Digestible calcium in poultry

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dsm-firmenich Animal Production Forum

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1. What is the challenge?
2. Ingredients – digestibility coefficients
3. Limestone quality
4. Digestible Ca requirements
5. Ongoing research and lingering questions

Digestible calcium

Age, weight and/or intake

Ingredients

Animal by products

Inorganic phosphate

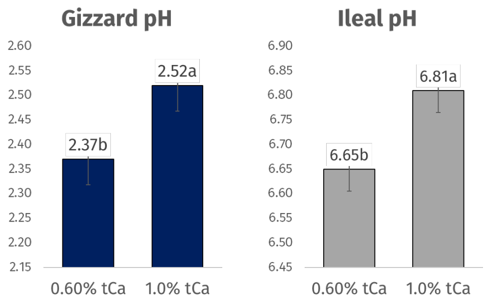
Phytate and phytase

Digestibility coefficients

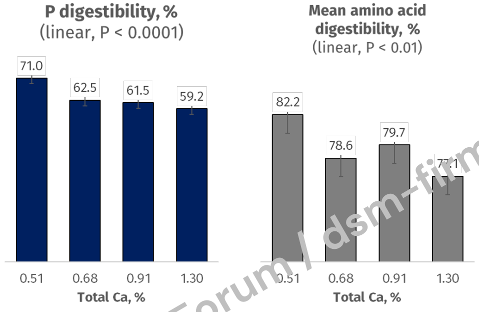
Limestone

Challenges with dietary calcium, predominantly from limestone

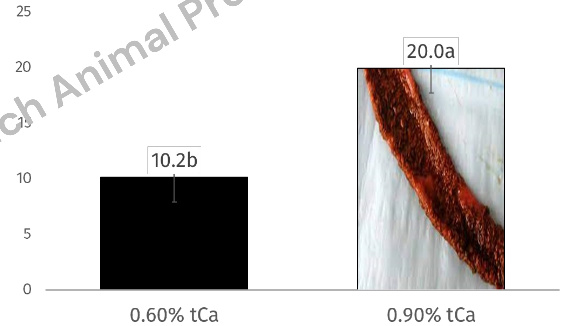
Influence of dietary calcium on gastrointestinal pH



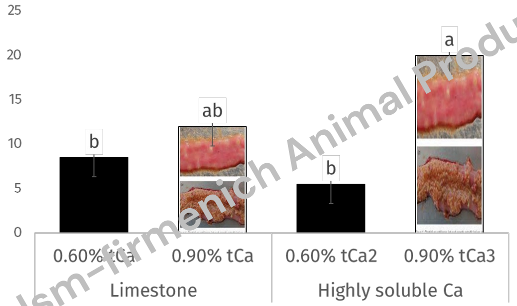
Influence of dietary calcium on P and amino acid utilization



Mortality associated with necrotic enteritis (%), hatch to day 35



Mortality associated with necrotic enteritis (%), hatch to day 21



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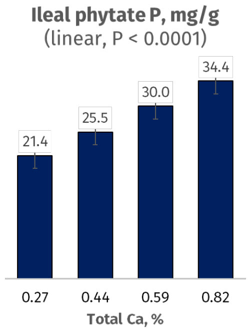

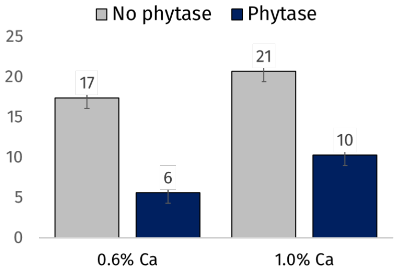

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Formulate broiler diets using standardized ileal digestible (SID) Ca

1. **Improve** our **understanding** and knowledge about dietary **ingredients that contain calcium**

2. **Mitigate negative effects** of **excess or 'unaccounted' calcium** in our ingredients and diets

3. Formulate diets to **optimize both calcium and phosphorus nutrition** with ancillary **benefits on amino acids and exogenous enzyme efficacy** (including phytase and protease)

4. **Precision nutrition** (e.g. digestible phosphorus and amino acids) improved broiler **growth** rate, feed **efficiency, resource allocation**, and **reduced nutrient losses** into the environment

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Animal Feed Science and Technology

Key messages:

1. Dietary ingredient information is available to implement digestible calcium in diets for broiler chickens
2. The data is variable due to differences in experimental methods, ingredients, Ca:P ratios, and – or + phytase

Check for updates

Towards a digestible calcium system for broiler chicken nutrition: A review and recommendations for the future

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A R T I C L E I N F O

Keywords:
Dicalcium phosphate
Limestone
Meat and bone meal
Monocalcium phosphate
Digestible calcium

