Phosphorus utilization in Laying hens

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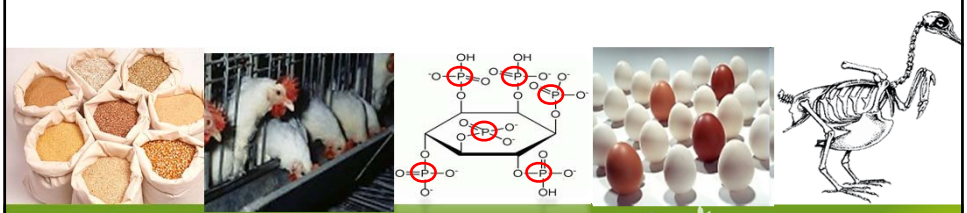
***INRA, « Function and regulation of egg proteins »**
UR83 Recherches Avicoles, 37380 Nouzilly, **FRANCE**



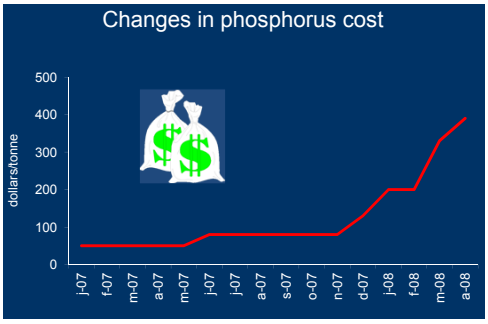
novel constrains for Phosphorus

ENVIRONMENT

- Phosphorus excretion in poultry manure → pollution : eutrophication of ground water
- non-renewable resource

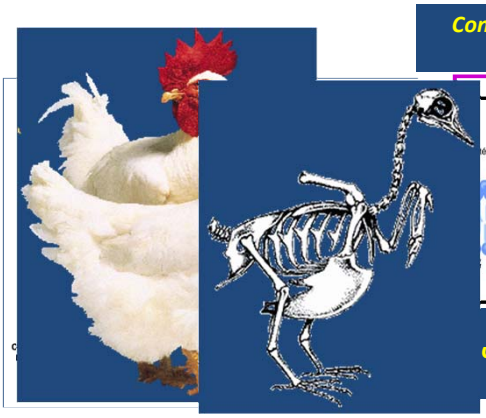
PHOSPHATE MARKET CRISIS

- problem of security in phosphorus supply
- ↑ dietary cost

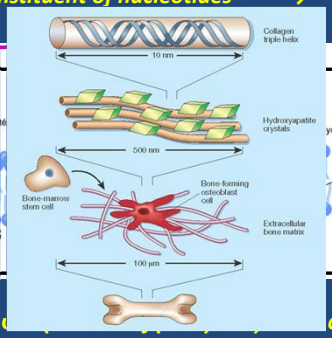


Phosphorus, a key element

➢ Involved in many metabolic functions: nucleotids, nucleic acids, phospholipids (cellular membranes), bone mineralisation (hydroxyapatite), regulation of acid-base balance



Constituent of nucleotides →



ycolipide

Cholestérol

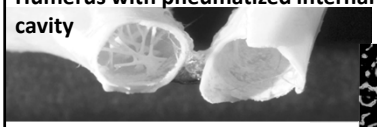
cell membrane

Specific requirement in phosphorus for growth , egg formation and bone mineralisation

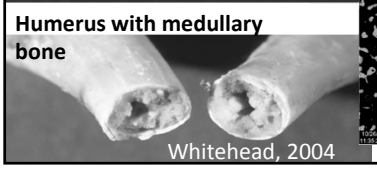
MEDULLARY BONE FORMATION

- **Medullary bone is a special type of woven bone, mostly appearing in the marrow of long bones (12% of total bone, especially the femur (21%)and tibia (12%)) at hen sexual maturity. Its mineral composition is similar to cortical or cancellous bone**
- **The rise in estrogen (+testosterone) at sexual maturity stimulate osteoblasts to produce medullary bone instead of structural bone.**
- **MB acts as a labile reservoir for the supply of eggshell calcium. MB can be metabolized at a rate 10–15 times faster than cortical bone**
- **Osteoclastic resorption of MB can supply as much as 40% of the calcium for eggshell formation**

