“Strategies to Improve Keel Bone Strength and Skeletal Integrity of Laying Hens in Various Housing Systems”

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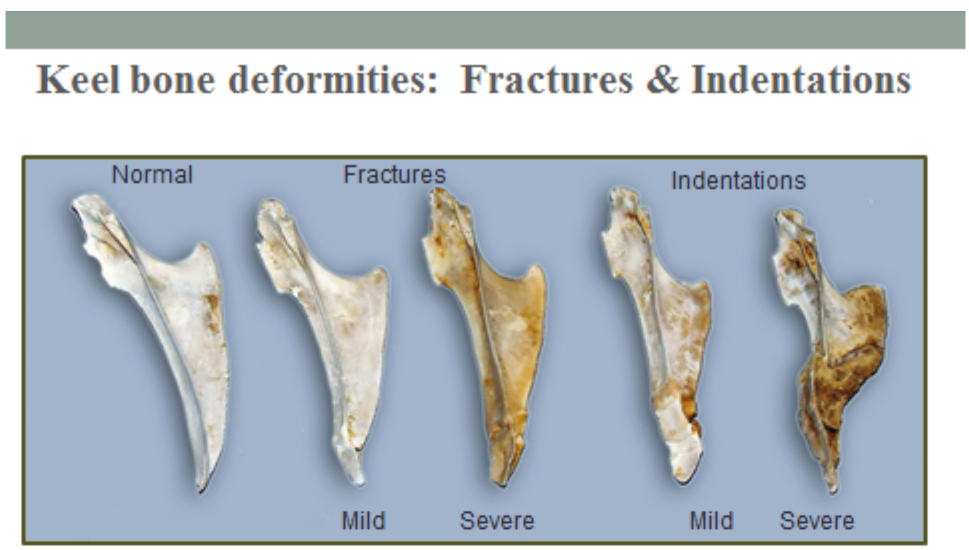
Conversion of poultry housing facilities to cage free systems escalated to unprecedented levels late 2015 due to consumer/retailer demand for cage free eggs. One of the major welfare issues facing the egg industry is the high incidence of keel fractures or deformities in alternative and cage housing systems. Bone fractures are not only welfare concerns but also can negatively affect egg production (Nasr et al., 2013). In particular, keel fractures account for 90 % of bone breaks in alternative housing systems at end of lay (Wilkins et al., 2004).



From: Wilkins et al. (2012)

Past studies to improve skeletal integrity have focused on manipulation of environment and nutrition during the layer phase; however, by this stage it may be too late to improve bone quality and reverse the onset of osteoporosis. Pullets reach their mature frame size by 12 wk of age, with subsequent formation of medullary bone that eventually constitutes up to 19 % of total body ash (Kwakkel et al., 1993). The modern pullet experiences low feed intake at the onset of lay and has the genetic potential to come quickly into peak production; substantial body reserves at the onset of production are indispensable to achieve satisfactory hen performance.

Strategies to improve bone quality and shell strength in the modern laying hen in today's new housing systems may include:

1. Feeding Large Particle Limestone during the Pullet Growth Cycle
2. Moderating the Ca: P ratio of pullet rations
3. Increasing level of Calcium fed in pullet and layer rations
4. Supplemental free choice calcium in floor pen systems

Such programs have been the subject of research at the University of Nebraska for the past 6 years and will be reported on in this presentation.

Study 1. Evaluation of limestone particle size (LPS) in two strains of laying birds housed in conventional cages or aviaries on bone integrity.

Lohmann Brown and Bovan White chicks were started in equal numbers on the floor or in battery brooders and were intermingled throughout all subsequent housing systems. At 5 wk of age, 432 floor-raised pullets were moved to 8 aviary cages. At 10 wk, 256 battery-raised pullets were transferred to 64 conventional layer cages. Pullets were given diets containing fine (**LPS-FINE**, 0.431 mm) or a blend of fine and coarse (**LPS-BLEND**, 0.879 mm) LPS from 7 to 17 wk. LPS- Fine and LPS-Blend were procured from Iowa Limestone Resources in Weeping Water, Nebraska. Hens received the same layer diet from 18 to 54 wk. Diets were formulated to have the same nutrient specifications and provided in mash form. All diets contained phytase.

Tibia bone mineral density (**BMD**) was determined using a dual energy x-ray absorptiometry. Presence of keel indentations, curvatures, or fractures was recorded.

