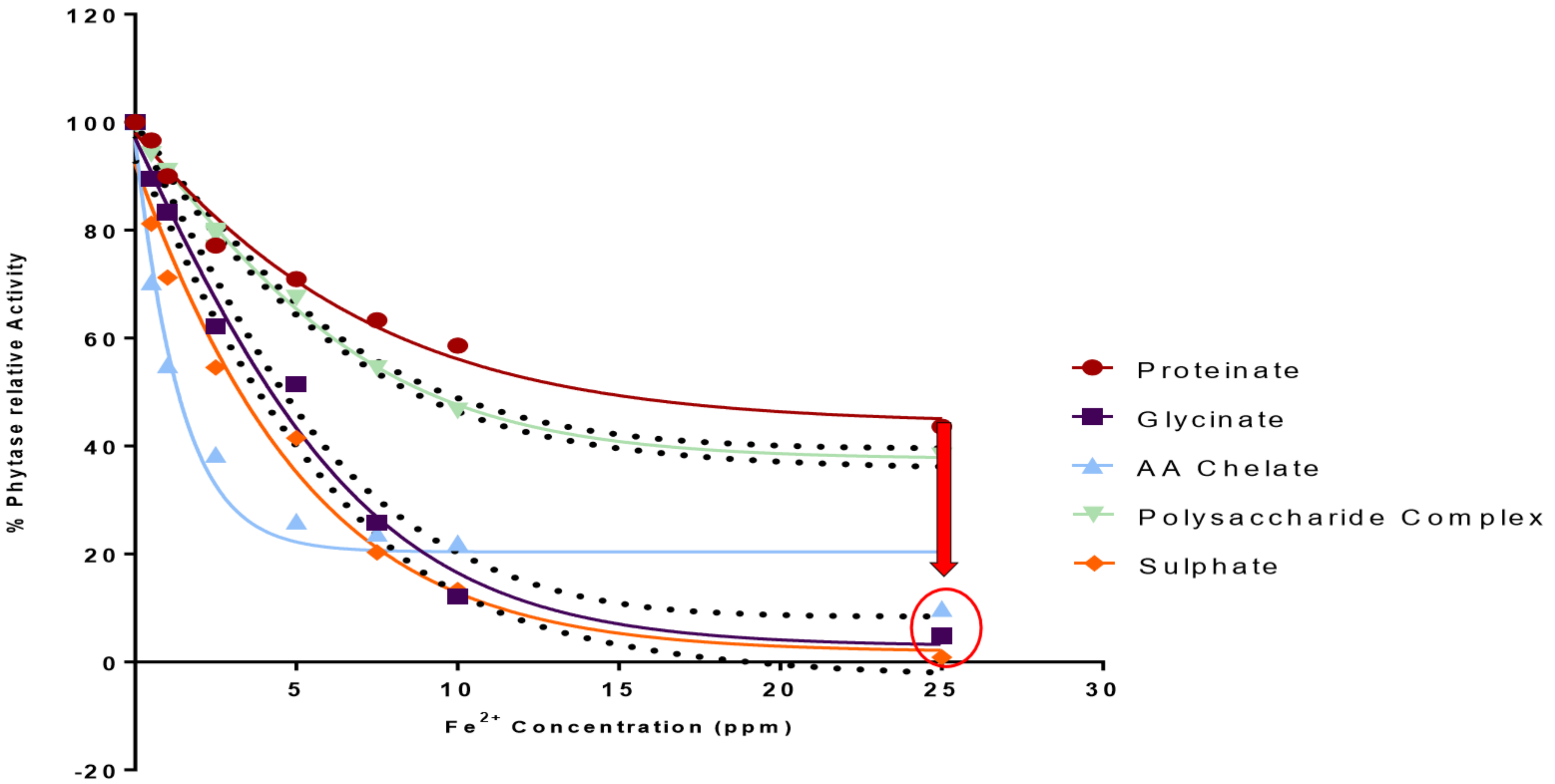
	mash	75° C	80° C	85° C	95° C
OptiPhos® CT	100	102	89	76	38
Quantum blue®	100	90	70	53	32

8. Synergistic effects of other Feed Additives (acidifier)



(Snow et al., 2004)

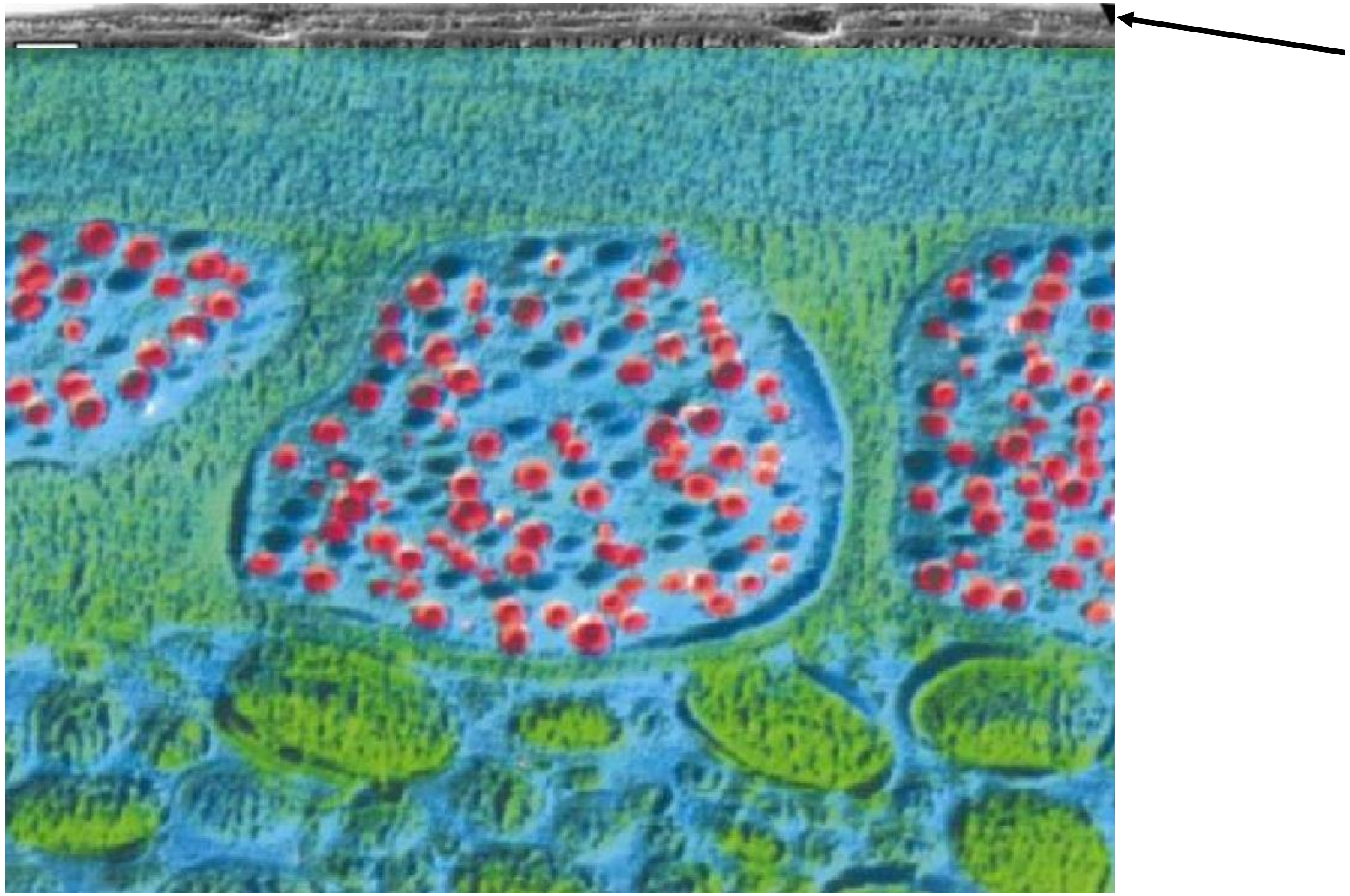
9. Dietary factors (minerals, vitamin D3 content)