Humerus with pneumatized internal cavity

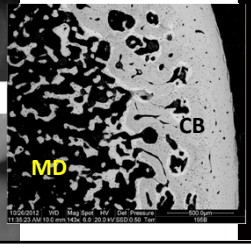


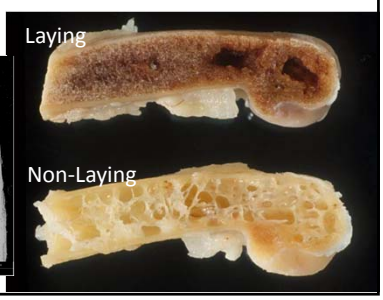
Humerus with medullary bone



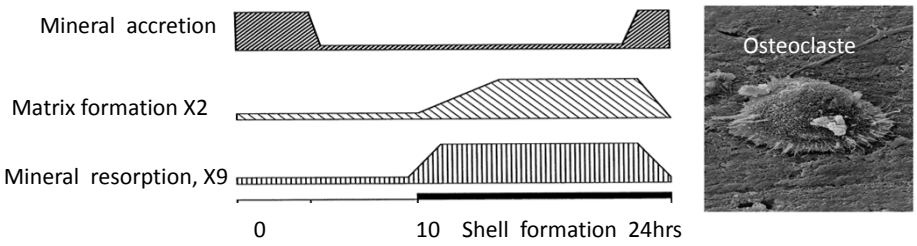
Whitehead, 2004

tibiae thin section





CYCLE OF MEDULLARY BONE CHANGE DURING EGGSHELL FORMATION

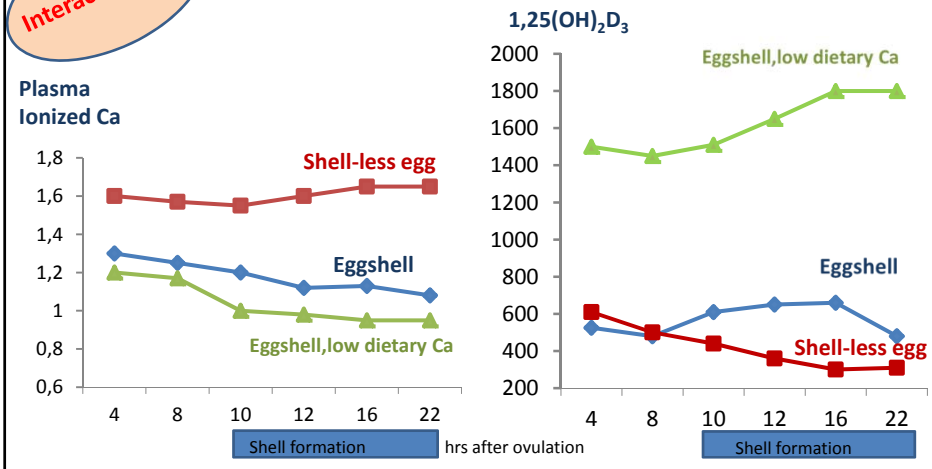


- During the active period of eggshell calcification, the active resorption surface in medullary bone increased nine fold and the percentage of osteoclast by sevenfold
- Osteoblast activity (osteoblastic surface) increased two fold during shell formation
- Mineral accretion occur mainly when no shell formation takes place