LPS-BLEND increased BMD (0.215 vs. 0.208, $P = 0.03$) at 18 wk. Caged pullets also had greater BMD than the Aviary birds at 18 wks and White strain hens had more BMD compared to Brown strain hens. During the pullet phase, the odds of pullets fed LPS-FINE displaying keel curvatures were 2.8 times the odds of those fed LPS-BLEND ($P = 0.04$). During the layer phase, hens fed the blended LPS as pullets laid eggs with heavier shells (7.39 vs. 7.49 g; $P = 0.05$). At 54 wk, hens fed LPS-BLEND as pullets had lower odds of keel indentations ($P = 0.02$). Taken together, feeding LPS-BLEND to pullets improved bone mineralization at the onset of sexual maturity and reduced keel damage during the pullet and layer phases, regardless of strain.

Table 1. Limestone particle size fed to pullets, housing system and strain effects on tibia bone mineral density[1] (BMD), bone mineral content[1] (BMC) and area[1] at 13 and 18 wk of age

Treatments	13 wk			18 wk		
	BMD (g/cm^2)	BMC (g)	Area (cm^2)	BMD (g/cm^2)	BMC (g)	Area (cm^2)
Limestone particle size						
Fine	0.172	1.81	10.45	0.208[b]	2.57	12.31
Blend	0.174	1.82	10.40	0.215[a]	2.68	12.39
	(0.002)	(0.02)	(0.12)	(0.002)	(0.05)	(0.15)
Housing system						
Cage	0.171	1.79	10.41	0.215[a]	2.57	11.87[b]
Aviary	0.175	1.84	10.44	0.208[b]	2.68	12.83[a]
	(0.002)	(0.03)	(0.13)	(0.002)	(0.06)	(0.16)
Strain						
Brown	0.172	1.87	10.82	0.198[b]	2.40[b]	12.09
White	0.174	1.75	10.04	0.225[a]	2.85[a]	12.61
	(0.004)	(0.07)	(0.33)	(0.004)	(0.12)	(0.34)
Source of variation	*P*-values					
Strain (S)	0.779	0.370	0.229	0.004	0.062	0.435
Housing system (HS)	0.196	0.191	0.890	0.061	0.207	0.001
Limestone particle size (LPS)	0.424	0.875	0.780	0.034	0.177	0.743
HS×S	0.023	0.182	0.973	0.191	0.473	0.688
LPS×S	0.592	0.613	0.625	0.540	0.939	0.442
LPS×HS	0.610	0.434	0.792	0.173	0.421	0.848
S×HS×LPS	0.369	0.908	0.369	0.435	0.830	0.305
BW	0.096	0.025	0.159	0.0002	0.0003	0.0004

[a-b] Means within the same column lacking a common superscript differ ($P \leq 0.05$).
[1]Values were adjusted by BW recorded at the time of scan.
[2]N = 16.
[3]A total of 14 (7 White and 7 Brown) pullets from each aviary unit and a total of 8 (4 White and 4 Brown) pullets from each cage group were sampled at 13 and 18 wk of age.
[4]Values in parentheses are SEM.
[5]S = Strain, HS = Housing system; LPS = Limestone particle size fed to pullets

Study 2. Effects of Limestone Particle Size and Dietary Phosphorus during the Pullet Period on Layer Bone Health and Eggshell Strength.

The objective of this experiment was to evaluate two limestone particle sizes (LPS) and dietary phosphorus level (P) fed to pullets from 5 to 18 wk of age housed in litter floor pens. At 1 day of age, 600 Bovan White pullets were housed in 12 floor pens (50 pullets/pen; 929 cm^2/ pullet). Floor pens contained perches, nest area, feeder tubes, and nipple drinkers. All chicks were fed the same ration to 5 weeks of age. Dietary treatments started at 5 wks; pullets were fed grower (5-14 wk, 0.35 vs. 0.25 % Av. P) and developer diet (15-18 wk, 0.30 or 0.20 % Av. P) including either a fine (F, 0.431 mm) or a blend (B) of fine and large particles (0.878 mm) of limestone (ILC).