Santos *et al* 2015

10. Combination of enzymes

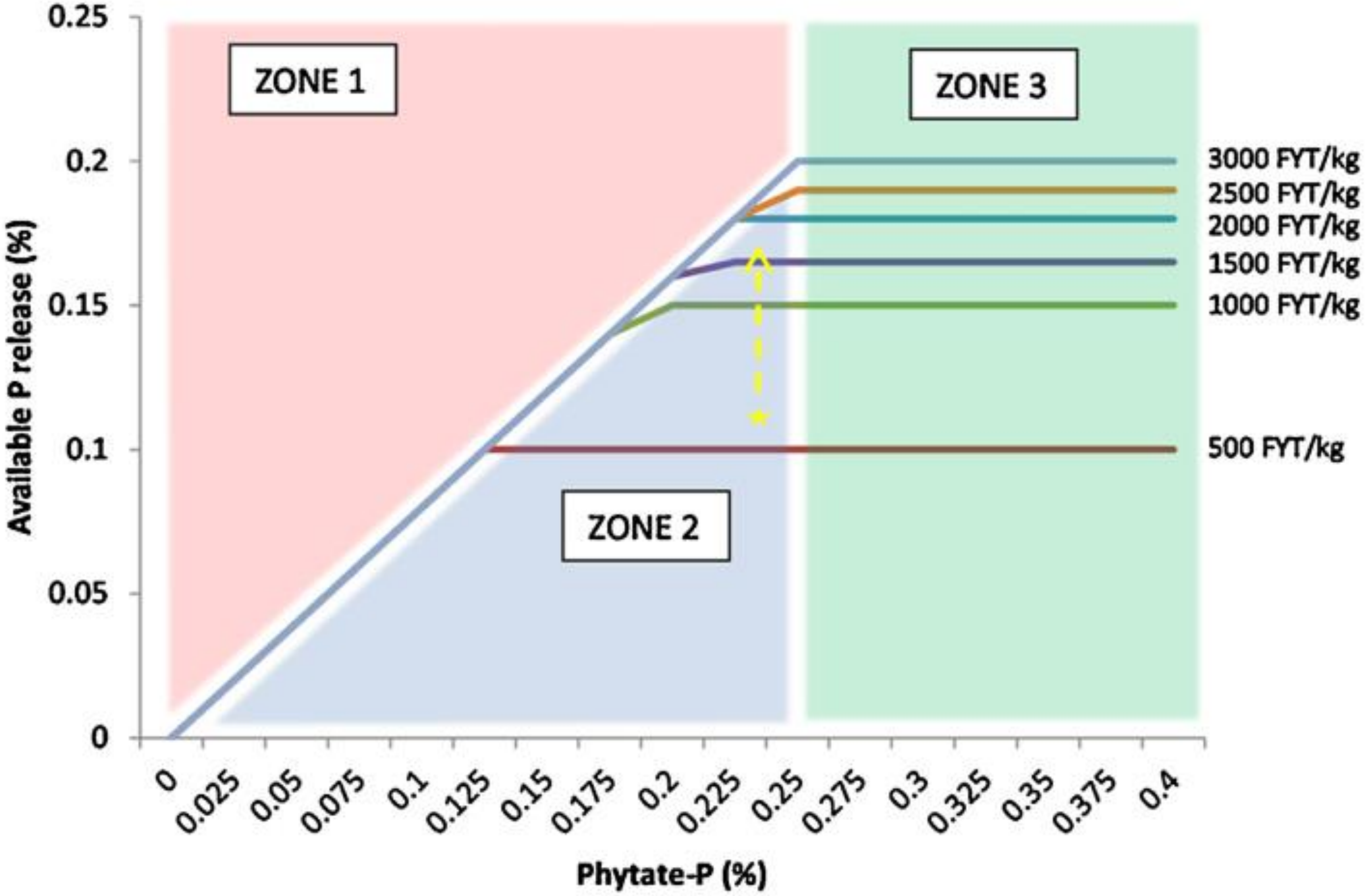
Red: phytate
Blue: protein
Green: carbohydrate



