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S2.3

Influence of Minerals on Litter Moisture

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Minerals that are required for weight gain and egg production can affect water intake and urinary output and hence litter moisture. Increased sodium, potassium and magnesium levels result in increased water intake and excreta moisture. The effect of these cations on water intake and excreta moisture increases with age and is dependent on the anion source. Effects of chloride on water intake and excreta moisture are less pronounced than those of sodium, potassium and magnesium. For chloride, effects on water intake and excreta moisture are dependent on the anion by which it is replaced. Increased calcium (in broiler chickens) and phosphorus (in laying hens) levels elevate water intake and excreta moisture. Incorrect calcium to phosphorus levels have a strong negative effect on litter quality, particularly in young broiler chickens.

Keywords: broiler chickens; laying hens; minerals; litter quality

Introduction

There is increasing interest in factors that affect excreta moisture and litter quality in poultry. An important reason for this is that welfare conditions will determine stocking density in future according to the EU broiler directive 2007/43/EC. These welfare conditions include the incidence of foot pad lesions and dermatitis. Litter quality is regarded as one of the major factors that affect foot pad lesions and dermatitis (Clark *et al.*, 2002; Mayne, 2005). Another reason for the increasing interest in litter quality is the fact that impaired litter quality is associated with dysbacteriosis in practice, which may result in the use of antibiotics. Moreover, an increase in excreta moisture content is associated with excreta and microbial contamination of eggshells (Smith *et al.*, 1999).

There are many factors that affect excreta moisture and litter quality (Butcher *et al.*, 2000; Collet, 2006; 2007; Shane, 2006). Minerals that are required to maintain osmotic pressure, anion-cation balance and bone strength are directly related with water intake and urinary output and hence with litter quality (Collet, 2006; Shane, 2006). The effects of these minerals will be discussed in this article. One complicating factor to improve litter quality by making changes in feed composition is that different parameters exist to describe litter quality and that these parameters are not always concurrent (table 1). It seems that dose-response studies provide better correlations between excreta moisture and visual litter score than other types of experiments. Another complicating factor is that also variables like age, stocking density, litter type and environmental temperature influence effects of feed composition on litter quality (Clark *et al.*, 2002; Mayne, 2005; Collett, 2007). This partly relates to differences in feed intake, excreta production and evaporation capacity (Collet, 2007). For example, the moisture content of fresh excreta can increase under heat stress conditions without negative effect on litter quality due to an increased evaporation of excreta moisture (table 2). Testing different feeds under thermo neutral conditions can therefore provide different conclusions than under heat stress conditions.

Table 1 Correlation between excreta moisture content and litter scores in broiler chickens in different experiments (internal data Nutreco)

Factor under study	Correlation between excreta moisture and litter score
Wheat in combination with different enzymes	0.20
Dose-response raw material inclusion	-0.61
Inclusion of different salts	-0.24
Dose-response sodium levels	-0.85

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Table 2 Effect of heat stress on excreta moisture content and litter condition at 31 days of age (internal data Nutreco)

Conditions	Excreta moisture content, g/kg	Litter score ¹
Thermo neutral	782 ^b	7.07 ^b
Heat stress ²	810 ^a	7.51 ^a

¹ a higher score indicates drier litter

² heat stress was induced by increasing temperature daily to 33 °C during 10 hours after 21 days of age

Sodium

An increase in dietary sodium level can result in increased litter moisture content and in impaired litter quality (table 3). The results presented in table 3 also indicate that the effect of increased sodium levels becomes clearer with age, as water and feed intake and excreta production per m² increase. Effects of sodium on litter quality also seem to be more pronounced during winter than during summer, as follows when results in table 3 and table 4 are compared. Enting *et al.* (1999) demonstrated that sodium levels do not clearly affect the capacity of excreta to lose moisture. This indicates that when evaporation is high due to high temperature and high ventilation speed, increased water intake due to increased sodium levels does not have to result in impaired litter quality. Bacteria activity in excreta is not influenced by dietary sodium levels, and it seems that particularly this activity has a negative effect on excreta moisture loss capacity (Enting *et al.*, 1999). Smith *et al.* (1999) observed increased bacterial numbers on ostensibly uncontaminated eggs with increased dietary sodium levels, but this was observed at sodium levels that are higher than those used in practice (5.0 to 15.1 g/kg). Effects of increased sodium levels on litter moisture seem to be dependent on health status; Hooge *et al.* (1999) did not observe increased excreta moisture in coccidiosis infected chickens.

