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Samenvatting NL Dit rapport is onderdeel van het project 'Verbeteren systematiek en procedure N-, TAN-, en P-excretie volgens WUM' (juni 2021). Het doel van dit project is het verbeteren van de onderbouwing, transparantie, en de kwantificering van de nauwkeurigheid van de berekening van de stikstof- (N), fosfor- (P) en totale ammoniakale stikstof (TAN)-excretie. Dit rapport geeft de resultaten weer van de gevoeligheidsanalyse van de berekeningen van de emissie 'onder de staart' volgens de WUM-methode. De gevoeligheid van de WUM-methode voor variaties in de inputgegevens is berekend voor de N-, P- en TAN-excretie. In totaal zijn er zeven scenario's doorgerekend, waarbij steeds één inputparameter van de WUM-methode is verhoogd met 10%. De overige parameters zijn constant gehouden. Op basis van de resultaten van deze gevoeligheidsanalyse en de eerder uitgevoerde onzekerheidsanalyse, en de bijdrage aan de totale TAN-excretie zijn prioriteiten gesteld voor vervolgonderzoek.

Summary UK This project focuses on improving the substantiation, transparency and quantification of the accuracy of the calculation of nitrogen (N), phosphorus (P) and total potential ammoniacal nitrogen (TAN) excretion by WUM (in Dutch: Werkgroep Uniformering berekening Mest- en mineralencijfers). The first step in this project is to assess the sensitivity of the N, P and TAN excretion to variation in the WUM model input. A single input parameter change of 10% was simulated in seven different scenarios, while all other input parameters were kept constant. Based on the results of this sensitivity analysis and of the uncertainty analysis performed earlier, and the contribution to the overall TAN excretion, topics for further research were defined and prioritized.

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Public Wageningen Livestock Research Report 1373

Table of contents

Samenvatting

Achtergrond
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Met de WUM-methode wordt de mestproductie (in kg stikstof en fosfaat) per diersoort jaarlijks berekend op basis van de hoeveelheid en samenstelling van het landelijk gemiddelde rantsoen, in kg per dier. Ook wordt de excretie van TAN berekend. Dit is de N in urine die potentieel in ammoniak kan worden omgezet. Voor de ammoniakemissie is de TAN-uitscheiding zeer bepalend. De TAN uitscheiding is gebaseerd op de verdeling van de N-excretie (excretie = opname met voer – vastlegging in product) over mest en urine. De juistheid van de P-uitscheiding in mest is van belang omdat deze gebruikt wordt om de N-uitscheiding in mest en urine en de daaruit verdwenen (geëmitteerde) N, te valideren.

De WUM-methodiek, op zichzelf staand, of als onderdeel van de ammoniakemissieberekeningen, is een aantal keer beoordeeld. Daaruit is een aantal verbeterpunten naar voren gekomen betreffende de onderbouwing van de gebruikte gegevens, transparantie van de gegevens, en de kwantificering van de nauwkeurigheid van de methodologie. Dit rapport is een eerste stap om deze verbeterpunten aan te pakken.

Gevoeligheidsanalyse
Als eerste stap in dit project is de gevoeligheid van de berekeningen van de emissie 'onder de staart' volgens de WUM-methode geanalyseerd. In een gevoeligheidsanalyse wordt het effect van variatie in een onafhankelijke variabele op een afhankelijke variabele berekend. In dit rapport is de gevoeligheid voor variaties in de inputgegevens berekend voor de N-, P- en TAN-excretie, volgens de WUM-methode. In totaal zijn er zeven scenario's doorgerekend, waarbij steeds één inputparameter is verhoogd met 10%. De overige parameters zijn constant gehouden. Het effect van de variatie van deze inputparameter op de uitkomst van het model is berekend, waardoor inzicht is verkregen in de gevoeligheid van de berekende excreties volgens de WUM-methode voor deze variatie. Deze berekeningen zijn gedaan voor verschillende subgroepen van de diercategorieën die het meest bijdragen aan de ammoniakemissie uit de veehouderij: melkvee, vleesvee, varkens, pluimvee, schapen, geiten en paarden. De resultaten geven aan welke inputparameters bij welke dier- en subcategorieën de meeste invloed hebben op de totale excretie.