Van de Velde 1984 Metab Bone Dis Rel Res 5, 191

CHANGE IN IONIC CALCIUM AND OF THE LEVEL OF THE ACTIVE METABOLITE OF VITMIN D3 WITH EGGSHELL FORMATION

Interaction Ca-P

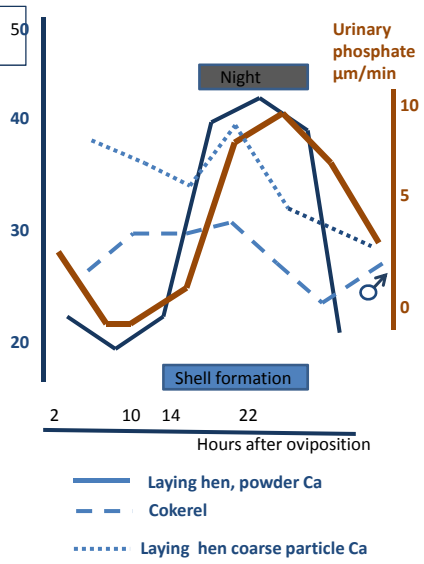


The active metabolite of vitamin D, $1,25(OH)_2D_3$, stimulates intestinal Ca absorption, resorption of bone in combination with PTH,

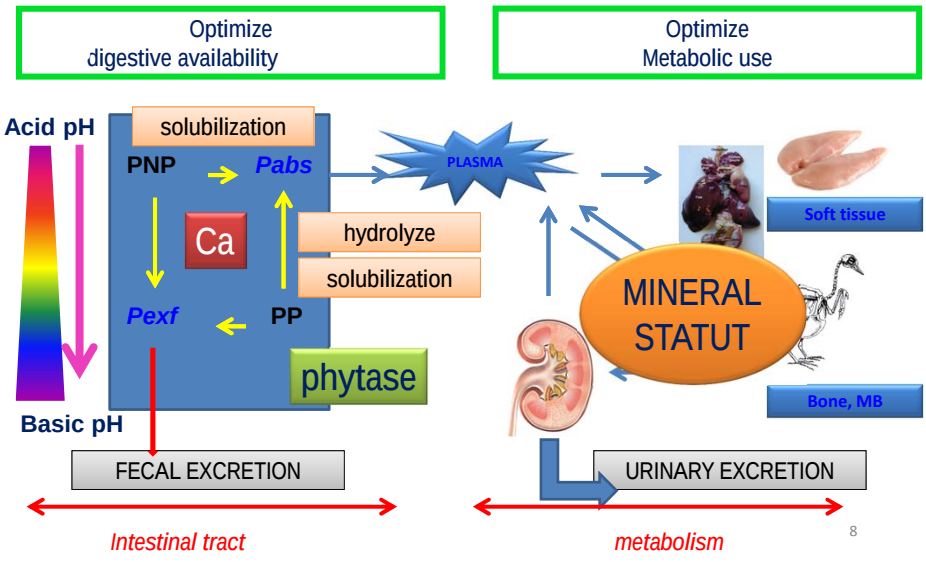
Interaction Ca-P

PHOSPHORUS MOBILISATION DURING THE PERIOD OF SHELL FORMATION

- The daily eggshell formation is associated with an increase in bone mobilisation in phosphatemia and excretion of phosphate
- 40% of the eggshell calcium can provide from bone resorption , corresponding to 0,4g phosphorus
- The use of coarse calcium particle abolishes the increased phosphatemia and excretion of phosphorus



INTERACTION BETWEEN CALCIUM AND PHOSPHORUS AT THE INTESTINAL AND METABOLIC LEVELS



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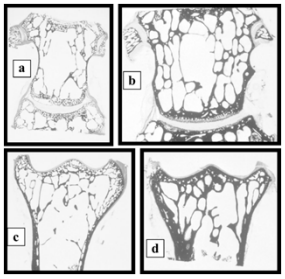
PHOSPHORUS EXPORTATION IN LAYING HENS

Cumulated Exportation of egg mass, phosphorus and calcium through a laying period

Weeks of age	Egg Mass*		Phosphorus (g)		Calcium (g)
	Kg	X body weigth	egg	urine	shell
60	15,7	X 8	32	136	750**
80	22,6	X 12	45	205	1130**

