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Water addition, evaporation and water holding capacity of poultry litter

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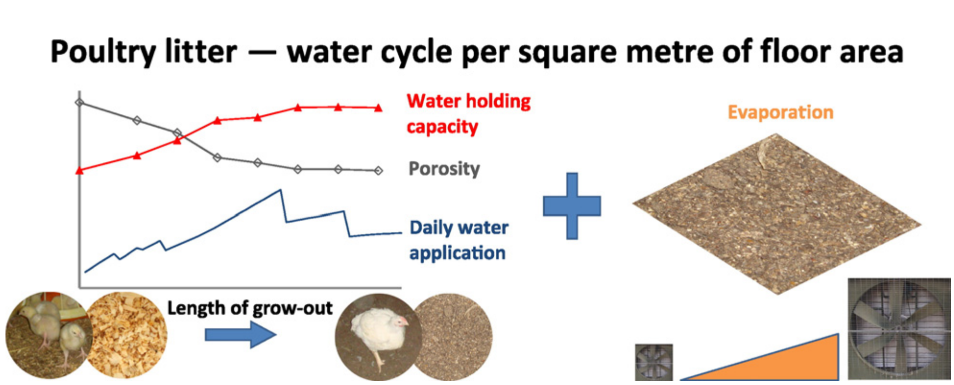
HIGHLIGHTS

- Water added daily to litter by meat chickens was estimated using an equation
- Water added to litter from excreta and spillage can be as much as 3.2 L/m^2/day
- Water holding capacity of litter increases during a grow-out cycle
- Water evaporation rate depends on litter moisture content and air speed

GRAPHICAL ABSTRACT



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ABSTRACT

Litter moisture content has been related to ammonia, dust and odour emissions as well as bird health and welfare. Improved understanding of the water holding properties of poultry litter as well as water additions to litter and evaporation from litter will contribute to improved litter moisture management during the meat chicken grow-out. The purpose of this paper is to demonstrate how management and environmental conditions over the course of a grow-out affect the volume of water A) applied to litter, B) able to be stored in litter, and C) evaporated from litter on a daily basis. The same unit of measurement has been used to enable direct comparison—litres of water per square metre of poultry shed floor area, L/m^2, assuming a litter depth of 5 cm. An equation was developed to estimate the amount of water added to litter from bird excretion and drinking spillage, which are sources of regular water application to the litter. Using this equation showed that water applied to litter from these sources changes over the course of a grow-out, and can be as much as 3.2 L/m^2/day. Over a 56 day grow-out, the total quantity of water added to the litter was estimated to be 104 L/m^2. Litter porosity, water holding capacity and water evaporation rates from litter were measured experimentally. Litter porosity decreased and water holding capacity increased over the course of a grow-out due to manure addition. Water evaporation rates at 25 °C and 50% relative humidity ranged from 0.5 to 10 L/m^2/day. Evaporation rates increased with litter moisture content and air speed. Maintaining dry litter at the peak of a grow-out is likely to be challenging because evaporation rates from dry litter may be insufficient to remove the quantity of water added to the litter on a daily basis.

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1. Introduction

Meat chickens are commonly raised in open-plan sheds with a litter covered floor. Litter is a mixture of bedding materials and manure that is used to provide a cushioning and insulating barrier between the birds and the ground. It needs to absorb moisture, dry readily, and allows birds to display natural behaviour such as scratching and dust-bathing (Shepherd and Fairchild, 2010; Collett, 2012). Control of litter moisture is complex and challenging due to environmental, economic, engineering and animal husbandry constraints (Tucker and Walker, 1992).

Litter moisture content has been found to influence ammonia emissions (Elliott and Collins, 1982; Liu et al., 2007; Miles et al., 2011), odours (Clarkson and Misselbrook, 1991; Murphy et al., 2014), dust (Roumeliotis et al., 2010), and health issues such as foot pad dermatitis (Bilgili et al., 2009; de Jong et al., 2012). Microbial populations flourish when litter has a moisture content greater than 35–40% (mass water/mass of litter), which can have consequences including increased odour production and greater risks to bird health and food safety (Eriksson De Rezende et al., 2001; Agnew and Leonard, 2003; Wadud et al., 2012). Moisture content also affects litter physical and handling properties including compressibility, compaction and cohesion (Agnew and Leonard, 2003; Bernhart and Fasina, 2009; Bernhart et al., 2010). Increased moisture content and compaction reduces thermal insulating properties and porosity resulting in anaerobic conditions and decreased pH (Agnew and Leonard, 2003).

Within a meat chicken shed, water is routinely added to the litter through excretion (faeces and urine, which in poultry are excreted simultaneously), spillage from drinkers, condensation, shed leaks and absorption from the air. Collett (2012) estimated that a flock of 20,000 birds can excrete up to 2500 L of water per day onto the litter.