In de gevoeligheidsanalyse is voor het jaar 2020 voor alle diercategorieën berekend hoe de N-, P- en TAN-excretie verandert wanneer:

1. De daadwerkelijk opname van N of P met het voer 10% hoger was dan in het huidige model;
2. De daadwerkelijke vastlegging van N of P in dierlijke producten 10% hoger was dan in het huidige model;
3. De daadwerkelijke verteringscoëfficiënt van ruw eiwit (VCRE) 10% hoger was dan in het huidige model;

Omdat de berekeningen voor melkvee uit meer variabelen bestaan, kan er gevarieerd worden met meer parameters. Om deze reden en omdat de bijdrage van melkvee aan de totale TAN excretie

aanzienlijk is (48%), zijn voor melkvee additionele scenarioberekeningen gedaan. Voor melkvee is voor het jaar 2020 ook berekend hoe de N-, P- en TAN-excretie verandert wanneer:

4. De daadwerkelijke voedereenheid melk (VEM)-behoefte van melk- en kalfkoeien 10% hoger was dan in het huidige model.
5. De daadwerkelijk beschikbare hoeveelheid van maiskuil, graskuil of krachtvoer 10% hoger was dan in het huidige model.
6. De daadwerkelijke melkproductie van melkkoeien 10% hoger was dan in het huidige model;
7. Het daadwerkelijke lichaamsgewicht van melkkoeien 10% hoger was dan in het huidige model.

1. Gevoeligheid voor variatie in opname

Variatie in opname van N en P via voer kan voortkomen uit 1. Een variatie in de daadwerkelijk opgenomen hoeveelheid voer bij dezelfde hoeveelheid N en P in het voer. 2. Een variatie in de N- en P-gehalten in het voer, waarbij de hoeveelheid opgenomen voer hetzelfde is.

Over het algemeen was de N-, P- en TAN-excretie bij de meeste diersoorten gevoelig voor een verandering in de opname van N en P met het voer. Een verhoogde opname van N en P met het voer van 10% resulteert over het algemeen in een toename in N-, P- en TAN-excretie die hoger is dan 10%. Dit geldt met name voor dieren met een efficiënte N- en P-vastlegging, en dus een lage excretie van N, P en TAN. Een correcte inschatting van de N- en P-opname met het voer is relevant voor alle diercategorieën. Dit zou daarom een van de vervolgstappen van dit project moeten zijn, met speciale aandacht voor melkvee, vleesvarkens, zeugen, vleeskuikens en leghennen omdat deze de grootste bijdrage leveren aan de totale excretie vanuit de veehouderij.

2. Gevoeligheid voor vastlegging in dierlijke producten

Variatie in de vastlegging van N en P in dierlijke producten (melk, vlees) kan verschillende oorzaken hebben. 1. In groeiende dieren kan deze variatie voortkomen uit een variatie in groeisnelheid of lichaamssamenstelling en dus in het N- en P-gehalte en de totale hoeveelheid in het lichaam van het dier. 2. In lacterende dieren kan deze variatie voortkomen uit een combinatie van variatie in groeisnelheid en melkproductie, of de melksamenstelling. 3. Voor leghennen kan de variatie voortkomen uit een combinatie van variatie in groeisnelheid en eiproductie.