A B S T R A C T

There is growing awareness that variability in the nutritional quality of Ca sources has significant effects on gastrointestinal pH, P and amino acid digestibility, exogenous enzyme efficacy and the microbial population in the gastrointestinal tract of broilers. In this regard, the interest in moving toward a digestible Ca system is gaining traction and the apparent ileal digestibility (AID) or standardized ileal digestibility (SID) coefficients for Ca in ingredients, such as limestone (n = 55), dicalcium phosphate (DCP; n = 21), meat and bone meal (MBM; n = 20), monocalcium phosphate (MCP; n = 12), and plant based ingredients are available. The aim of this review was to compile the

AID or SID Ca coefficients are available for some feed ingredients for broilers

Broiler trials (n = 15) to evaluate calcium digestibility of ingredients

Ingredient	n	Average standardized ileal digestibility (SID) of Ca, % (± std dev)	n	Average apparent ileal digestibility (AID) of Ca, % (± std dev)	Reference
Limestone	10	55 ± 14	45	53 ± 12	Walk et al., 2021
Oyster shell (< 500 µm)	1	33	1	32	Anwar et al., 2017
Oyster shell (> 1000 µm)	1	56	1	55	Anwar et al., 2017
Dicalcium phosphate	9	39 ± 12	12	44 ± 16	Walk et al., 2021
Monocalcium phosphate	6	36 ± 7	6	34 ± 6	Walk et al., 2021
Meat and bone meal	6	46 ± 7	14	45 ± 6	Walk et al., 2021
Fish meal	1	24	1	23	Anwar et al., 2018
Poultry by-product meal	1	29	1	28	Anwar et al., 2018
Corn	1	70	1	46	Aw-Yong, 1974; Venter et al., 2023
Wheat	1	71	1	73	Aw-Yong, 1974; Venter et al., 2023
Soybean meal	4	55 ± 8	1	47	Aw-Yong, 1974; Angel et al., 2013; Trairatapiwan et al., 2018; Venter et al., 2023
Canola meal	1	31	2	34 ± 7	Anwar et al., 2018; Venter et al., 2023
Sunflower meal			1	61	Venter et al., 2023
Sorghum			1	54	Venter et al., 2023
Full fat soybean meal			1	70	Venter et al., 2023

No significant difference between AID Ca or SID Ca (Walk et al., 2021) presumably because the endogenous losses of Ca in broilers is small > 0.03%.

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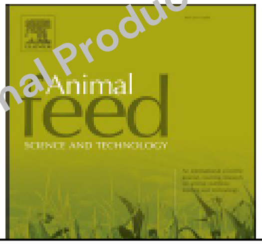


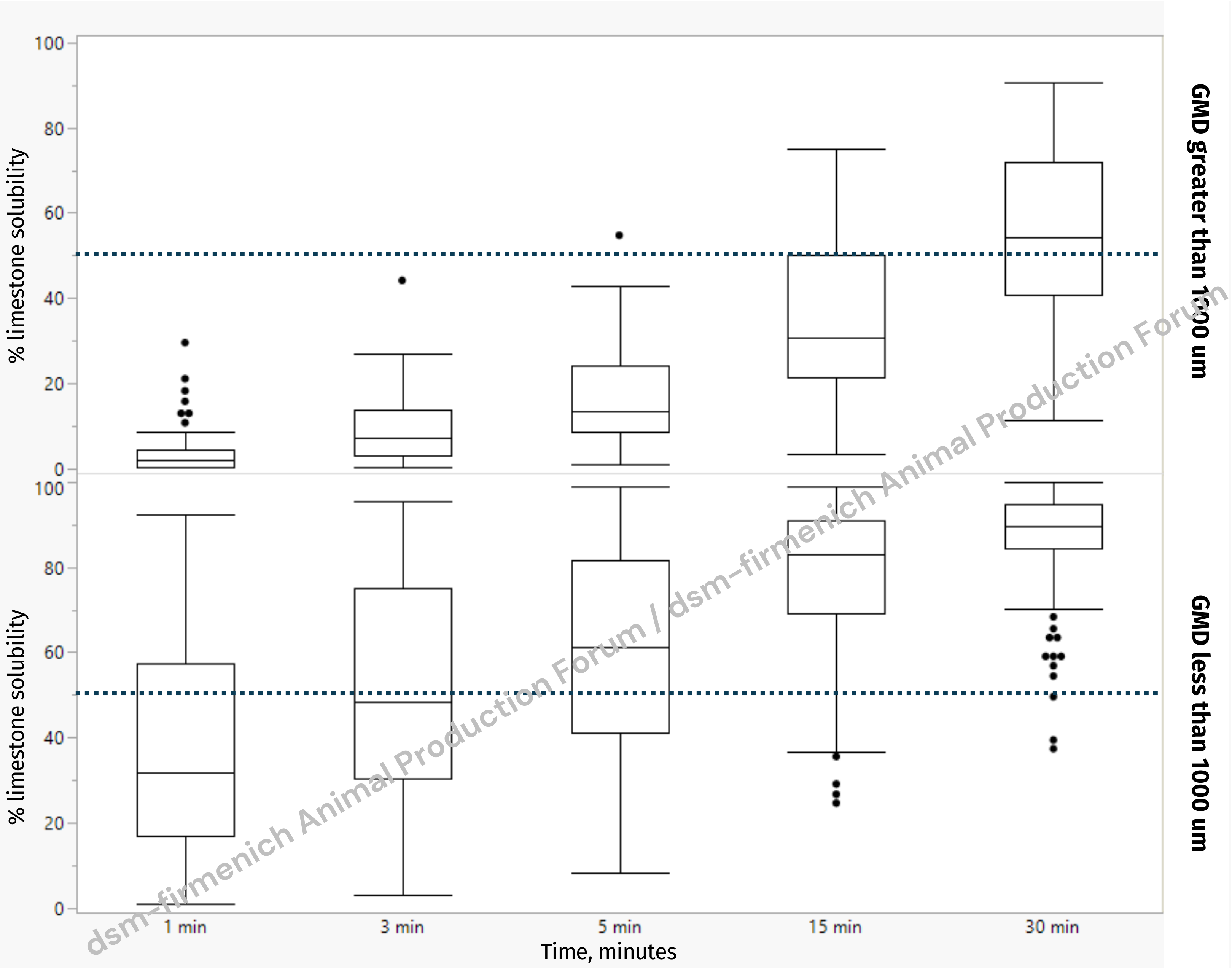
Key messages:

1. Dietary ingredient information is available to implement digestible calcium in diets for broiler chickens
2. The data is variable due to differences in experimental methods, ingredients, Ca:P ratios, and – or + phytase
3. Limestone digestibility is influenced by particle size and rock type (marble, hard limestone, limestone, chalk)

Table 1
Reported calcium digestibility values of limestone in broiler chickens from 11 to 25 days of age using diverse methodologies and adaptation lengths.

Inorganic calcium source	n	Adaptation, h	Calcium digestibility coefficient			Reference
			Mean	Min	Max	
Limestone	1	24	0.65	–	–	David et al., 2019
Limestone	12	32	0.49	0.38	0.57	Kim et al., 2018
Limestone	8	36	0.53	0.20	0.72	Kim et al., 2019
Limestone	29	72	0.55	0.34	0.77	Anwar et al., 2016b, 2016c, 2017; David et al., 2019
Limestone	4	120	0.56	0.44	0.62	Zhang and Adeola, 2018
Limestone	1	168	0.36	–	–	David et al., 2019
Average	55		0.53	0.20	0.77	

Limestone solubility (%) at pH 3 in a glycine buffer solution over time:



GMD greater than 1000 um:

n = 58 to 60

GMD mean = 1586 ± 391 (1066 to 2500 um)

13 countries

Solubility range = 0.2 to 90.8%

GMD less than 1000 um:

n = 153 to 180

GMD mean = 292 ± 233 (9 to 970 um)

22 countries

Solubility range = 1.0 to 100%

AID Ca range = 2.4 to 77.4%

Phytase effect (abs) = 7.0 (3.2 to 9.5)

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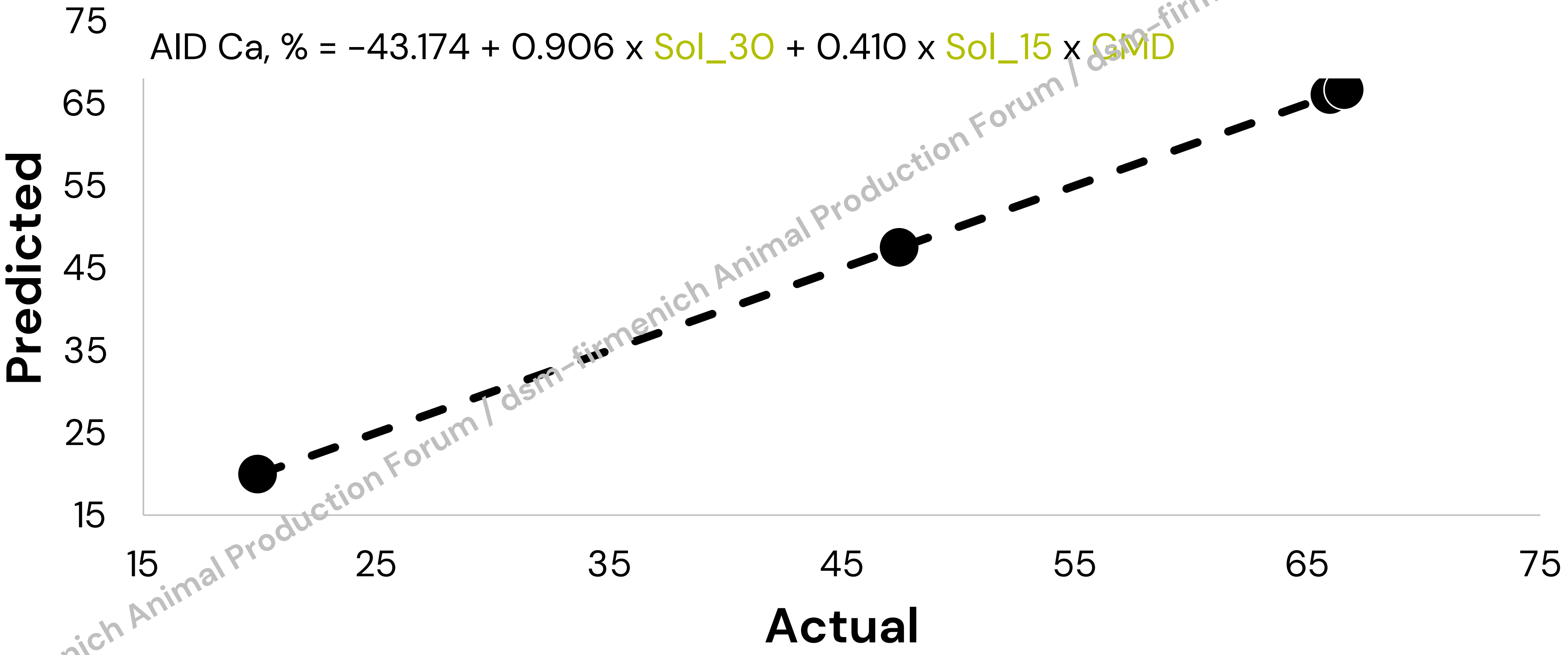
Limestone minerals:

Mineral	n	Mean	SD	Minimum	Maximum
Ca, %	233	37.7	2.0	29.1	40.1
Mg, mg/kg	175	5,810	11,752	318	108,858
Fe, mg/kg	175	1,145	3,033	31	33,373
Zn, mg/kg	175	20.9	49.2	< 10	467

Broiler trials to correlate limestone in vitro solubility with in vivo digestibility

Apparent ileal digestibility of calcium from limestone predicted using particle size (GMD, mm) and limestone solubility at 15 and 30 minutes. $R^2 = 0.99$



Kim et al., 2019

Standardized ileal digestible Ca in meat and bone meal

Table 5
Linear relationship between digesta calcium outputs (g/kg of DMI) and dietary calcium concentrations (g/kg DM) of the three meat and bone meal samples.

	Regression equation[a]	SE of the slope[b]	SE of the intercept[b]	r^2	Endogenous Ca losses (g/kg DMI)	Digestibility coefficient[c]
MBM-1	$Y = 0.3999X + 0.2923$	0.05	0.21	0.82	0.292	0.60^{y}
MBM-2	$Y = 0.5369X + 0.1226$	0.04	0.25	0.93	0.123	0.46^{z}
MBM-3	$Y = 0.5027X + 0.174$	0.03	0.20	0.95	0.174	0.50^{yz}

±23%

Regression method was used in the present study to determine the true ileal Ca digestibility of MBM. A strong linear relationship between dietary Ca concentrations and digesta Ca output indicated that regression method can be successfully used for the estimation of true Ca digestibility of MBM. The true Ca digestibility coefficients of the three MBM samples ranged between 0.46 and 0.60, but this variability cannot be attributed to the contents of ash, Ca and bones or particle size.

Table 4. True ileal calcium digestibility coefficients of three meat and bone meal (MBM) samples as influenced by methodology.[1,2]

	MBM-1	MBM-2	MBM-3	Probability P≤
Direct method	0.560^{a}	0.446^{b}	$0.517^{a,b}$	0.05
Regression method[3]	0.600^{a}	0.463^{b}	$0.497^{a,b}$	0.05

[a–c]Values with a different superscript in a row differ significantly ($P < 0.05$).

[1]Data were subjected to two-way analysis of variance.

[2]MBM effect, $P < 0.05$; method effect, $P > 0.05$; MBM x method, $P > 0.05$.

[3]From Anwar et al. (2015). The same MBM samples were evaluated in both studies.

Anwar et al. (2015, 2016)

Digestible calcium requirements for broilers from hatch to day 42

Updated: Jan 2023

Phase	Stater phase (day 0 to 14)			Grower phase (day 11 to 24)			Finisher phase (day 25 to 42)		
Criteria	BW gain	Tibia ash	ATTR P	BW gain	Tibia ash	ATTR P	BW gain	Tibia ash	ATTR P
Estimated dgCa requirement, %	0.47	0.54	0.49	0.36	0.51	0.42	0.25	0.38	–
Mean	**0.50**			**0.43**			**0.32**		

dgCa:dgP[1]	1.25	1.05	0.91
dgCa:nPP[2]	1.04	0.99	0.82
dgCa:avP[3]	1.04	0.99	0.82
References	Walk et al., 2021 (Poult. Sci. 100:101364) Walk et al., (PSA abstract, July 2022)	Walk et al., 2022 (Poult. Sci. 101:101836) Walk et al., 2022 (LATAM PSA, Oct 2022)	Walk et al., 2022 (Poult. Sci. 101:102146) Walk et al., 2022 (accepted ESPN, June 2023)

[1] CVB coefficients for digestible phosphorus.