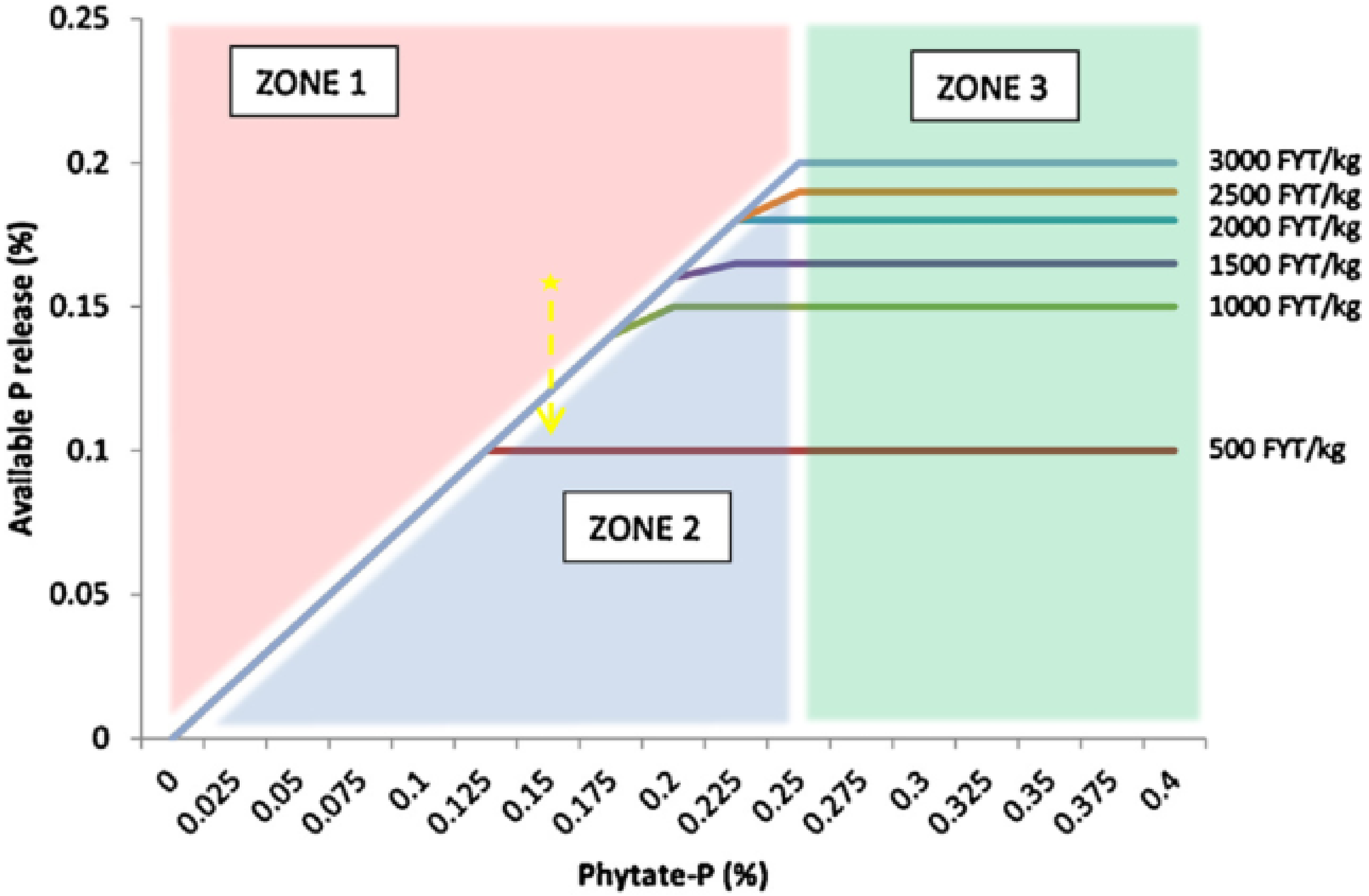
Effect of Phytase Dose

The Potential of Super Dosing

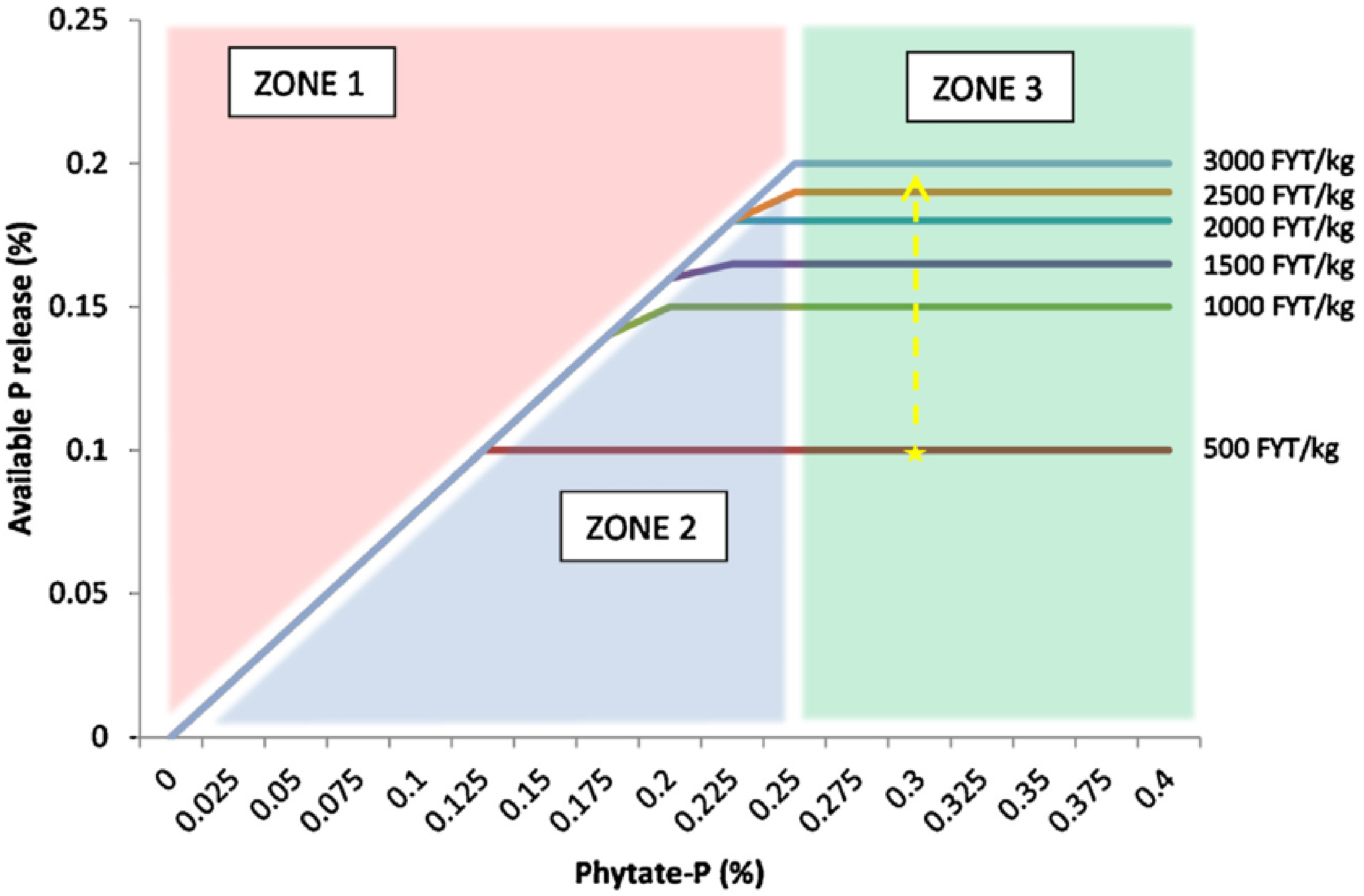
11. Phytase dosage



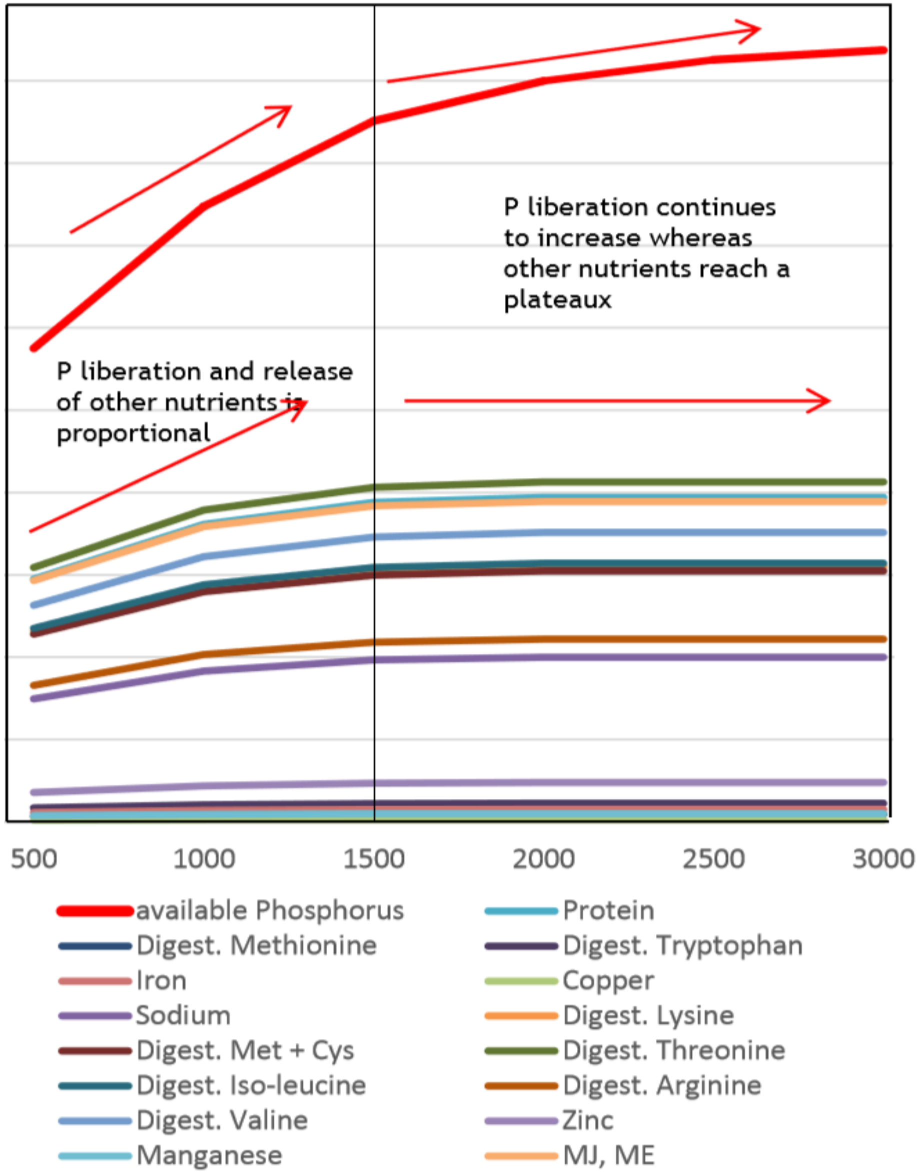
11. Phytase dosage



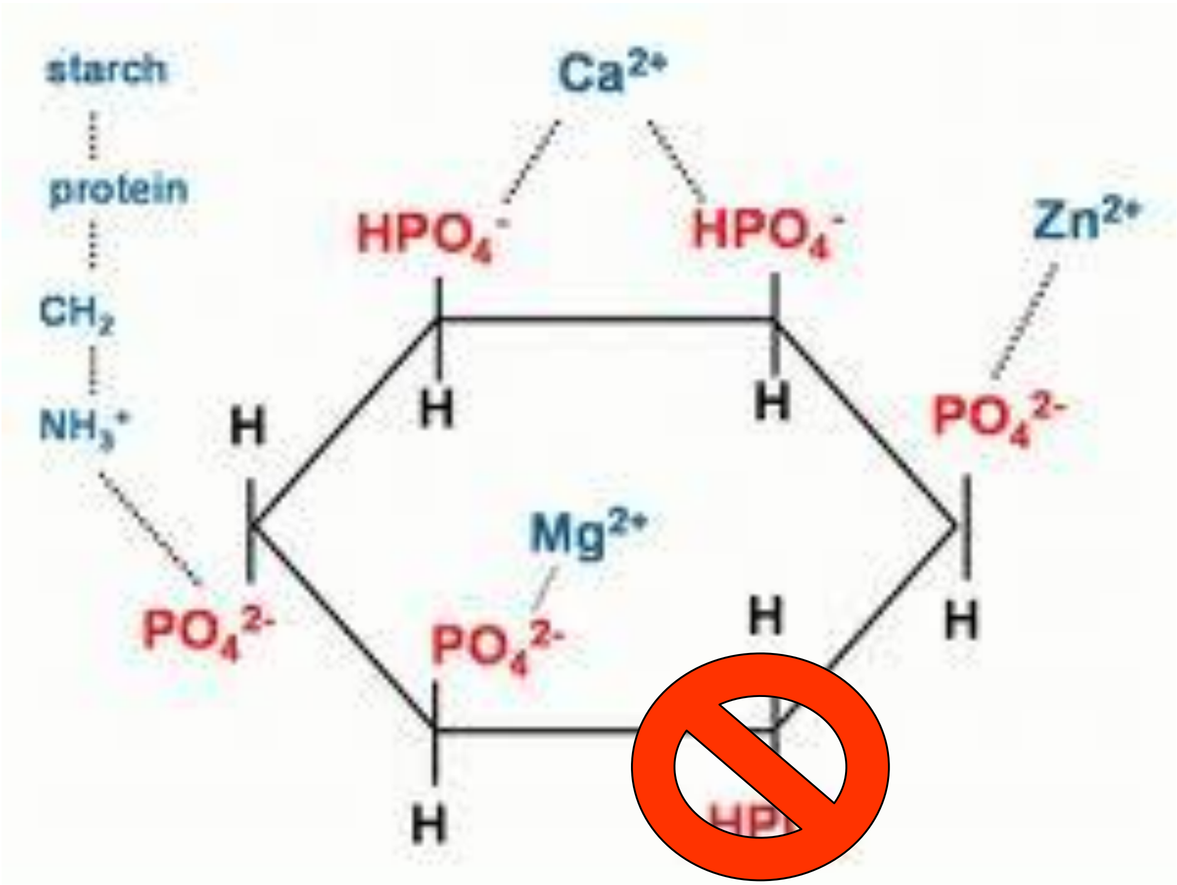
11. Phytase dosage



11. Phytase dosage

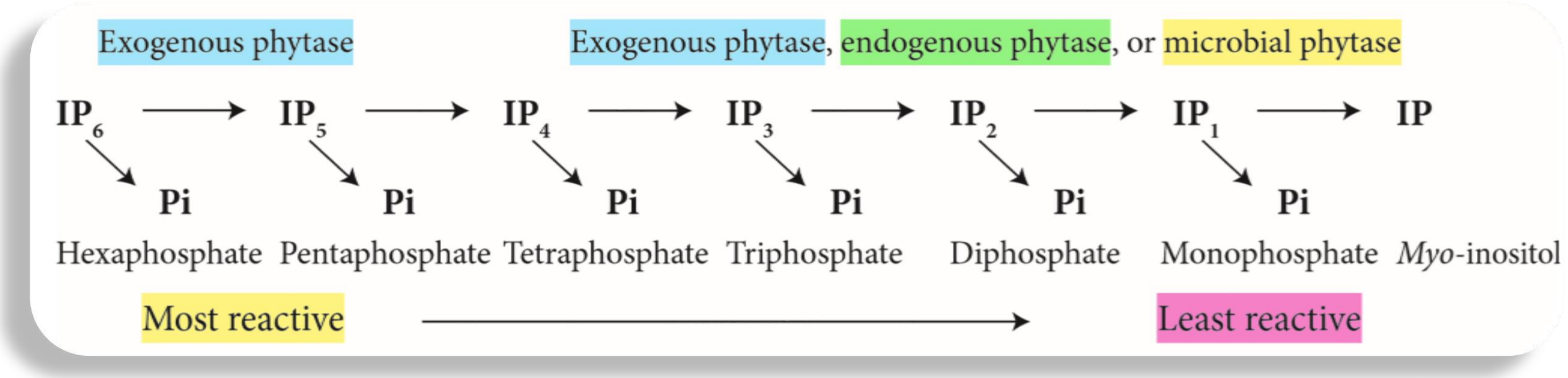