Over het algemeen was de gevoeligheid voor variatie in vastlegging van N en P lager dan de gevoeligheid voor opname met het voer. Dit is te verklaren doordat de absolute opname groter is dan de absolute vastlegging, waardoor opname in de berekeningen meer invloed heeft op de excretie. Variatie in vastlegging bij groeiende dieren kan voortkomen uit variatie in groei of variatie in de groeisamenstelling. Verder onderzoek is nodig voor diercategorieën waarbij vastlegging in lichaamsweefsel van belang is. Dit geldt voor groeiende dieren zoals jongvee jonger dan 1 jaar en kalveren voor witvlees- en rosévleesproductie, vleesvarkens en vleeskuikens. Bij melkkoeien wordt N en P voornamelijk vastgelegd in melk, waarvan de N- en P-gehalten al accuraat worden geanalyseerd en is vervolgonderzoek minder urgent.

3. Gevoeligheid voor variatie in verteringscoëfficiënt van ruw eiwit (VCRE)

Variatie in VCRE kan voortkomen uit variatie in samenstelling en kwaliteit van mengvoer en van het totale rantsoen. Door een toename van de VCRE bij gelijkblijvende vastlegging van N in dierlijke producten verschuift de N-excretie van mest naar urine, in de vorm van TAN.

Over het algemeen was de gevoeligheid voor variatie in VCRE hoog voor alle diercategorieën. Dit vraagt daarom extra aandacht. Voor sommige diercategorieën is al veel onderzoek gedaan naar de VCRE, omdat dit belangrijk is voor optimalisatie van het rantsoen, zoals bij varkens en pluimvee. Voor melkvee is de VCRE goed onderbouwd en gebaseerd op het Tier 3-model. Voor de overige rundveesoorten is de VCRE hiervan afgeleid en dus minder accuraat. Om dit te verbeteren zijn waarschijnlijk genoeg gegevens voor literatuuronderzoek beschikbaar.

4. Gevoeligheid voor variatie in VEM-behoefte

Variatie in de VEM-behoefte kan resulteren in variatie in de voeropname, die is gebaseerd op het VEM-systeem.

Variatie in de VEM-behoefte had grote impact op de N-, P- en TAN-excretie in deze gevoeligheidsanalyse. In de WUM-methode wordt het VEM-systeem gebruikt als bron voor berekening van de voeropname, hoewel het systeem hier oorspronkelijk niet voor bedoeld is. Inmiddels bestaan er nieuwere modellen die wel specifiek zijn ontwikkeld voor het inschatten van de voeropname. Het is van groot belang om de inschattingen van de voeropname te onderzoeken om na te gaan of deze te verbeteren zijn, met name vanwege de bijdrage van melkvee aan de totale excretie.

5. *Gevoeligheid voor variatie in beschikbare hoeveelheid van maiskuil, graskuil of krachtvoer*

Variatie in de beschikbare hoeveelheid van maiskuil, graskuil of krachtvoer heeft invloed op de berekende hoeveelheid vers gras die wordt opgenomen om in de energiebehoefte (VEM) te voorzien.

In de drie verschillende deelscenario's voor variatie in 1. maiskuil, 2. graskuil of 3. krachtvoer was de gevoeligheid voor variatie in de beschikbaarheid van voercomponenten voor melkvee over het algemeen vrij laag. De hoogste gevoeligheid werd berekend voor de beschikbaarheid van maiskuil. Ten opzichte van graskuil en krachtvoer heeft de beschikbaarheid van maiskuil daarom een hogere prioriteit voor verder onderzoek.

6. *Gevoeligheid voor variatie in melkproductie.*

Variatie in de melkproductie heeft invloed op de energiebehoefte van koeien met als gevolg, vergelijkbaar met punt 4, een hogere voeropname en tevens een hogere N-opname met het voer.

Vanwege de verhoogde melkproductie neemt ook de vastlegging van N en P toe. In tegenstelling tot de andere scenario's, waarbij de vastlegging in melk gelijk is gehouden, is de toename van de TAN-excretie niet hoger dan de totale toename van de N-excretie. Daarnaast wordt de melkproductie op dit moment al accuraat berekend. Het verbeteren van inputwaarden voor melkproductie heeft daarom geen prioriteit.