[2] Calculated from total phosphorus minus phytate phosphorus.

[3] Aviagen guidelines.

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Digestible calcium requirements for broilers

In vitro solubility (%), 15 minutes	Limestone Ca digestibility coefficient, %	Estimated Ca requirements for broiler chickens using tibia ash*, hatch to day 10/14			Reference
		dgCa, %	tCa, %	dgP, %	
69	0.56	0.53	1.06	0.48	Walk et al., 2021b
96	0.70	0.54	0.89	0.43	Walk et al., 2023
–	0.55	0.45	0.95	0.50	David et al., 2021
–	–	0.61	1.00	0.53	Angel, 2017 (FEDNA)

* Values represent the maximum response from quadratic models.

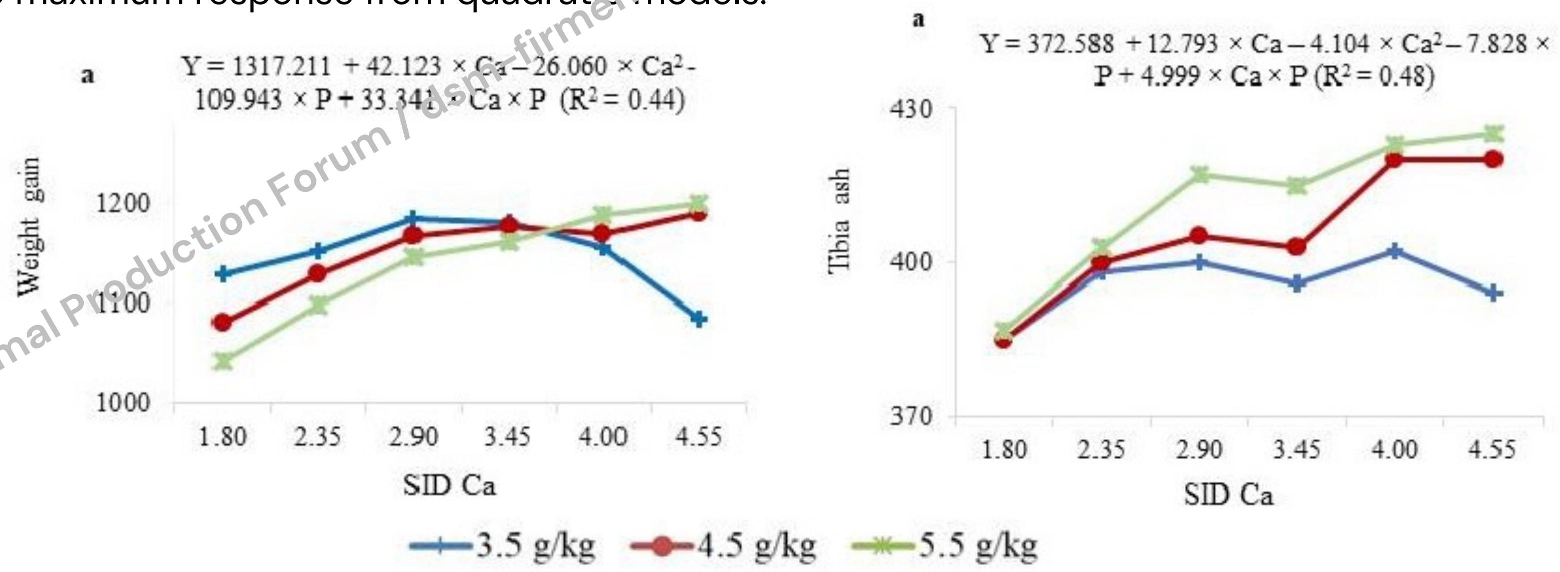
Possible reasons for the different estimated requirements between the experiment stations:

1. Ingredient digestibility coefficients differ between the experimental labs → working to understand this
2. Different prediction models and concentrations of dgP, dietary phytate and/or phytase in the experimental diets
3. Limestone sources (particle size, solubility, trace minerals, Ca content, rock-type)

Digestible calcium requirements for broilers

In vitro solubility (%), 15 minutes	Limestone Ca digestibility coefficient, %	Estimated Ca requirements for broiler chickens using tibia ash*, day 11 to 24			Reference
		dgCa, %	tCa, %	dgP, %	
69	0.56	0.515	0.95	0.41	Walk et al., 2022
–	0.55	0.369	0.73	0.35	David et al., 2022
–	0.55	0.455	0.90	0.55	David et al., 2022