*Calculated for Brown eggs, 2012
** Corresponding to 1,89 and 2,82 kg eggshell

Osteoporotic bone | Normal bone



Change in egg bone quality with hen age

weeks of age	15	25	50	70
Medullary bone (%)	0	11.1b	12.1b	16.8a
Tibia BBS (N)	26.5a	28.2a	18.2b	19.5b

→ **Risk of osteoporosis and bone fractures**

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PHASE FEEDING OF DIETARY PHOSPHORUS (NPP) IN (0-18 WKS) ON INITIAL PERFORMANCE OF HENS (18-26 WKS. BABCOCK, HY-LINE)

Pullets

◆ Low dietary Phosphorus at the inital period of pullets growth delays egg production and increase mortality

NPP, g/kg Period: 0-6-12-18-26 sem	Egg % 18-26 wks	Egg weight	FCR	Specific gravity	Mortality %
3.4/3/2.3/3.9 g	70.5	52	2.5	1.08	.6
2.5/2/1.6/2.9 g	67	=	=	=	=
1.5/1/0.8/1.8 g	39	-3	+1.5	=	15
1.2/0.7/0.8/1.2 g	25	-3.5	+2.7	+.002	30
0.8/0.7/0.8/0.8	17	-4.5	+6	=	28

Keshavarz, 2003

◆ dietary Phosphorus can be lowered during the 8-16 wks period

aP g/kg 8-20 wks	Body weigth 20wks	Egg prod. %	Egg specific gravity	Tibial ash %
1,2	1.41	74.3	1.090	58.1
2,5	1.49	74.3	1.089	58.4
4,0	1.46	74.7	1.088	58.5

Douglas et Harm, 1986

EFFECT OF HIGH DIETARY CALCIUM OR PHOSPHORUS LEVEL BEFORE THE ONSET OF EGG PRODUCTION ON LAYING HEN PERFORMANCE

Pullets

Calcium

% Ca*	Age (wks)	Egg prod. %	Shell quality	Bone mineral	Authors
3*	15-21	+	+	+	Brooks et al., 1985
3,5*	19-23	+	+	=	Leeson et al., 1986
3,5*	18-20	=	=	=	Keshavarz, 1987
3,75*	16-21		+	+	Hudson and Britton 1989
3.9/2,2	15-19	= (15-65)	=	nd	Bar et al., 1998

control 0.8-1.1 % Ca

- Selection for increasing egg number (<2000) carried out by early sexual maturity (less 4 weeks in 10 years)

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EFFECT OF HIGH DIETARY CALCIUM OR PHOSPHORUS LEVEL BEFORE THE ONSET OF EGG PRODUCTION ON LAYING HEN PERFORMANCE

Pullets

Phosphorus

NPP 18-24 wks, g/kg	1.8	2.3	2.8	3.2	4.8
Egg prod at 24W	85c	88b	89ab	93ab	94a
Feed intake	85b	86b	88ab	92a	92a
Egg weight	49b	49b	49.4ab	50.1a	50.3a
Bone breaking strength * kg	12b	14ab	16ab	18a	19a
Bone density g/cm2	0.26b	0.3ab	0.36ab	0.4b	0.4b

Rao et al 1992 PS 71 691

- pre-laying diet (2,2% Ca, 0.35 NPP) or layer diet should be introduced before the first eggs
- Favour the formation of medullary bone and avoid any cortical bone resorption induced by Ca deficiency in early mature hens