At unchanged potassium and chloride levels, the increase in water to feed ratio due to increased sodium levels appears to be dependent on the sodium source: sodium bicarbonate resulted in a significantly higher water to feed ratio and litter moisture than sodium carbonate and sodium sulphate (table 5; Ahmad *et al.*, 2005). This might be due to differences in plasma osmolarity, which can influence the thirst centre (Borges *et al.*, 2004), and to changes in requirements during heat stress (Belay *et al.*, 1992). Due to its effect on osmolarity, betaine can partially counteract effects of sodium on plasma osmolarity (Honarbakhsh *et al.*, 2007). Ravindran *et al.* (2008) observed that phytase increases sodium availability in broiler chickens and it appeared that phytase has a sodium sparing effect (Ravindran *et al.*, 2008; Cadogan *et al.*, 2009). Therefore, it might be beneficial to assign a sodium value to phytase in feed formulation.

Table 3 Effect of dietary sodium levels on excreta moisture content and litter quality of broiler chickens during winter (internal data Nutreco)

Na, g/kg		0.9	1.3	1.7	2.4
Excreta moisture content, g/kg	day 15	794	796	794	803
	day 28	763 ^b	777 ^{ab}	795 ^{ab}	806 ^a
Litter score ¹	day 15	8.9	9.0	9.0	9.0
	day 28	5.2 ^a	5.3 ^a	5.0 ^a	4.6 ^b

¹ a higher score indicates drier litter

Table 4 Effect of sodium levels in grower and finisher feeds on water to feed ratio and litter quality of broiler chickens during summer (internal data Nutreco)

Na, g/kg	1.1	1.5	1.8	2.0
Water to feed ratio	1.69	1.70	1.71	1.74
Litter score ¹ , day 11	6.9	7.0	7.1	6.9
Litter score ¹ , day 28	6.1	6.3	6.3	6.0

¹ a higher score indicates drier litter

Table 5 Effect of the addition of different sodium salts on the water to feed ratio of heat stressed broiler chickens from 1 to 42 days of age (Ahmad *et al.*, 2005)

Treatment	Water to feed ratio	Litter moisture, g/kg
Control	3.152 ^d	204 ^c
NaHCO ₃	3.638 ^a	273 ^a
Na ₂ CO ₃	3.454 ^b	249 ^b
Na ₂ SO ₄	3.389 ^c	238 ^b

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Potassium

Increased potassium levels result in increased water to feed ratio, impaired litter quality (table 6) and increased excreta and litter moisture (Pesti *et al.*, 1999). As with sodium, the effect becomes clearer with age. Smith *et al.* (2000b) concluded that an increase in 1 g/kg potassium in layer diets provides a somewhat larger increase in excreta moisture content than an increase in 1 g/kg sodium (12.0 vs. 9.1 g/kg respectively). Pesti *et al.* (1999) found other increases of 14.1 and 26.0 g/kg respectively for each increase of 1 g/kg of potassium and sodium. At unchanged potassium, sodium and chloride levels, the potassium source seems to affect water to feed ratio and excreta moisture, as was found with sodium sources (table 7). Potassium bicarbonate results in higher water to feed ratio and excreta moisture than potassium carbonate and potassium sulphate (Ahmad *et al.*, 2005). The latter two salts hardly affected water to feed ratio, while potassium chloride provided a clear increase in water to feed ratio (Smith and Teeter, 1992). It does not seem to be required to adjust potassium levels when phytase is used, since potassium availability is not affected by phytase (Cadogan *et al.*, 2009).

