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PHOSPHORUS RETENTION MATERIALS IN OUTDOOR LAYING HEN PADDOCKS FOR REDUCED ENVIRONMENTAL IMPACT AND INCREASED NUTRIENT USE EFFICIENCY

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Abstract: This study investigated phosphorus (P) retention materials of sand and limestone outside houses in paddocks for organic laying hens, as a measure to retain P and reduce leaching.

When manure P, accumulated in the materials during 6 months, was exposed to rain simulations in a lysimeter study, P concentrations in drainage water were high from all treatments (58-136 and 130-197 mg L^{-1} of PO_4-P and total-P respectively). On average, 14% of the manure P, captured in the materials was leached after 100 mm of simulated rainfall.

The conclusion is that these materials may efficiently retain P during the outdoor season (May to October), but in order to reduce the risk of losses to waters during the following winter they need to be removed from the paddocks, preferably to arable fields. The materials can be regarded as potential P fertilizers and may thereby combine increased P use efficiency and environmental performance of organic outdoor poultry systems.

Introduction: Organic egg production enterprises face new challenges to combine animal welfare and environmental issues when giving the hens access to outdoor paddocks. Organic eggs are highly demanded in Sweden, but the authorities have insufficient knowledge for making accurate environmental risk assessments of nutrient leaching from paddocks, and for suggesting appropriate measures. This study investigated 2 types of P-retention materials (sand and limestone) outside houses for laying hens, as a measure to retain P and reduce leaching. The materials were selected based on different criterias, including P retention capacity, compatibility with regulations, cost, egg production, and animal health. The limestone material was hypothesized to work as a filter for chemical binding of P, while the sand as a physical filter. This paper focuses on environmental performance, while results on animal distribution within the paddocks are presented in a companion paper by Salomon et al. in these proceedings.

Material and methods: A bed of sand or limestone ($CaCO_3$), both with a diameter of 0-4 mm, was placed just outside the entrance (0-3.3 m) of the hen house with a thickness of 0.2 m. This was done in April 2018, in an experimental facility with small paddocks (3.4 * 20 m). Nine paddocks, i.e. 3 replicates, including a control with gravel bed (8-12 mm) outside the house, were used for 9 groups of young laying hens (*Gallus gallus domesticus,* breed Bovans Robust*),* 76 birds in each (1.1 m^2/bird). Production parameters were continuously recorded. The distribution of hens within each paddock was observed daily using a protocol, during the 6 month outdoor season (May 1-October 31). For this, the paddocks were divided into three areas; 0-3.3, 3.3-6.8 and 6.8-19.9 m, respectively. In October, lysimeters (0.2 m in diameter and 0.2 in depth) were collected of the sand, limestone and gravel materials, two from each paddock, i.e. 6 from each treatment. The lysimeters were placed in an indoor rainfall simulator, and exposed to rain simulations, corresponding to 25 mm (5 mm/hr) during 4 days, in total 100 mm. This was supposed to represent common autumn rains. Drainage water from each daily event was collected and analysed for total-P and PO_4-P. Total-P concentrations were determined colorimetrically on unfiltered samples after oxidation with sulphuric acid and potassium persulphate. The concentrations of PO_4-P were determined on filtered samples (0.2 µm) without oxidation. The P-retention materials were analysed for content of total-P and P extracted with ammonium lactate (P-AL, easily soluble P) according to Egnér et al. (1960). Phosphorus sorption capacity was determined by P adsorption isotherms (Bolster and Hornberger, 2007). The three sub-areas in each paddock were also sampled for analysis of P-AL before and after the outdoor season. This is the common soil P analysis in Sweden for estimation of plant-available P (easily soluble) in the soil. All analyses were made at the Department of Soil and Environment at the Swedish University of Agricultural Sciences. Statistical analyses of P concentrations in drainage water and materials, and of soil P in the paddocks were made with ANOVA analyses (one-way and 3-way, respectively). The study was financed by the Swedish Farmer´s Foundation for Agricultural Research.

Results: The amounts of hens staying outside were considerable and varied with distance from the hen house, but the distribution of hens within the paddocks was not affected by the treatments (see companion paper by Wahlund et al. in these proceedings). The materials placed in the paddocks were intensively used by the hens. Measurements of easily soluble P (P-AL) in the soil of the paddocks revealed that there was an accumulation of P with manure in all 3 zones from May until October, but also that there was a difference between zone 2 and 3, Figure 1. Zone 3, i.e. beyond 7 m from the hen house, had significantly lower values for easily soluble P than within the first 7 m. This indicates that this could be the area where a P-retention material would be needed, under the circumstances in this specific study, with small groups and a high animal density in the paddocks.