Water is removed from litter by evaporation. Water removal can be enhanced with ventilation and litter turning (Collett, 2012). Specific knowledge of evaporation rates from litter is important for managing litter moisture but can also be related to diffusion rates of gases such as ammonia and other odorants from litter. Evaporation of water has been found to be representative of the emission of gas-phase controlled volatile organic compounds (VOCs), which includes many of the odorants identified as contributing to odour impacts (Hudson and Ayoko, 2008; Parker et al., 2010, 2013). The advantage of using water evaporation (water flux) instead of VOCs is the relative ease, low cost and accuracy of measuring water evaporation (Parker et al., 2013).

Understanding the relationships between water addition, storage and evaporation throughout a grow-out (otherwise known as a grow-out cycle or period; batch; or production cycle) will improve litter moisture management. The purpose of this paper is to highlight the volume of water that is A) applied daily to litter, B) able to be stored in litter, and C) evaporated daily from litter over the course of a grow-out and with different environmental conditions and management. In this paper, water quantities are expressed in the same unit of measurement for direct comparison (litres of water per square metre of poultry shed floor area, L/m^2, assuming a litter depth of 5 cm).

2. Materials and methods

Daily water additions to litter from bird excretion and normal drinking spillage were calculated using an equation that drew on empirically derived relationships between feed intake, water usage and water losses for commercial meat chickens. In separate experimental work, the volume of water stored in litter per square metre of floor area, water evaporation rates and litter porosity were measured.

2.1. Calculating litter wetting due to excretion and normal drinking spillage

An equation was developed to estimate daily application of water to litter from excretion and normal drinking spillage (Eq. (1)). It includes water inputs ($w_{drinking}$, w_{feed} and $w_{metabolic}$), retention (w_{growth}) and evaporation losses (w_{latent}) from each bird plus adjustments to account for stocking density, percentage of shed in use (relevant for part-shed brooding) and percentage of the flock remaining in the shed (relevant for when a percentage of the flock is harvested for slaughter during the grow-out). Water applied to litter was calculated on a square metre (m^2) basis (assuming a litter depth of 5 cm) to enable direct comparison of water addition to litter, storage within litter and evaporation from litter. Using this equation requires assumptions that normal spillage is small compared to the amount of water consumed and that the birds are healthy, have an optimal diet, and are in a thermo-neutral environment.

The following production values were used in this study. These values are commonly used on farms in the senior author's region, but any reasonable production values can be used in the calculations. Stocking density used in this example was 17 birds/m^2, with allowable maximum live mass density limited to 36 kg/m^2. The stocking density was varied during the grow-out to accommodate partial shed brooding and thinning. Partial-shed brooding in this example included using only 50% of the shed for days 1–6 of the grow-out, 66% of the shed for days 7–10 and 75% of the shed was used for days 11–14. This study also included flock thinning (a production process where a portion of the flock is removed from the shed for slaughter) by removing 33% of the flock on day 35, and 33% of the remaining flock on day 46 to maintain live mass density under 36 kg/m^2, with all birds removed for slaughter at the end of the grow-out on day 56. Feed consumption and growth rate data were averaged from as-hatched data for Ross 308 and Cobb500™ breeds.

$$w_{litter} = (w_{drinking} + w_{feed} + w_{metabolic} - w_{growth} - w_{latent}) \times \rho_{stocking} \div P_{shed} \times f_{remaining} \quad (1)$$

where:

w_{litter} is the water applied to litter through bird excretion and normal drinking spillage (L/m^2/day)

$w_{drinking}$ is the water used in the shed for drinking (including spillage) by each bird (L/bird/day) (Eq. (4))

w_{feed} is the water ingested by birds in the feed (L/bird/day) (assumed that feed has 10% moisture content, 100 g/kg 'as-fed' feed)

$w_{metabolic}$ is the water released during metabolism and available for excretion (L/bird/day) (Eq. (5))

w_{growth} is the amount of water retained by the birds (L/bird/day) (assumed water accounts for 70% of daily growth)

w_{latent} is the water evaporated from the bird during thermo-regulation (i.e. panting and losses through the skin) (L/bird/day)—under thermo neutral conditions this is assumed to be half of total available water: $w_{latent} = 0.5 \times (w_{drinking} + w_{feed} + w_{metabolic} - w_{growth})$

$\rho_{stocking}$ is the stocking density for the entire shed floor area (birds/m^2)

P_{shed} is the percentage of the shed in use in the case of part-shed brooding (%)

$f_{remaining}$ is the percentage of flock remaining after each thinning (%).

2.1.1. Estimating daily water consumption

Water consumption was related to feed intake using the water:feed ratio over the course of a grow-out (*wfr*, total water used in drinker lines divided by total feed consumed). The water used in drinker lines inherently includes water consumed by the birds plus normal drinking spillage. This ratio is typically 1.8 L/kg but can vary from 1.5 to 2.0 L/kg (Feddes et al., 2002; Collett, 2007; Manning et al., 2007). The water:feed ratio increases with temperature (Manning et al., 2007), stocking density (Feddes et al., 2002) as well as certain dietary imbalances, feed ingredients and health issues (Collett, 2012). It is also affected by type of drinker, with nipple drinkers (without evaporation cups) producing the lowest ratio (Manning et al., 2007).