7. *Gevoeligheid voor variatie in lichaamsgewicht van melkkoeien*

Variatie in lichaamsgewicht heeft gevolgen voor de vastlegging van N en P in dierlijke producten en voor de VEM-behoefte.

Het WUM-model is niet erg gevoelig voor variatie in lichaamssamenstelling en lichaamsgewicht bij melkvee. Het onderzoeken van lichaamsgewicht heeft geen prioriteit voor het verbeteren van de WUM-methode, vanwege het kleine effect en de recent geactualiseerde gegevens voor lichaamsgewicht van melkvee (CVB).

Tabel 1 *Overzicht van de gevoeligheid van de WUM-methode voor de verschillende inputparameters met de prioriteiten voor verbetering per inputparameter*.*

Diercategorie	Bijdrage totale TAN excretie (% van totaal)	Inputparameter	Gevoeligheid TAN	Betrouwbaarheid inputgegevens	Prioriteit
Jong melkvee (0-2 jr)	10	Opname	++	+++	+
		Vastlegging	+	++	+
		VCRE	++	+	+++
Melkkoeien	48	Opname	++	++	+++
		Vastlegging, melkproductie, VCRE	+/++	+++	0
		VEM-behoefte	++	+++	+
		Lichaamsgewicht	+	++	0
		Beschikbaarheid maissilage	+	+	++
		Beschikbaarheid grassilage	+	++	0
		Beschikbaarheid krachtvoer	+	+++	+

Diercategorie	Bijdrage totale TAN excretie (% van totaal)	Inputparameter	Gevoeligheid TAN	Betrouwbaarheid inputgegevens	Prioriteit
Wit- en rose vleeskalveren	2	Opname, vastlegging, VCRE	+/++	++	+
		VEM-behoefte	0	++	+
Jong rundvee (0-2 jr)	2	Opname, vastlegging, VCRE, VEM-behoefte	+/++	++	0
Zoog-, mest- en weidekoeien	1	Opname, vastlegging, VCRE, VEM-behoefte	+/++	++	0
Schapen, geiten, paarden en pony's	4	Opname, vastlegging	+/++	++	+
		VCRE	++	++	0
Vleesvarkens	13	Opname	+++	+++	0
		Vastlegging	++	++	+++
		VCRE	++	++	++
Opfokzeugen	1	Opname, vastlegging	+/++	++	+
		VCRE	++	++	0
Zeugen	5	Opname	+++	+++	+
		Vastlegging	+	++	+
		VCRE	+++	++	0
Opfokberen en dekberen	<1	Opname, vastlegging	+/++	+	+
		VCRE	++	+/++	0
Vleeskuikens	4	Opname, vastlegging	+++/++++	++/+++	+++
		VCRE	++++	++	0
Ouderdieren van vleeskuikens	1	Opname, VCRE	++	++	0/+
		Vastlegging	+	++	+
Leghennen	7	Opname	++	+++	0/+
		Vastlegging	+	+++	0/+
		VCRE	++	++	0
Eenden, kalkoenen	<1	Opname, vastlegging, VCRE	++/+++	+/++	0

**De mate van gevoeligheid, betrouwbaarheid en prioriteit in bovenstaande tabel is als volgt weergegeven:*

0	*niet gevoelig*	*minst betrouwbaar*	*geen prioriteit*
+	*gematigd gevoelig*	*minder betrouwbaar*	*laagste prioriteit*
++	*gevoelig*	*betrouwbaar*	*hogere prioriteit*
+++	*erg gevoelig*	*erg betrouwbaar*	*hoogste prioriteit*
++++	*heel erg gevoelig*	*heel erg betrouwbaar*	