11. Phytase dosage

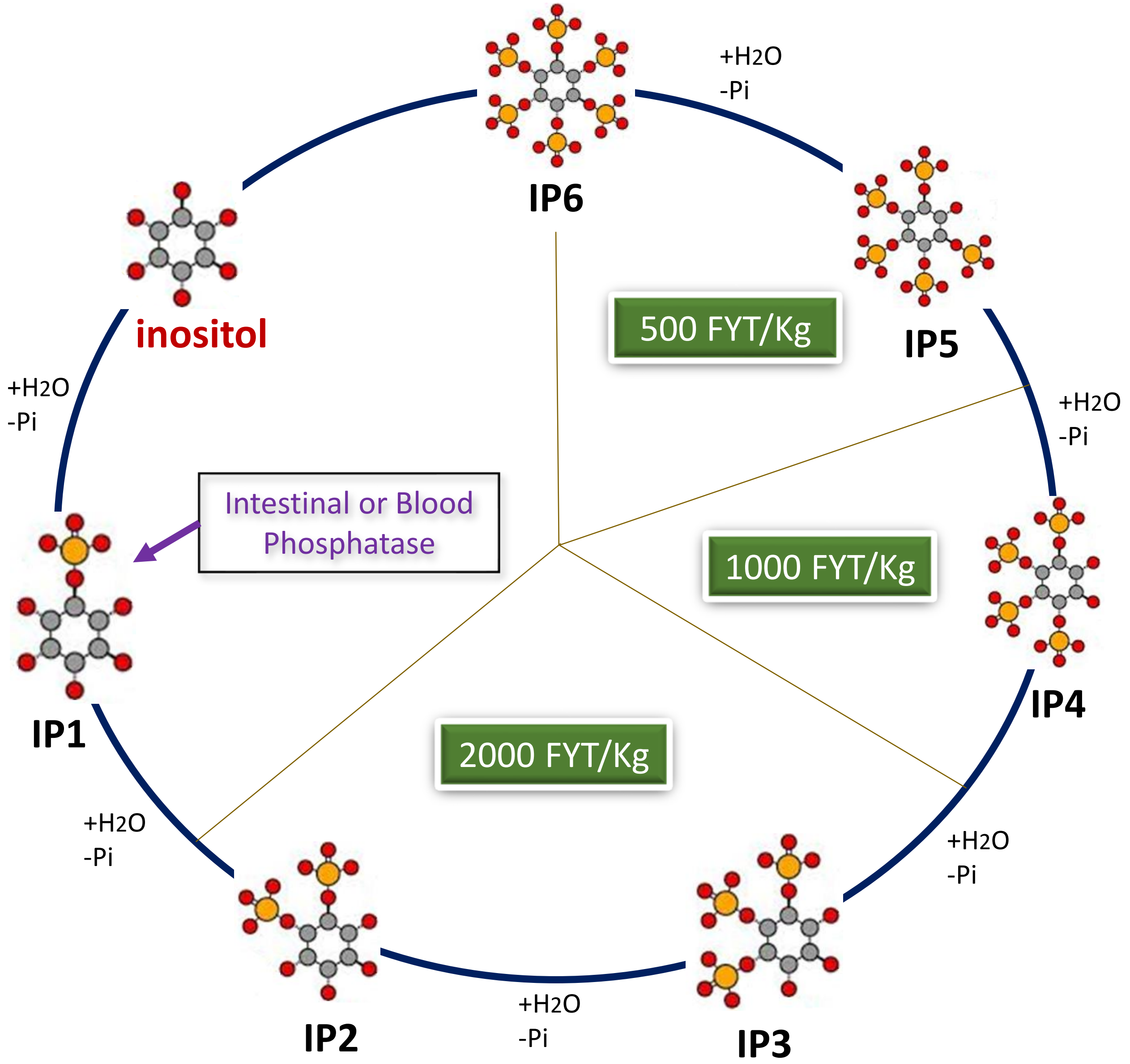


Traditional phytase hydrolyses less than 0.35 of dietary phytate

11. Phytase dosage



11. Phytase dosage

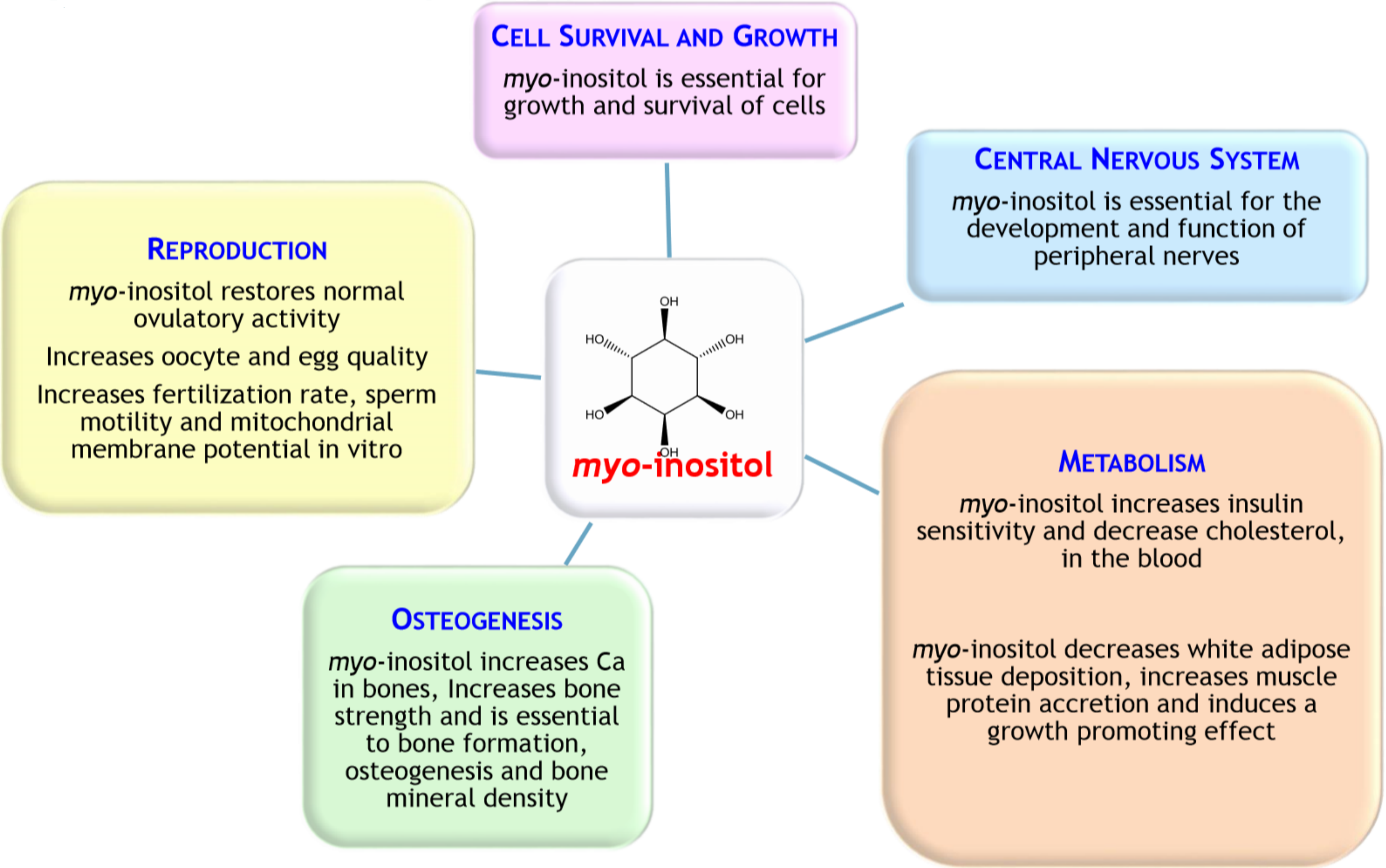


11. Phytase dosage

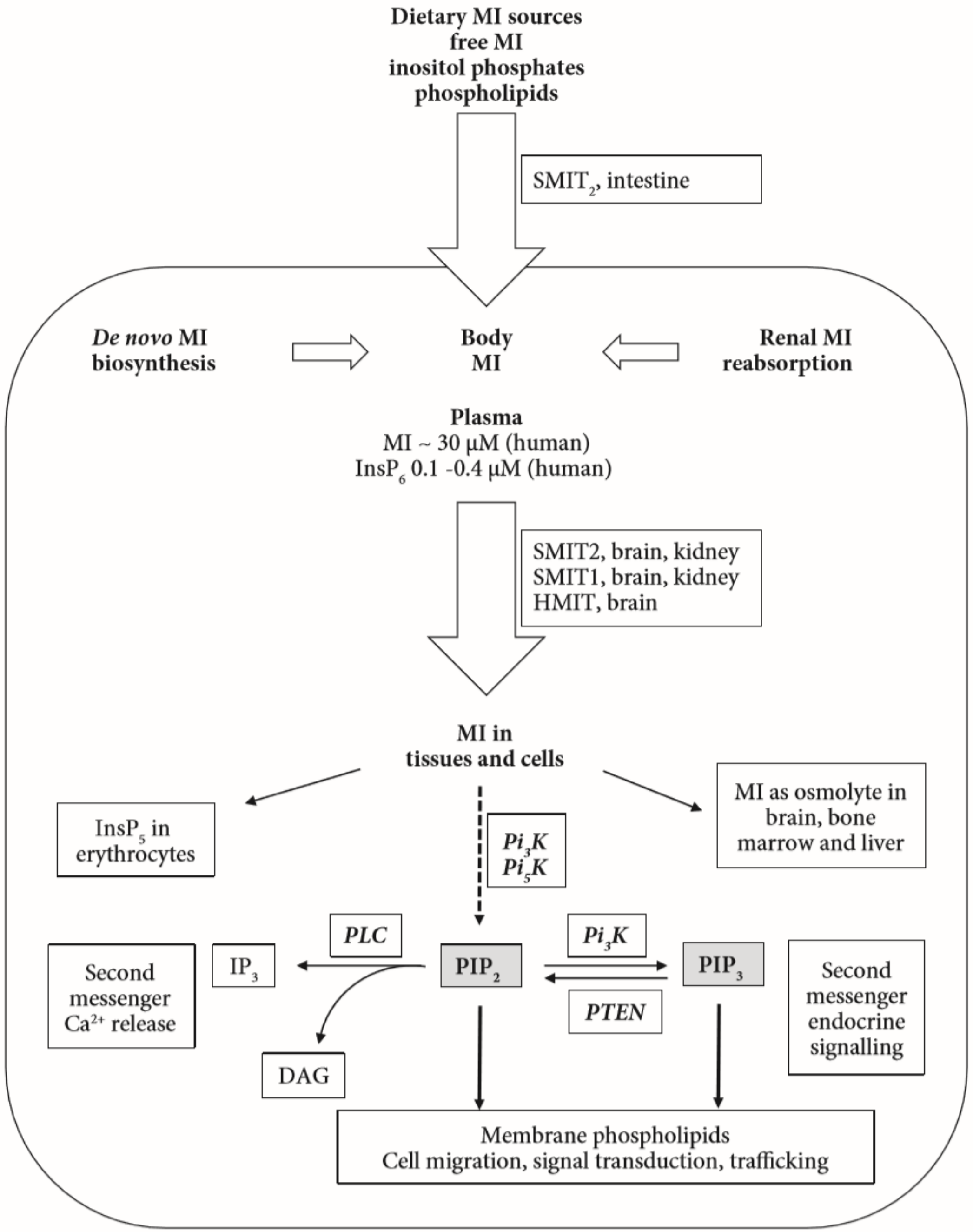
The effect of phytase supplementation (0–12,000 FTU kg^{-1}) on growth performance, nutrient utilisation, bone mineralisation, energy utilisation and total tract phytate-P degradation in broilers (adapted from Shirley and Edwards, 2003)

Phytase (FTU kg^{-1})	Growth performance			Coefficient of nutrient retention			Tibia ash (g)	AMEn (MJ kg^{-1})	Phytate-P disappearance (coefficient)
	Weight gain (g/bird)	Feed intake (g/bird)	FCR (g g^{-1})	Ca	P	N			
0	287	381	1.32	0.456	0.510	0.584	26.0	13.46	0.403
375	399	490	1.23	0.423	0.538	0.689	28.9	13.97	0.495
750	424	505	1.19	0.441	0.608	0.721	29.7	14.13	0.584
1500	459	548	1.19	0.423	0.654	0.745	34.3	14.20	0.652
6000	494	580	1.17	0.495	0.777	0.769	38.6	14.28	0.849
12000	515	595	1.15	0.534	0.797	0.777	40.7	14.29	0.948

