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Research Paper

Reduction of ammonia emissions from dairy manure using novel urease inhibitor formulations under laboratory conditions

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Ammonia emissions from livestock manure can have detrimental effects on environment, health and reduce the value of the manure as fertiliser. A promising approach for reducing ammonia emissions from dairy farming is the use of urease inhibitors. They were tested in this study under standardised conditions in a laboratory set-up. Four selected inhibitors (designated D, L, K and E) were tested in concentrations of 0.01% and 0.1% of total Kjeldahl nitrogen (TKN) and at manure temperatures of 18 °C, 20 °C and 25 °C. At 0.1% [TKN] all inhibitors showed a reduction in ammonia emissions at all temperatures settings (22 %–70 %). The reference inhibitor (D) and the modified inhibitor (L) had reduction potentials of 48% and 27%. At 20 °C inhibitor E showed no improvement in the reduction potential compared to the other inhibitors used, and was therefore not tested further. At all temperature settings, inhibitor K at concentrations of 0.1% [TKN] showed the highest reduction at 64%. Mixtures of two different inhibitors (0.1% [TKN], 20 °C) did not improve the reduction effect compared to the pure inhibitors. These ammonia reduction results showed that inhibitor K was the most promising with the potential to be used in further practical studies.

1. Introduction

Ammonia (NH_3) leads to environmental damage by acidification and eutrophication. It has an indirect greenhouse effect due to possible conversion to nitrous oxide and also adverse health effects to humans and animals (Buijsman, Maas, & Asman, 1987; EEA, 2012; Erisman, Bleeker, Galloway, & Sutton, 2007; Roelle & Aneja, 2002). From an agricultural perspective, NH_3 emissions are a nitrogen loss, because this nitrogen is not available to the plant, as a nitrogen source (Niclas, Michel, Schuster, Hucke, & Palmer, 2007; Schilling, Kerschberger, Kummer, & Peschke, 2000). Because of the greenhouse and environmental effects, NH_3 reduction is

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Nomenclature

CF	conversion factor mg m^{-3}
DM	dry matter %
ES	emitting surface m^2
H_2O	water
MV_{total}	average manure volume in the glass bottles l
nBTPT	N-(n-butyl) thiophosphoric triamide
NDIR	non-dispersive infrared spectroscopy
NEC	national emission cellings
NH_3	ammonia
$NH_{3\ con}$	ammonia concentration ppm
$NH_{3\ rel\_1}$	ammonia release at 45 min mg
Ø $NH_{3\ rel\_1}$	average concentration of ammonia release at 45 min g
$NH_{3\ rel\_2}$	ammonia release based on emitting surface over 144 h g m^{-2}
$NH_{3\ rel\_3}$	averaged ammonia releases from four replicates per treatment g m^{-2}
ODM	organic dry matter %
$ratio_{UI\ to\ TKN}$	ratio of urease inhibitor to total Kjeldahl nitrogen content of manure % [TKN]
SR	suction rate m^3 min^{-1}
TKN	total Kjeldahl nitrogen %
TKN_{total}	average TKN content of the manure samples g kg^{-1}
UI	urease inhibitor
UI $adittion_{100\ ml}$	amount of urease inhibitor per 100 ml of water g l^{-1}
UI $adittion_{manure}$	amount of urease inhibitor per litre of manure g l^{-1}
UIS	urease inhibitor solution
UI_{weight}	urease inhibitor amount g
US	urea solution
water $addition_{1000\ ml}$	addition of distilled water ml

increasingly the focus of national and international policy (Brose, 2000; Döhler et al. 2002; Gallmann, 2003; Hartung, 1995; Keck, 1997; Monteny, 2000; Reitz, 2000; UBA, 2001; UBA, 2013b; UN/ECE, 1999). Germany has committed in the Gothenburg protocol (UN/ECE, 1999) and in the EU national emission ceilings (NEC) directive 2001/81/EG (EU, 2001) there is a commitment to reduce annual emissions of NH_3. In the target year 2010 of the NEC directive the NH_3 emission ceiling was complied in Germany by 547,000 t (UBA, 2013a). In 2011, the NH_3 emission ceiling was exceeded in Germany by 1.8%. A further reduction of emissions has already been agreed in the revised UN/ECE CLRTAP – multicomponent protocol in 2012 (UBA, 2013b). Also, a revision of the EU NEC directive is in preparation. To comply with the national emission ceilings a reduction of NH_3 emissions is necessary.

Agriculture is the largest source of NH_3 in Germany and livestock, in particular cattle farming, the largest emitter (Dämmgen & Erisman, 2006; Döhler et al. 2002; Hartung, 2001; Niclas et al. 2007; UBA, 2001). For this reason, NH_3 reduction should be most effective in cattle farming (Asman, 1992; Gallmann, 2003).

The cause of NH_3 emissions in animal husbandry is the urease-catalysed hydrolysis. Urease inhibitors inhibit the reaction of urease and thus release NH_3 (Amtul, Rahman, Siddiqui, & Choudhary, 2002; McCarty, Bremner, & Lee, 1990). Several studies tested the use of urease inhibitor in animal husbandry (Leinker, 2007; Ludden, Harmon, Larson, & Axe, 2000; Panetta, Powers, & Lorimor, 2005; Parker et al. 2005; Reinhardt-Hanisch, 2008; Todd & Ming, 2001; Varel, Nienhaber, & Byrnes, 1997; Varel Nienhaber, & Freetly, 1999) but their use has not been implemented in common farm practice. The inhibitors used in previous studies showed small and/or non-enduring reducing effects and they were not yet available for purchase or still in development. The market requires an effective inhibitor with an optimized formulation that can be produced at a reasonable market price.

This study is based on the studies of Reinhardt-Hanisch (2008) who developed a standardised laboratory set-up and has tested five various inhibitors on their reduction potential of NH_3. The aim of this study was to test and compare the potential of one novel and one modified urease inhibitor formulation, as well as mixtures of inhibitors, for reducing NH_3 release from cattle manure in a standardised laboratory (Reinhardt-Hanisch, 2008). Following this work, the most effective urease inhibitor or mixture will be used in on-farm investigations.

2. Materials and methods

The laboratory tests of urease inhibitors were performed using the experimental design, setup and procedure described by Reinhardt-Hanisch (2008). The standardised measurement of NH_3 release from cattle manure allows different inhibitors and inhibitor concentrations to be compared in serial and parallel experiments.

2.1. *Experimental setup*

The measuring system operated on the principle of dynamic chambers (Fig. 1). A water bath permitted a uniform water and manure temperature over the entire test period and also enabled tests at different temperature conditions. The measuring system consists of 28 glass bottles which are filled with 2 L of cattle manure each. The manure was sampled from the manure pit of a typical German cubicle dairy housing system. The manure, which was composed of urine and faeces, was stirred before filling the glass bottles to obtain a homogeneous mixture. A manure sample was taken from each bottle at the beginning and end of each measurement. The parameters of dry matter (DM), organic dry matter (ODM) and total Kjeldahl nitrogen (TKN) were analysed in an external laboratory.

The urease inhibitor was applied once in the first day of the experiments. The release of NH_3 from the manure was provoked by the addition of artificial urea solution (20 g l^{-1}). 100 ml of either the urea solution, or water, were applied daily to the bottles without stirring.

The concentration of NH_3 was measured using a specific gas analyser (UNOR 610; Maihak) according to the principle of non-dispersive infrared spectroscopy (NDIR; Table 1). The sampling time was 90 s per measuring bottle at a setting time of 75 s, so that only the values of the last 15 s (sampling rate