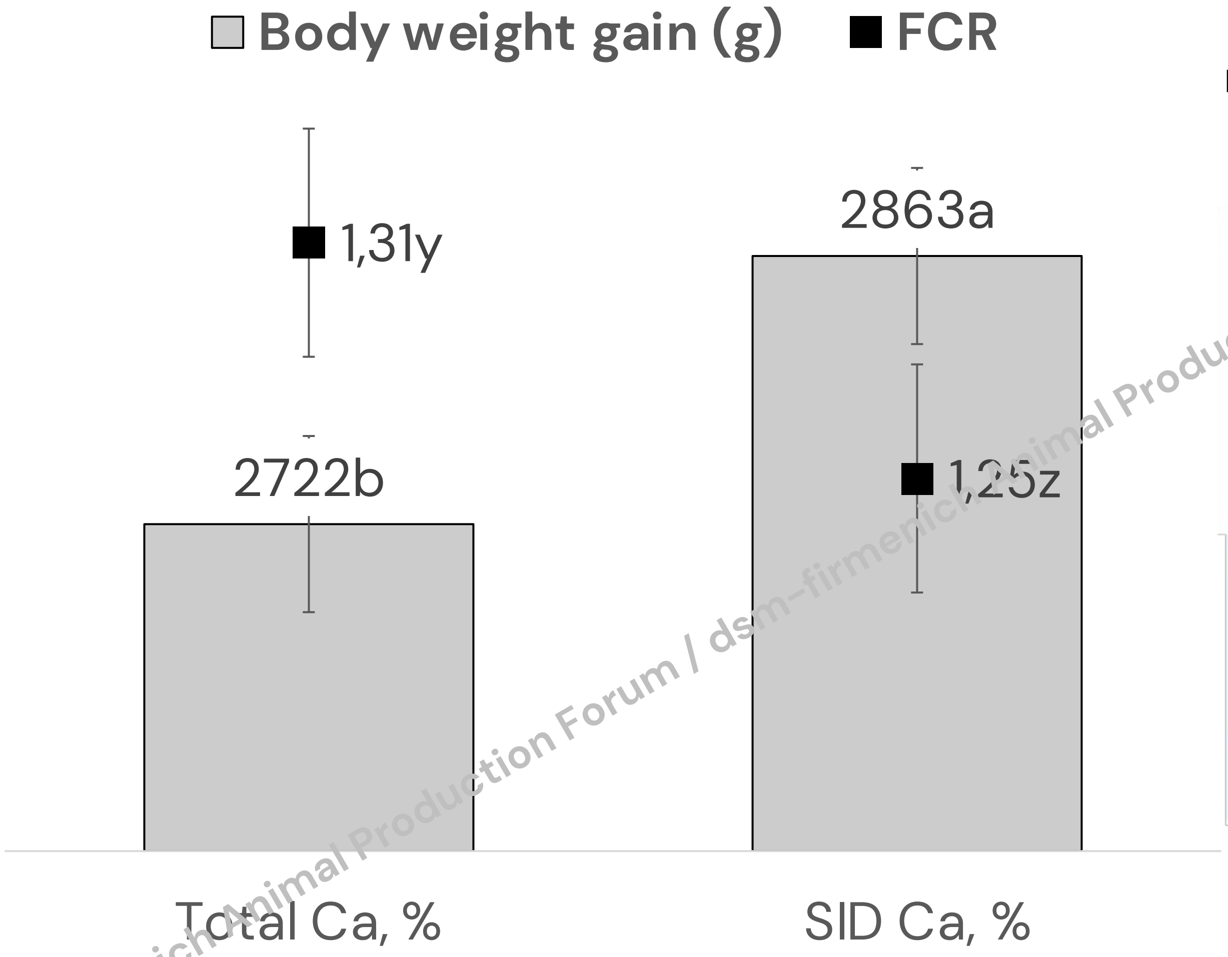
* Values represent the maximum response from quadratic models.



David et al., 2022

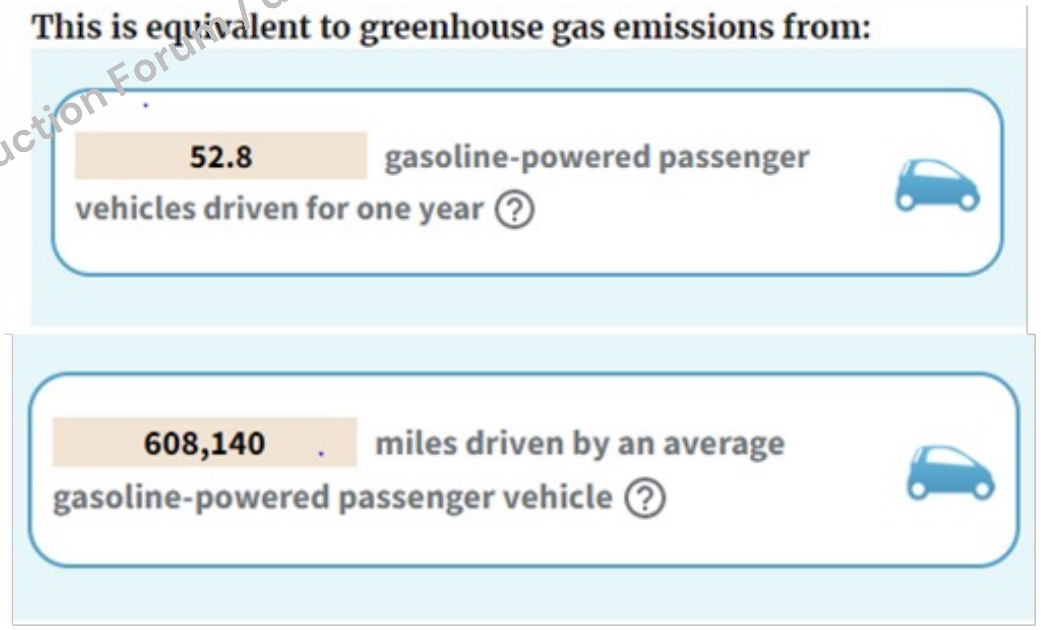
Why move to standardised ileal digestible (SID) calcium in broilers?