Figure 1. Interaction between LPS and P on BW

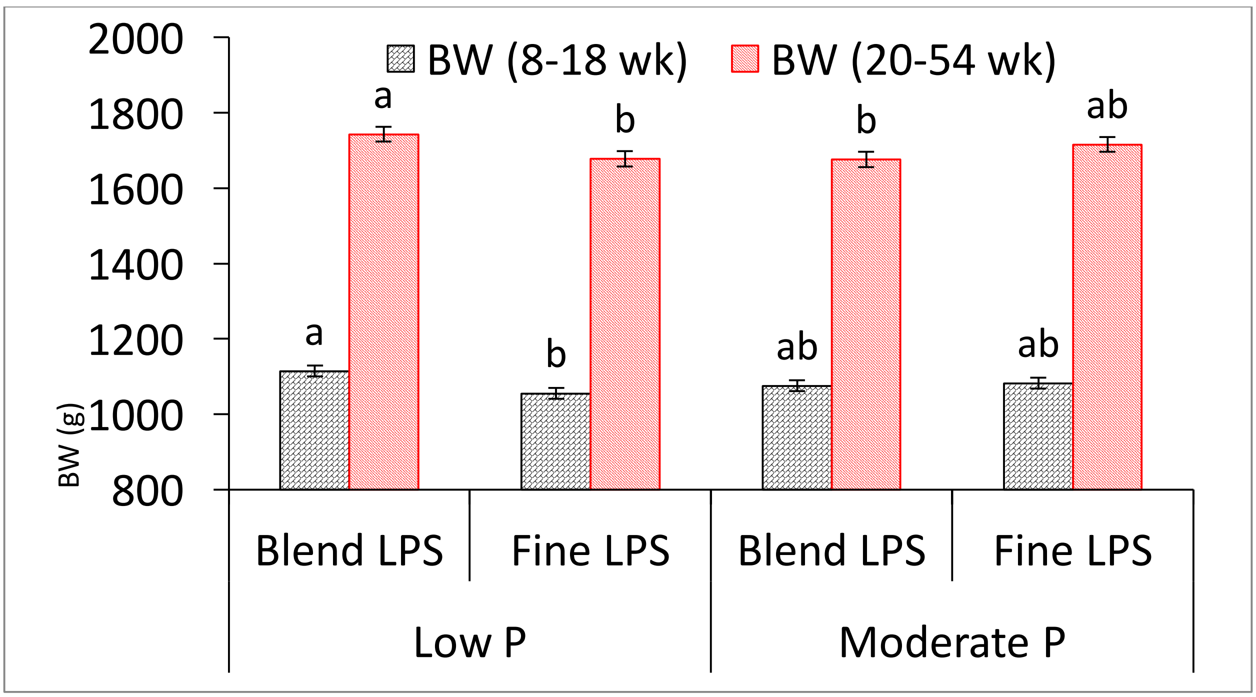
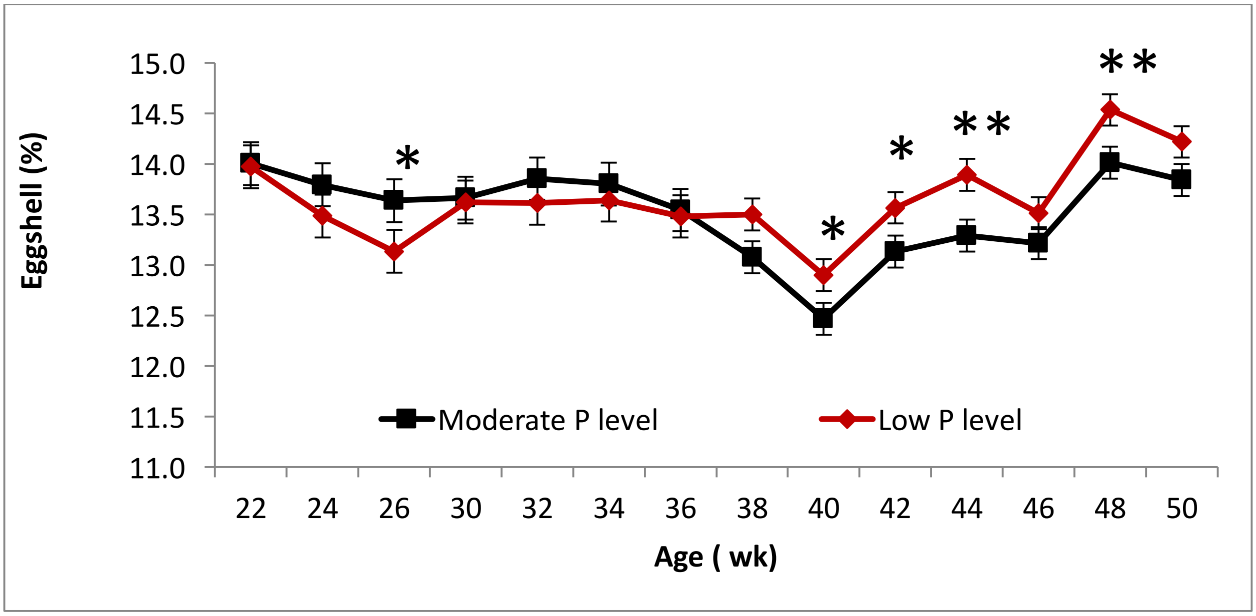


