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# Sensitivity Analysis and Application of a Dynamic Simulation Model of Nitrogen Fluxes in Pig Housing and Outdoor Storage Facilities

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This article presents the sensitivity analysis of a deterministic model proposed by Berthiaume *et al.* (2005) for the prediction of daily nitrogen concentrations $N_{conc}$ in kg [N] $t^{-1}$[slurry] and loads $N_{load}$ in kg [N] inside buildings and storage facilities at the production site scale. This model makes use of many parameters and therefore, it is important to evaluate the impact of each of these. Identification of those parameters which most affect the output values allows for the rationalisation of resources when establishing a sampling protocol for determining more precise parameter values. The most important parameters identified were the proportion of proteins in feed $P$, the temperature of the slurry $T$, the pH of the slurry $h$, and, the air speed over slurry $v$. It therefore confirmed the already acknowledged high importance of feed content and methods of distribution—information that can be easily obtained from producers and, thus, can be used in the determination of regional amounts of nitrogen produced by swine production systems (*e.g*, municipality, county or watershed level). In addition, this sensitivity analysis confirmed that some characteristics that are seldom known to producers—slurry pH and air speed over slurry—are also of great importance. Finally, two sets of simulation scenarios were used to illustrate potential applications of this model as a management tool and to further demonstrate its coherent behaviour over different sets of parameter values.


## 1. Introduction

In recent years, intensive pig production has been associated with nitrogen non-point sources of water pollution resulting from spreading of slurry in excess of crop requirements. This situation has prompted experimental studies aiming at a better understanding of the role of feeding, genetic, slurry management and building characteristics on nitrogen loads (Canh, 1998; Canh *et al.*, 1997, 1998a, 1998b; Dourmad and Henry, 1994; Dourmad and van Milgen, 1998; Portejoie *et al.*, 2004; Portejoie *et al.*, 2003; Quiniou *et al.*, 1994). It has also inspired the development of mathematical equations for these factors but these have not been integrated simultaneously at the production site scale (Aarnink and Elzing, 1998; Dourmad *et al.*, 1992). A deterministic mathematical model was recently developed by Berthiaume *et al.* (2005) to predict the effect of these factors at the production site level, and therefore facilitate management. This model allows for the prediction of daily nitrogen concentrations $N_{conc}$ in kg [N] $t^{-1}$[slurry] and loads $N_{load}$ in kg [N] inside buildings and in storage facilities. Although the model represents a particularly well-adapted tool intended to take into account the impact of major pig farming characteristics at the production site level, it necessitates many parameter values; hence the need to evaluate the impact of the lack of precision associated to each of these. A sensitivity

 

**Notation**

| | |
|---|---|
| $A$ | area of emitting ammonia solution, $m^2$ |
| $B$ | output value of a simulation |
| $\overline{B}$ | output value when simulated using reference values for every parameters |
| $b_1$–$b_{12}$ | coefficients |
| $C_{dej}$ | daily dejection volume correction coefficient |
| $C_{tan}$ | total ammonia nitrogen concentration in slurry or urine, mol $m^{-3}$ |
| $E$ | daily ingested digestible energy, MJ $day^{-1}$ $sow^{-1}$ |
| $F_{wasted}$ | proportion of feed wasted, % |
| $f$ | un-ionised ammonia-nitrogen fraction in solution |
| $H$ | Henry's constant |
| $h$ | pH of slurry |
| $h_e$ | effective corrected pH of slurry |
| $h_u$ | pH of urine |
| $k$ | mass transfer coefficient, m $s^{-1}$ |
| $N_{conc}$ | total nitrogen concentration, kg [N] $t^{-1}$[slurry] |
| $N_I$ | ingested nitrogen, g $pig^{-1}$ $day^{-1}$ |
| $N_{load}$ | total nitrogen load, kg [N] |
| $N_R$ | nitrogen retained, kg $animal^{-1}$ $day^{-1}$ |
| $N_U$ | proportion of total nitrogen excreted in urine, decimal |
| $N_V$ | ammonia nitrogen volatilisation, mol [N-$NH_3$] $s^{-1}$ |
| $n_{lit}$ | litter size, number of piglets |
| $P$ | proportion of proteins in feed, % |
| $p$ | parity number correction (+0·5, −0·6, −1·7, −2·5. respectively, for parity 1, 2, 3 and 4 or more), g $day^{-1}$ $sow^{-1}$ |
| $Q$ | daily volume of slurry produced, $m^3$ |
| $R_{corr}$ | daily precipitation correction coefficient |
| $R_{evap}$ | daily evaporation correction coefficient |
| $S_R$ | relative sensitivity, dimensionless |
| $S_S$ | scenario sensitivity, % |
| $T$ | temperature, K |
| $v$ | air velocity, m $s^{-1}$ |
| $W_{ADG}$ | average daily weight gain, kg $day^{-1}$ |
| $W_{evapo}$ | daily water evaporation correction coefficient, dimensionless |
| $\overline{X}_p$ | the reference value for the $i^{th}$ parameter |
| $x_p$ | the value of the $i^{th}$ parameter |
| $Z_{cf}$ | 0·88, correction factor, dimensionless |
| $\alpha$ | ratio of the value of the parameter used for the sensitivity assessment to the standard value of the same parameter |
| $\Delta B$ | difference between $\bar{B}$ and result with the studied parameter modified |
| $\Delta x_p$ | corresponds to a positive increase (5%) in the value of the targeted parameter |

*Subscript*

| | |
|---|---|
| $D$ | dry sows |
| $DGL$ | the combination of dry sows, gestating sows and lactating sows |
| $dej$ | faeces and urine falling on the floor |
| $F$ | floor |
| $G$ | gestating sows |
| $L$ | lactating sows |
| *lagoon* | slurry lagoon |
| $p$ | parameter |
| *pig* | growing-finishing pig |
| *pen* | pen |
| *tank* | concrete slurry tank |
| $TS$ | temporary storage structure |
| $UF$ | area receiving slurry under the slatted floor |

analysis, that is an analysis focussing on how variations in the output of a model can be apportioned to the different sources of variation and how the model depends on the information fed into it (Saltelli *et al.*, 2000), was performed. The identification of those parameters exerting the most significant effect should allow for the rationalisation of resources when deciding on a sampling protocol for getting the parameter values. Many important characteristics in swine production such as genetics, feeding efficiency, feed content, feed distribution methods, slurry management systems and building characteristics are included in the aforementioned mathematical model. The main objectives of the sensitivity analysis presented in this paper were: (1) to ascertain the relative impact of each parameter on model outputs and (2) to study the behaviour of the model in relation to the modification of the input parameter values. The presentation of the sensitivity analysis constitutes the first section of this paper while the second section aims at illustrating the usefulness of the model as a decision support tool through simulation of two potential applications scenarios.