Formulating broiler diets **using SID Ca vs total Ca significantly improved BWG and FCR** from hatch to day 36



Live wt cost	$1.50/kg	$1.39/kg

Formulating diets using digestible Ca **reduced** the impact of broiler production on **climate change** by an average of **3.5%**



*assuming a 1 million broiler operation.

Walk et al. 2022

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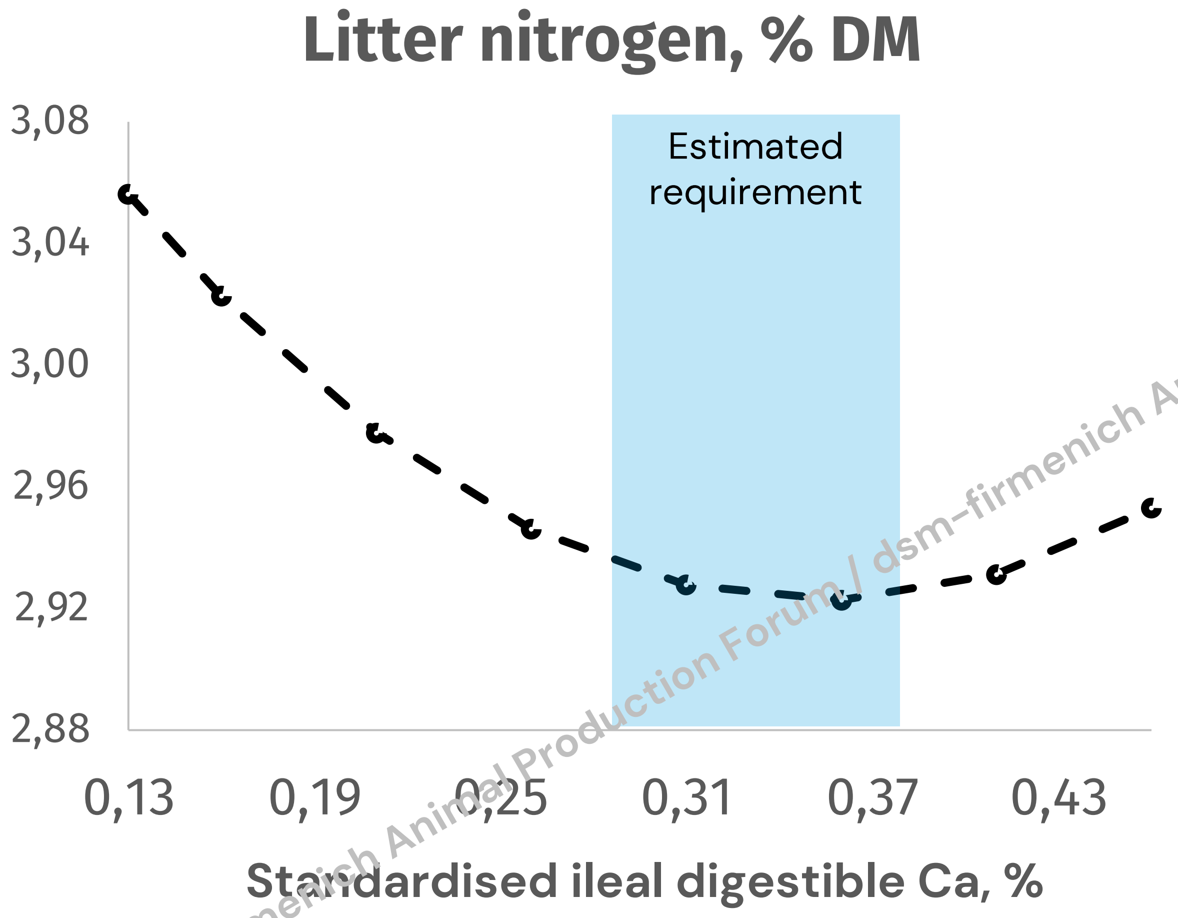
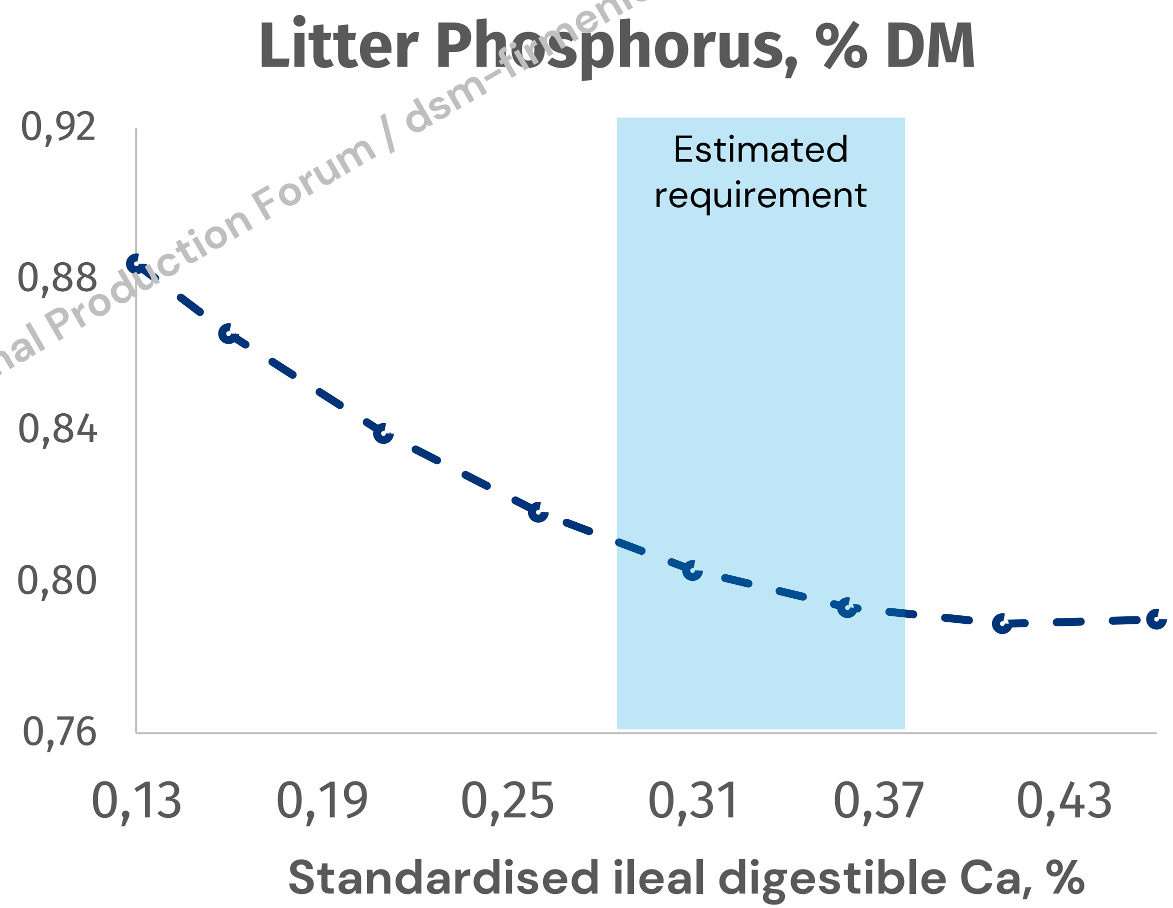
Why move to standardised ileal digestible (SID) calcium in broilers?