Laying hens

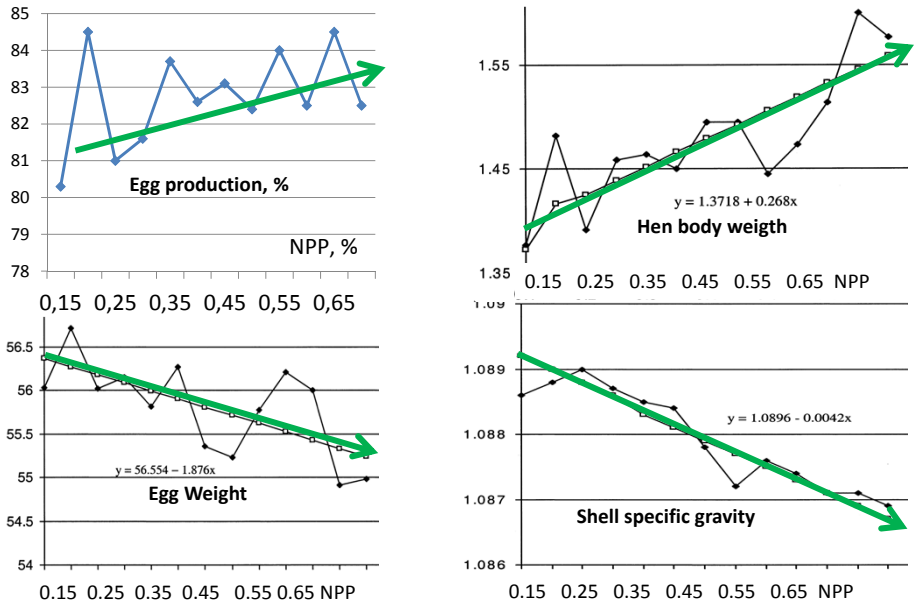
EFFECT OF INCREASING DIETARY PHOSPHORUS ON EGG PERFORMANCE AND EGG QUALITY (22-62 SEM)

	Dietary available phosphorus %			
	0.16[1]	0.25	0.46	1.26
Mortality %	6.3	4.7	3.6	5.2
Egg prod.,%	75.6a	82b	83b	83.6b
Egg weight, g	62.6	62.7	63.6	64
Shell thickness µm	383	380	378	363

Dietary Calcium: 3 to 4 %, 0,32 TP in basal diet, White Leghorn

Hartel, 1990, BPS31, 473

EFFECT OF INCREASING DIETARY PHOSPHORUS ON EGG PERFORMANCE AND EGG QUALITY (22-62 SEM)



Sohail and Roland, 2002, PS 81,75

Laying hens

EFFETS OF DIETARY PHOSPHORUS PHASE FEEDING ON HENS PERFORMANCE (30-66 SEM. BABCOCK)

NPP (g) periods: 30-42-54-66 wks	Egg prod. %	Feed intake g	Egg weight, g	Specific gravity	Tibial ash %
4 / 3.5 /3	83.7a	100	59.9	1.0786a	59.6a
3 / 2.5 / 1.5	80.5b	98	=	=	56.3ab
2 / 1.5 /1	71.5c	96	=	1.0795b	54.3b
2 /1 / 1	62.5d	95	=	1.0800b	57.9ab

FCR increased from 2 until to 2.9 with decreased dietary NPP

Keshavarz, 2000

Decrease dietary NPP to level lover than 2g/kg
drastically reduced egg production

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Laying hens

EFFECT OF CALCIUM PARTICLE SIZE ON LAYING HEN'S BONE

	Particle size		Source origin	
Bone quality	ground	coarse	marine	limestone
Bone breaking strength (N)	97b	114a	103	108
Stiffness (N/cm)	930b	1099a	995	1058
Ash content (%)	50.1b	53.4	51.6	52.5

Guinotte and Nys, 1993

	calcium	15wks	25ws	50wks	70wks
Medullary bone (%)	**powder**	0	11.1b	12.1b	16.8a
Medullary bone	**particle**	0	11.5	14.8	21.4
Tibia BBS (N)	**Powder**	26.5a	28.2a	18.2b	19.5b
Tibia BBS (N)	**particle**	26.1ab	28.2a	22.5b.	23.6b

Fleming 2008 Proc Nut societ 67-17—2008

Increased in bone mineralisation by about 20 % (Whitehead and Fleming, 2000, Saunders-blades et al., 2009)

Laying hens

INTERACTION CALCIUM –PHOSPHORUS ON LAYING HEN'S PERFORMANCE

MORTALIY, %	Dietary Calcium (%)		
Dietary phosphorus (TP)	2	3	4
0.32	33	25	39
0.42	17	5	42
6.2	17	3	3