Table 6 Effect of dietary potassium levels on water to feed ratio and litter quality of broiler chickens (internal data Nutreco)

K, g/kg	8.0	9.0	10.0	11.0
Water to feed ratio	1.44 ^b	1.61 ^{ab}	1.70 ^a	1.74 ^a
Litter score ¹ , day 14	9.3	9.4	8.7	8.9
Litter score ¹ , day 28	5.8	5.5	4.5	3.7

¹ a higher score indicates drier litter

Table 7 Effect of the addition of different potassium salts on the water to feed ratio of heat stressed broiler chickens from 1 to 42 days of age (Ahmad *et al.*, 2005)

Treatment	Water to feed ratio	Litter moisture, g/kg
Control	3.152 ^b	204 ^b
KHCO ₃	3.367 ^a	232 ^a
K ₂ CO ₃	3.175 ^b	207 ^b
K ₂ SO ₄	3.179 ^b	198 ^b

Chloride

Effects of chloride on litter quality seem to be less clear than those of sodium and potassium. Vogt (1971), Damron *et al.* (1986), Damron and Wideman (1992), Murakami *et al.* (1997) and Rezaei *et al.* (2004) did not observe an effect of chloride levels on excreta moisture. Murakami *et al.* (2003) found an increase in excreta moisture between 1.4 and 1.94 g/kg chloride in the diet and a slight decrease at higher chloride levels. Pesti *et al.* (1999) observed an increase in water consumption and excreta moisture content when dietary chloride level was increased. The observed increase in moisture content was comparable with that of sodium (23.3 g/kg per gram of chloride vs. 26.0 g/kg per gram of sodium). An increase in chloride intake by adding ammonium chloride to the drinking water resulted in an increase in water to feed ratio and excreta moisture (Ahmed *et al.*, 2005).

On the basis of own experimental data, it seems that effects of reduced chloride levels on excreta moisture are dependent on the mineral that is used to replace sodium chloride (table 8). A moderate reduction of the chloride level by substitution with bicarbonate or sulphate did affect excreta moisture and litter quality significantly, but a further reduction to about 1.5 g/kg resulted in a significant increase in excreta moisture when chloride was substituted by sulphate. In temperate temperature conditions, the sodium sulphate (0.1 %) treatment showed the lowest ammonia values as compared with sodium bicarbonate (15 vs. 20 mg/kg, P=0.09, De los Mozos and Mercier, 2007), which might be beneficial to prevent foot pad lesions (Kamyab, 2001). According to Cadogan *et al.* (2009), phytase does not affect chloride availability.

Table 8 Effect of different chloride levels on excreta moisture and litter score (internal data Nutreco)

Sodium source	Day 0-13		Day 14-43		Day 31 Excreta moisture, g/kg	Litter score ¹
	Na, g/kg	Cl, g/kg	Na, g/kg	Cl, g/kg		
NaCl	1.6	2.9	1.5	2.8	784 ^b	7.25
NaCl+NaHCO ₃	1.6	2.1	1.5	2.4	783 ^b	7.29
NaCl+Na ₂ SO ₄	1.6	2.2	1.5	2.3	797 ^b	7.39
NaCl+Na ₂ SO ₄	1.6	1.6	1.5	1.5	820 ^a	7.23

¹ a higher score indicates drier litter

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Magnesium

Leeson and Summers (2005) mentioned that dolomite limestone with high levels of magnesium can cause wet litter. Own experimental data indicate that increased magnesium levels result in increased water to feed ratio and in impaired litter quality (table 9). The effect of magnesium on water to feed ratio seems to be comparable with that of potassium on the basis of our own data (0.09 unit increase in water to feed ratio per gram of magnesium vs. 0.10 per gram of potassium). Gebert *et al.* (1999) observed that phytase increases magnesium digestibility, but Silva *et al.* (2005) did not find changed magnesium levels in faeces by varying phytase levels in the diets. Therefore, it might not be necessary to adjust dietary magnesium levels when phytase is used.