Figure 2. Interaction Between P level and time on % Egg Shell



Feeding blend LPS to pullets increased BW during the pullet and layer phase only when low P levels were fed to pullets. The use of low levels of P during the pullet phase improved late eggshell %. The inclusion of different levels of P and LPS did not affect keel bone deformities incidence in the one-tier cage-free housing system. When pullets were fed moderate P, pullets fed B-LPS had higher bone area than those fed F-LPS at 14 wk ($P = 0.07$). There were no effects on keel bone problems ($P > 0.10$).

Table 2. Interaction between LPS and P level on Bone Characteristics (14 WOA)

Phosphorus Level	Limestone Particle Size (LPS)	Bone mineral Density g/cm2	Bone Mineral Content grams	Bone Area Cm2
Low	Blend	0.1672	1.42	8.53
Low	Fine	0.1667	1.45	8.67
Moderate	Blend	0.1663	1.48	8.92
Moderate	Fine	0.1686	1.42	8.55
p-value		NS	NS	0.07

Study 3. Increasing Dietary Calcium during Pullet Grower/Developer Phases and Layer Period through Peak Production

Dietary treatments: Hens were given isocaloric and isoprotein diets containing either standard (STD) or increased dietary Ca and P (CaP+) levels from 7 to 52 wk of age.

Table 3. Dietary Treatments

	Grower 7-10 wks	Grower	Developer 11-15 wk	Developer	Prelay 16-17 w	Prelay	Lay	Lay
Ca, %	1.00	1.45	0.95	1.43	2.40	3.60	4.01	5.01
AP,%	0.48	0.65	0.41	0.62	0.45	0.68	0.40	0.50
Ca/P	2.1	2.2	2.3	2.3	5.3	5.3	10	10