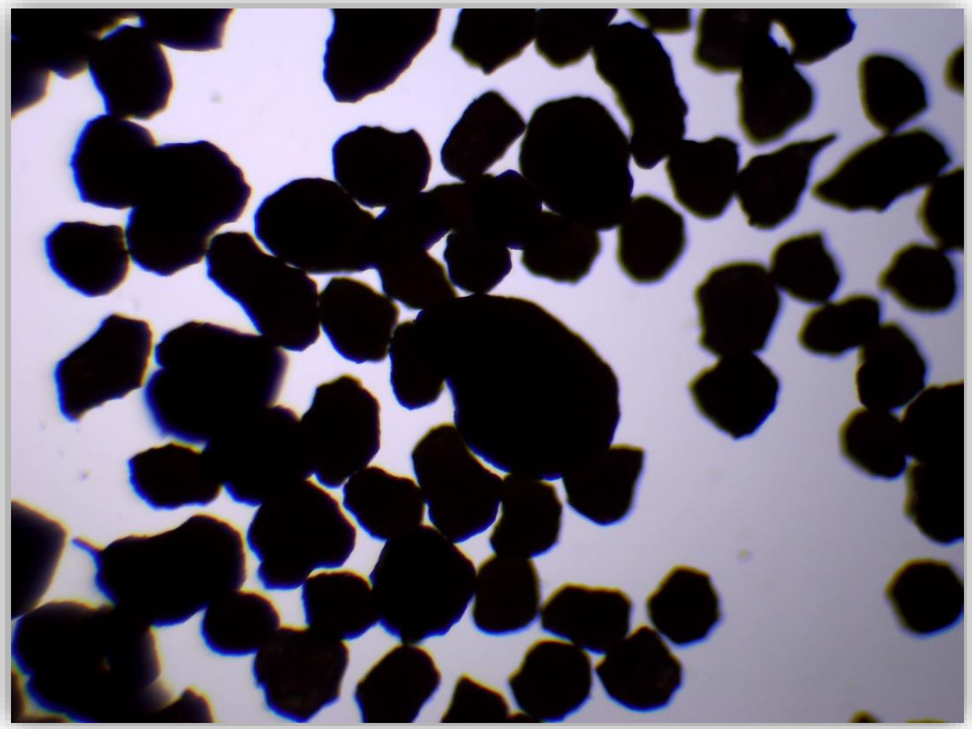
11. Phytase dosage

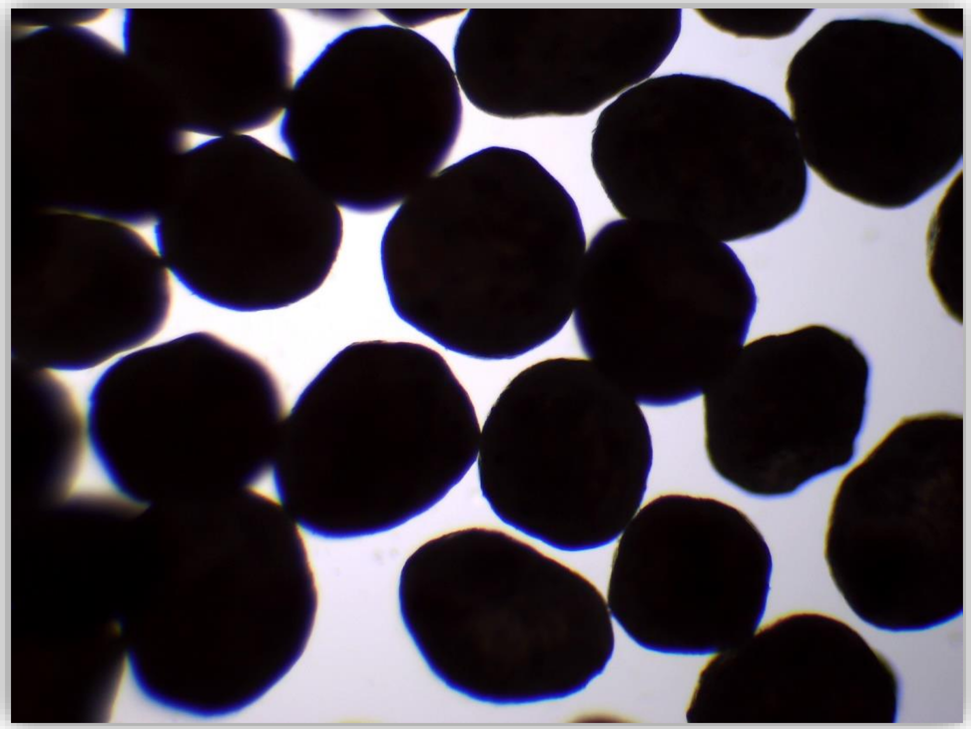


11. Phytase dosage



12. Particle size and mixability of commercial phytase





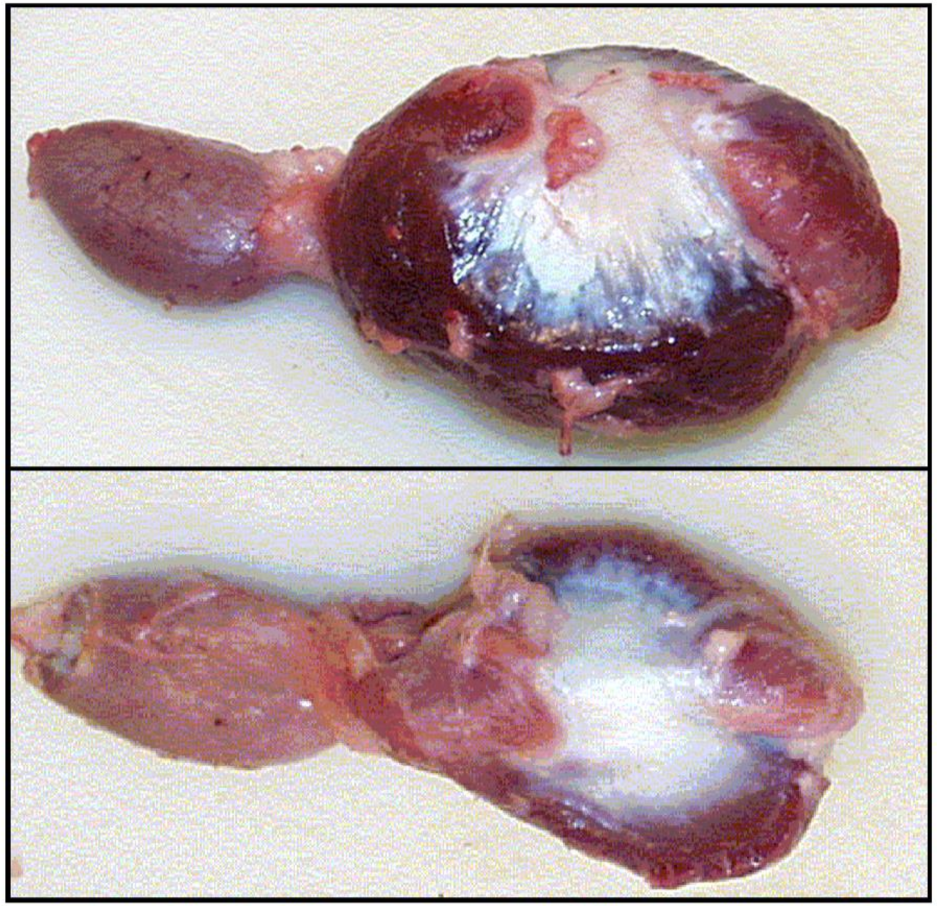
12. Particle size and mixability of commercial phytase