Table 9 Effect of dietary magnesium levels on water to feed ratio and litter quality of broiler chickens (internal data Nutreco)

Mg, g/kg	2.3	3.0	3.6	4.1
Water to feed ratio	1.80	1.80	1.89	1.96
Litter score ¹ , day 14	6.9 ^a	6.8 ^a	6.7 ^a	6.4 ^b
Litter score ¹ , day 28	6.8 ^a	6.4 ^a	4.7 ^b	4.5 ^b

¹ a higher score indicates drier litter

Calcium and phosphorus

On the basis of literature data, effects of calcium and phosphorus on excreta moisture seem to be different for laying and growing poultry. Chandra *et al.* (2004) did not observe changes in excreta moisture with increased dietary phosphorus levels in broilers, while an increase in water intake and excreta moisture was reported with increasing phosphorus levels in laying hens (Smith *et al.*, 2000b). The effect of 1 g/kg phosphorus on excreta moisture was about half of that of 1 g/kg sodium or potassium. These authors concluded that effects of minerals were approximately additive, which was also found by Hijikuro (1976). Changes in dietary calcium levels had no significant effect on water intake and excreta moisture content in laying hens (Roland and Caldwell, 1985; Smith *et al.* 2000b), while increased calcium levels negatively affected litter quality in broiler chickens. This negative effect appears to be more pronounced when phytase is used (figure 1), which is due to an increased calcium availability with phytase (Selle and Ravindran, 2007; Singh, 2008). Incorrect calcium to phosphorus ratios can compromise water retention and can cause wet litter (Wideman *et al.*, 1985; Pos *et al.*, 2003). The latter authors showed that decreasing calcium levels with the use of phytase improved litter quality significantly (table 10). In contrast to minerals like sodium and potassium, effects of incorrect calcium to phosphorus ratios on litter quality seem to decrease with age in broiler chickens (Pos *et al.*, 2003). Therefore, young birds seem to tolerate high calcium levels less well than elder birds.

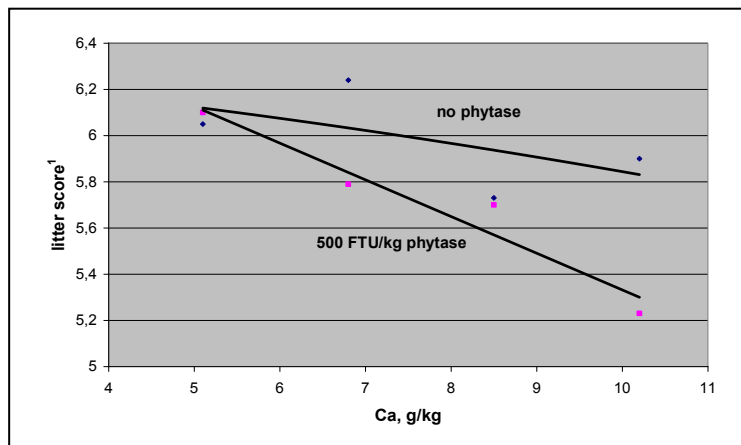


Figure 1 Effect of different calcium levels with and without phytase on litter score on 20 days of age

¹ a higher score indicates drier litter

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Table 10 Effect of addition of phytase to a low P broiler chicken diet and decreased dietary calcium levels on litter quality (Pos et al., 2003)

Litter quality ¹	Day 14	Day 21	Day 28
Positive control ²	7.7 ^a	7.1 ^a	5.8
Negative control, - 1.25 g/kg aP	5.3 ^d	6.1 ^b	6.2
Negative control, + 500 FTU /kg phytase	6.2 ^c	6.2 ^b	5.3
Negative control, + 500 FTU/kg phytase, - 0.8 g/kg Ca	6.9 ^{bc}	6.5 ^{ab}	5.6
Negative control, + 500 FTU/kg phytase, - 1.6 g/kg Ca	7.5 ^{ab}	6.9 ^a	5.4

¹ a higher score indicates drier litter

² according to CVB, 2003

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