Hartel, 1989, BPS31,473. Leghorn, **22-62 wks**

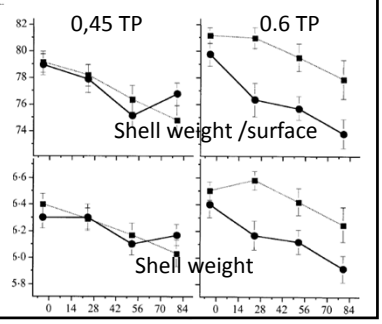
→ High interaction at extreme dietary Ca and P

TP	Ca	Mortality %	Egg production	Egg weight	Shell, g/100cm2
0.45	4	2.5	0.87	71.8	7.66
0.45	5	**10**			7.65
0.6	4	2.5	0.88	71.7	7.53
0.6	5	0.0			7.94

Bar et al, 2002 Brown egg BPS43, 261, **65-95 wks**

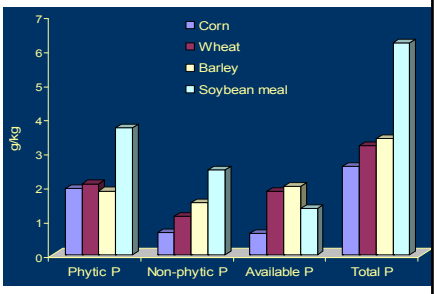
→ Phosphorus to be increased at high dietary Ca in aged hens

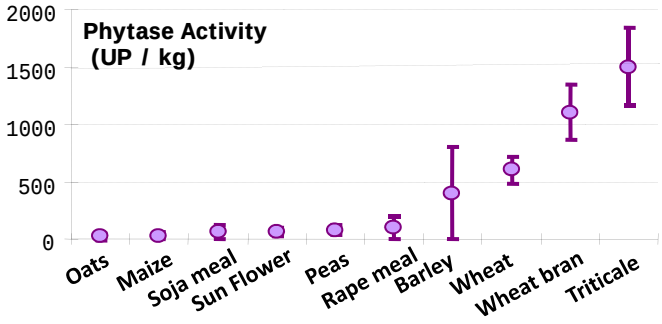
Eggshell quality at 80-93 wks of age, no interaction in younger hens



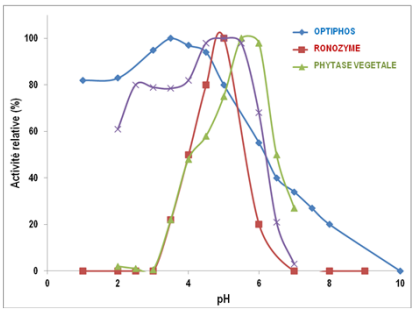
PHYTIC PHOSPHORUS AND PHYTASE IN HENS

- **Phytic phosphorus level is relatively stable in layers diet , 2.2-2.5 g/kg**
- **Presence of plant phytase in some cereals**
- **Availability of microbial phytase**



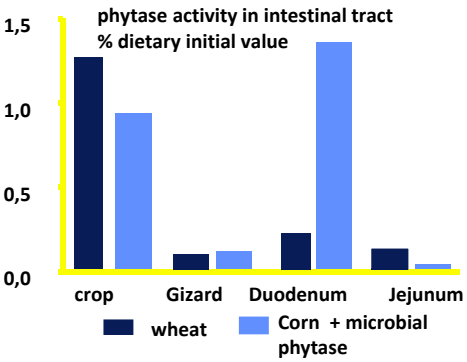


COMPARAISON PLANT AND MICROBIAL PHYTASE



Plant phytase
Microbial phytase
(3 commercial products)

Narcy et al., 2012



Frapin and Nys , 1996

- ❖ **Higher stability of microbial phytase**
- ❖ **High activity for a large range of pH**
- ❖ **Microbial phytase twice more active than plant phytase Availability of microbial phytase**