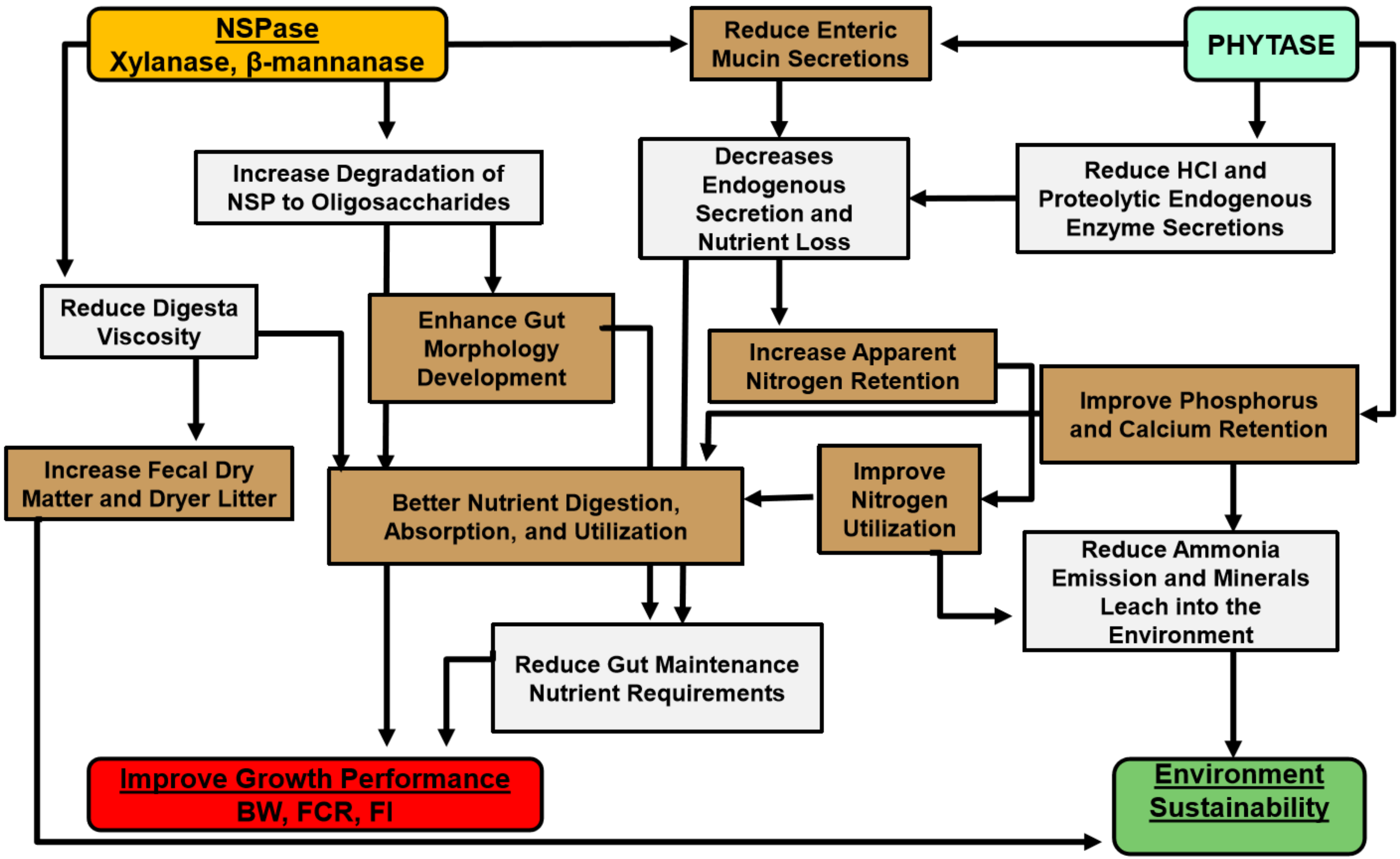
	Commercial phytase I	Commercial phytase II	Commercial phytase III
Phytase activity, fyt/g	10'000	10'000	50'000
~ Dose, g / T feed	150	100	20
Average particle number per g of product	14'000 - 16'000	12'000 - 14'000	159'000
Number of particles per dose (150g / 100g / 50g/ 20g)	approx. 2.2	approx. 1.4	approx. 4.8
Average particle size (mm)	0.45	0.49	0.23
< 0.05mm	0%	0%	0%
0.05 - 0.15mm	0%	0%	6%
0.15 - 0.25mm	2%	1%	55%
0.25 - 0.425mm	42%	31%	38%
0.425 - 0.60mm	40%	38%	38%
0.60 - 0.85mm	15%	24%	1%
>0.85	1%	6%	0%
Bulk density (kg/l)	1.08	1,2	0.87
Dusting, mg on Heubach1	0	0	0
Flowability	Good	Good	Good

13. Water pH and temperature

+	-
• Water pH <6	• Water pH >8
• Water temperature <20° C	• Water temperature >30° C

14 . Functionality of GIT




NSPase
Xylanase, β-mannanase
Reduce Enteric Mucin Secretions
PHYTASE
Increase Degradation of NSP to Oligosaccharides
Decreases Endogenous Secretion and Nutrient Loss
Reduce HCl and Proteolytic Endogenous Enzyme Secretions
Reduce Digesta Viscosity
Enhance Gut Morphology Development
Increase Apparent Nitrogen Retention
Improve Phosphorus and Calcium Retention
Increase Fecal Dry Matter and Dryer Litter
Better Nutrient Digestion, Absorption, and Utilization
Improve Nitrogen Utilization
Reduce Ammonia Emission and Minerals Leach into the Environment
Reduce Gut Maintenance Nutrient Requirements
Improve Growth Performance
BW, FCR, FI
Environment Sustainability

دریافت جایزه تحقیق در تغذیه طیور توسط دکتر مایکل بدفورد

توسط مدیر / یکشنبه ۱۴ مرداد ۱۳۹۷ / نوشته شده در اخبار سایت

دکتر مایکل بدفورد، جایزه تحقیق در تغذیه طیور انجمن علمی مرغداری (PSA) را در جلسه سالانه این انجمن که هفته گذشته در تگزاس برگزار شد، دریافت نمود. دکتر بدفورد مدیر تحقیقاتی AB Vista در انگلستان، توسعه نوعی افزودنی خوراکی را رهبری کرد که به انقلابی در مقابل اثرات ضدتغذیه ای فیتات منجر شد. به کارگیری این افزودنی خوراکی سبب جذب بهتر فسفر، انرژی و پروتئین خوراک توسط حیوان میشود، بازده تولید را افزایش و آلودگی محیط را کاهش می دهد.

دکتر بدفورد و همکارانش سالانه حدود ۹۰ پروژه تحقیقاتی را به ثمر می رسانند. ایشان بیش از ۳۰۰ تالیف داشته اند، مطالب هفت ژورنال را ارزیابی می کنند و با بیش از ۱۰۰ محقق و متخصص تغذیه ارتباط دارند و کار می کنند. دکتر بدفورد دارای دکترای تغذیه و بیوشیمی و دو فوق دکترا در زیست شناسی مولکولی و تغذیه طیور از دانشگاه گوئلف کانادا هستند.