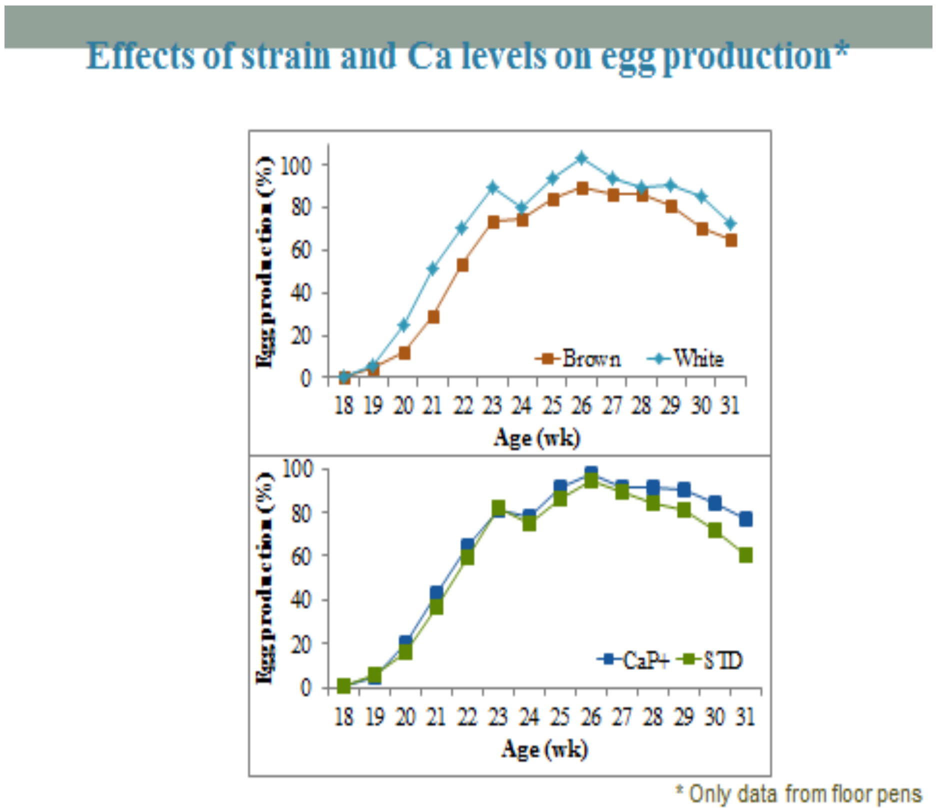


Figure 3. Trial 3. Strain and Ca/P effects on Egg Production

Strain of hen and level of dietary Ca/P affected egg production regardless of housing. White hens consistently produced more eggs than the Browns and hens fed diets with supplemental Ca and P produced more eggs and were more persistent in lay after peak production. Egg weights were positively increased during early lay due to increased levels of Ca/P.

Figure 4 shows the significant interaction effect of housing system and strain of hen on the incidence of keel bone deformities. Brown hens housed in the aviary systems had the highest rate of keel bone deformities averaging over 10% followed by white hens in either cages or aviaries averaging over 4% incidence of keel bone indentations. Brown caged hens had very little keel bone deformities. Figure 5 shows the effects of housing and dietary Ca/P supplementation on eggshell breaking strength. The effects of Ca/P supplementation were more marked early on in hens housed in cages. Floor pen housed hens did not show much benefit to supplemented Ca/P on eggshell strength.