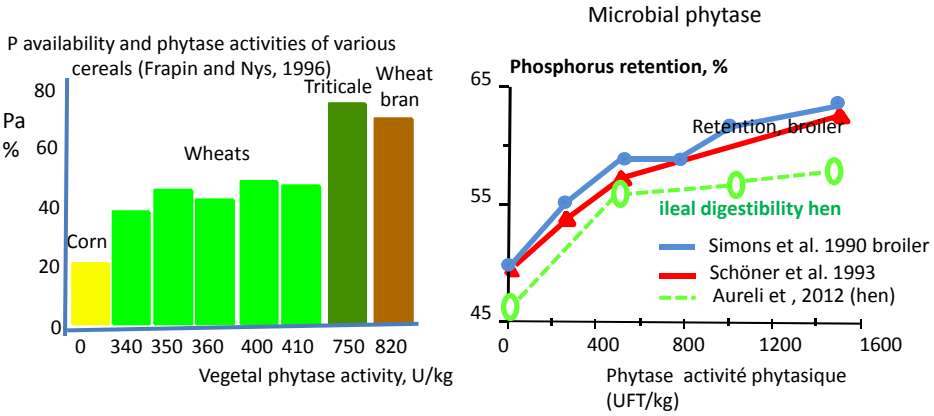
COMPARAISON PHOSPHORUS RETENTION IN BROILER AND HENS

	Phytic hydrolyse %		P apparent retention %	
Feedstuffs	broiler	hen	broiler	hen
Corn	31	23	34	28
Corn + Phytase 300	59	52	41	45
Soymeal	35	26	27	37
Soymeal + phytase 300	72	62	58	53
Rice bran	33	36	15	36

Leske et Coon, 1999.

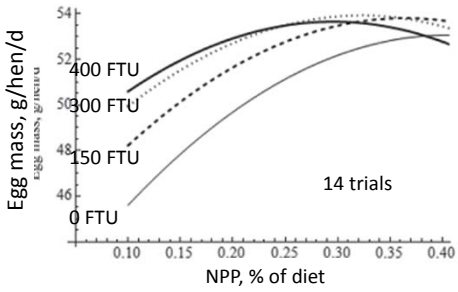
- ❖ **Phytic hydrolysis and P retention show limited difference between broilers and layers in this report even if they hav equite different digestive physiology. Availability of microbial phytase**

EFFICIENCY OF PLANT AND MICROBIAL PHYTASE



- ❖ **Large use of of microbial phytase in practise in layers**
- ❖ **Plant phytase sensitive to technological treatment but possible interest in layers feed with wheat (large particle or whole wheat) , alternative feed system?**

How far can nPP be lowered Without affecting Egg performance?



Minimal levels of NPP required to optimize the response of: egg production, egg mass and feed conversion ratio

Phytase, FTU/kg	0	150	300	400
NPP, % diet	0,22	0,18	0,15	0,14

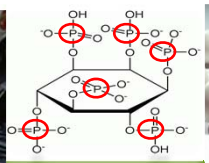
Ahmadi and Rodehutscord, 2012

Phytase : 300FTU/kg equivalent to 0.7 g/kg NPP

To conclude

- phosphorus in layer nutrition has large economical and environmental impact
- Too severe restriction in dietary P markedly reduced egg production, favour the appearance of bone osteoporosis and induced high mortality
- Long term and shifted responses on hen viability (often irreversible) rather than direct effect on egg quality: need for preventive measure, being cautious!
- Limited effect on egg quality mainly observed in presence of extreme level of P
- Ca-P interact at intestinal and metabolic levels : real risk at low dietary P (< 2,5 g NPP).
- Particle size calcium save phosphorus excretion and protect against bone osteoporosis
- Reduction in dietary P with age might be at risk when extending egg laying period
- Numerous experimental studies demonstrating high efficiency of microbial phytase to correct performance in hens fed diet without inorganic phosphorus and limit CA-P interaction favouring absorption of other nutrients
- Combination of microbial phytase (300-500 FTU) and of at least 1g of supplemented NPP to fit layers performance





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