Meeting the SID Ca requirement of finishing broilers (25 to 42 days of age) **significantly decreased nitrogen** and **phosphorus excretion**





Walk et al., 2022

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Summary and next steps:

Considerable information available on digestible Ca

- Questions remain and work continues → method development, ingredient quality, nutrient recommendations, new models,...
- Accurate inclusion of Ca-containing ingredients in diets is critical for implementation of digestible Ca and HiPhorius
- Limestone quality can be measured and incorporated to implement digestible Ca and HiPhorius matrix recommendations.

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- Accurate inclusion of Ca-containing ingredients in diets is critical for implementation of digestible Ca and HiPhorius
- Limestone quality can be measured and incorporated to implement digestible Ca and HiPhorius matrix recommendations.

What can we do today?

- Measure total Ca in your ingredients (inorganics, MBM, premixes)
- Measure particle size and solubility of your limestones
- Include dgCa coefficients in your formulations – compare with tCa
- Consider the phytate content of your diets and how this could influence Ca digestibility
- De-phytinize your diets with high doses of an efficient phytase

Formulating diets using digestible Ca:

⇧ weight gain by 4.9%

⇩ FCR by 6 pts

⇩ feed costs by €1.60 per MT

⇩ cost by 0.11 USD per kg live weight

Welfare

Longevity

Economics

=

Requirements were developed to optimise gain, P-retention, skeletal development, or economics

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