Figure 4. Trial 3. Effects of strain and housing on Keel Bone Deformities

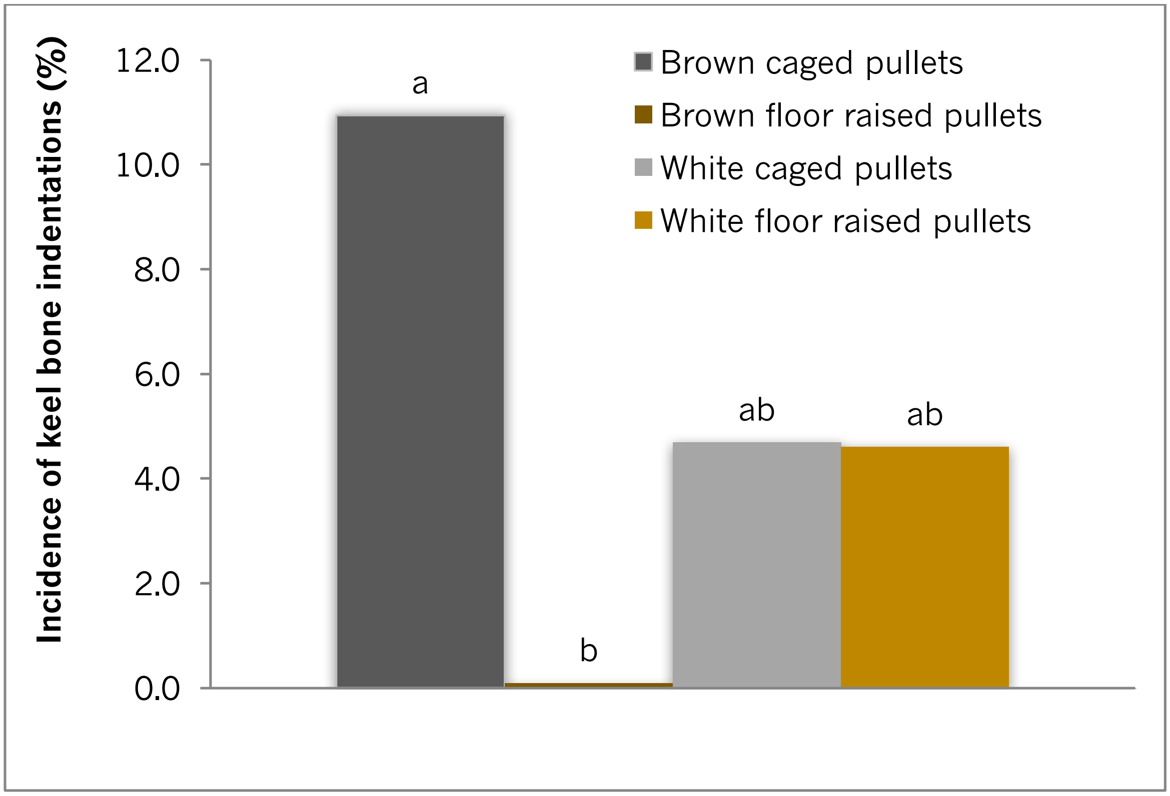
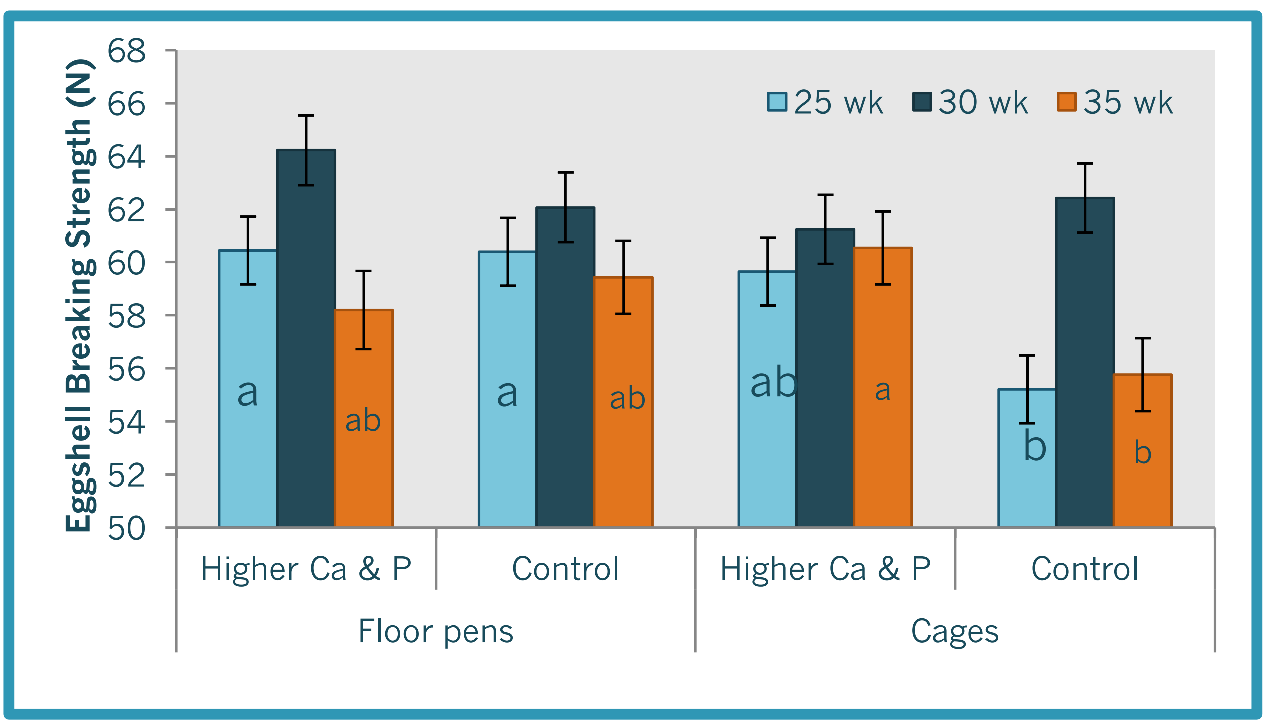


Figure 5. Study 3. Effects of age, housing and Ca/P on Eggshell Breaking Strength



Study 4. Supplemental Free Choice Calcium from Oyster Shell in Aviary Pens

This study started Summer 2015 with Hyline Brown hens in Big Dutchman Aviary units. Supplemental oyster shell is offered free choice in small feed pans to the hens and replenished biweekly. Below is a picture of the hens right after the feed pan has been filled. They love it and are anxious to eat fresh shell. Some dust bathe in it as well. Measurements of keel bone deformities, eggshell strength and bone mineral density are being made in the hens during this trial.

Summary: More attention needs to be paid to the mineral nutrition program of young developing pullets as they go through their developer and early lay stages to improve bone health. Providing large particle limestone during the pullet growth stages improves long term bone health and possible eggshell quality. Cage free housing systems offer new options for supplementation of calcium in non-traditional formats that may also improve shell quality, bone health as well as being a housing enrichment.

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