Phosphorus adsorption isotherms (adapted to Langmuir) revealed that the sand had very small P binding capacity (Smax=170 mg kg^{-1}), while limestone had much higher capacity (Smax=10800 mg kg^{-1}). Despite this, exposure to rain simulation events resulted in very high P concentrations in water draining from the lysimeters, and considerable leaching losses from both sand and limestone materials. Obviously, the limestone did not protect against P losses, despite high theoretical adsorption capacity. There were no significant differences in drainage water concentrations between the two materials. Mean concentration of PO_4-P in water drained from the control (gravel) was lower than from sand and limestone, Table 1. However, concentrations of PO_4-P from gravel material were highest after the first rain event and then decreased, while the dynamics were the opposite for the others. Both soluble and particulate P was more efficiently washed out from the gravel and some was probably lost already during the season. PO_4-P constituted 40% of total P in water draining from the gravel lysimeters, while 65% in the others. On average, 14% of the manure P, captured in the materials of sand and limestone was leached after 100 mm of simulated rainfall.

*Table 1. P concentrations in drainage water from lysimeters exposed to four rain events (4 * 25 mm). Superscript letters indicate significant differences between treatments ($p<0.05$), and standard deviations are given within brackets*

	Drainage water, P concentrations mg L^{-1}					
	PO_4-P	*PO_4-P*	*PO_4-P*	*PO_4-P*	*PO_4-P*	*Total P*
	Event 1	*Event 2*	*Event 3*	*Event 4*	*Mean*	*Mean*
Sand	97 (18) [a]	135 (45) [a]	161 (69) [a]	150 (68) [a]	136 (56) [a]	197 (71) [a]
Limestone	86 (49) [a]	132 (63) [a]	133 (75) [a]	110 (59) [a]	115 (61)[a]	163 (75) [ab]
Control	95 (25) [a]	30 (16) [b]	46 (27) [a]	59 (27) [a]	58 (33) [b]	130 (36) [b]

Figure 1. Mean values of the amount of easily soluble P in May and in October, in P-retention materials of sand and limestone in zone 1 and in the soil of zone 2 and 3. The materials contained no P in May 1. Significant differences between May 1 and October 31 and between zone 2 and 3 are indicated by different letters ($p<0.05$).

Discussion: The P-retention materials retained manure P during the summer, which was very dry this year. However, P accumulated showed to be highly vulnerable to losses when exposed to wet conditions, like in autumn, and concentrations of P on drainage water were very high. A lysimeter study like this, where there is no percolation of water through a subsoil, represents a worst case scenario for the system. These materials worked as a physical filter for P during the outdoor season, but in order to reduce the risk of losses to waters during the winter they need to be removed in autumn, preferable to arable fields. There was a substantial accumulation of P with manure, especially within the first 7 m from the hen house, which suggests that P-retention materials should cover this area. These sand and limestone materials can be regarded as potential P fertilizers and may thereby combine increased P use efficiency and environmental performance of organic outdoor poultry systems.

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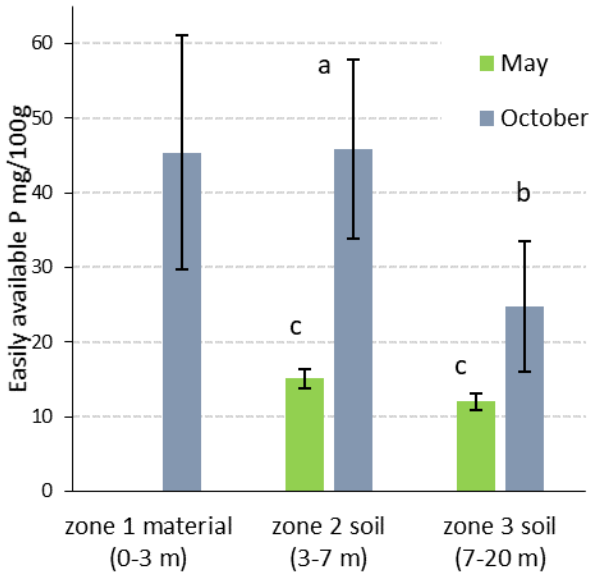
Image 2:



Disclosure of Interest: None Declared

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