Conclusie

Op basis van de bijdrage aan de totale TAN-excretie, deze gevoeligheidsanalyse en de eerder uitgevoerde onzekerheidsanalyse wordt voorgesteld eerst na te gaan hoe accuraat de inputparameters met grote invloed op excretie worden ingeschat volgens de WUM-methode (tabel 1). Per input parameter en per diersoort wordt deze combinatie van de bijdrage, de gevoeligheid en betrouwbaarheid gebruikt om vervolgonderzoek te prioriteren. Vervolgens kan worden geïnventariseerd of er nieuwe of betere informatie beschikbaar is die kan helpen bij het verbeteren van de volgende inputwaarden:

- Melkvee: N- en P-opname met voer, beschikbaarheid van maiskuil, VCRE van jongvee en vleesvee;
- Varkens: N- en P-opname met voer, N- en P-vastlegging (lichaamssamenstelling);
- Pluimvee: N- en P-opname met voer, N- en P-vastlegging (lichaamssamenstelling).

Summary

Background

This project focuses on improving the substantiation, transparency and quantification of the accuracy of the calculation of nitrogen (N), phosphorus (P) and total potential ammoniacal nitrogen (TAN) excretion by WUM (in Dutch: Werkgroep Uniformering berekening Mest- en mineralencijfers). Consequently, the National Emission Model for Ammonia (NEMA) uses TAN excretion to calculate the ammonia emission in the Netherlands. The N and P excretion is the addition of the excretion in both faeces and urine, where the total N and P excretion equals the N and P intake minus N and P retention, respectively, in animal products. The TAN is the part of the N that is excreted via the urine.

Sensitivity analysis

The first step in this project is to assess the sensitivity of the N, P and TAN excretion to variation in the model input. For all animal subgroups of the main animal categories (cattle, pigs, poultry, sheep, goat, and horses) of the WUM method, the calculated N, P and TAN excretions were analysed for their sensitivity to variation in the input data. A single input parameter change of 10% was simulated in each scenario, while all other input parameters were kept constant. In the sensitivity analysis, the effect on N, P and TAN excretion is calculated for 2020 by a 10% variation in:

1. Intake of N and P with feed;
2. Retention of N and P in animal products;
3. Digestion coefficient of crude protein (DCCP);
4. Net Energy for Lactation requirement (according to the Dutch VEM system);
5. Availability of maize silage, grass silage and concentrates;
6. Milk production;
7. Body weight.

1. *Sensitivity to variation in intake*

   In general, for most species, the excretion of N, P and TAN is sensitive to especially a change in the intake of N and P. This is especially the case in animals that currently have a high efficiency of utilization (retention) of N and P. This means special focus for dairy cows (also see below at specific dairy cow scenarios), fattening pigs, sows, broilers and laying hens.

2. *Sensitivity to variation in retention*

   In general, the sensitivity to changes in retention was lower than the sensitivity to intake. A change in retention may be caused by either a change in growth or a change in body composition while growing. For species where retention in body tissues is important (growing animals), it is advised to investigate further.

3. *Sensitivity to variation in DCCP*

   The sensitivity for TAN to DCCP is generally high for all species and could merit further investigation. For dairy cows and the larger pig and poultry species, DCCP is a parameter that is generally well investigated already. However, DCCP is estimated by extrapolation from dairy cattle for other cattle species. Moreover, it remains uncertain whether the composition of compound feed and total ration used in the WUM model are representative for all Dutch livestock.

4. *Sensitivity to variation in NEL requirement*

   A change in NEL requirement has a large impact on the excretion of N, P and TAN for lactating and dry dairy cows. Since the development of the NEL system, other models that are more specifically developed for estimating feed intake have been developed. This warrants further investigation of the estimation of intake in the WUM for this important animal category with high importance.

5. *Sensitivity to variation in feed components*

   For the availability of 1. maize silage, 2. grass silage or 3. concentrates, the sensitivity to a

change in availability was quite low in all three sub scenarios. Regarding feedstuff availability, maize silage can have the highest priority before the availability of grass silage and concentrates.

6. *Sensitivity to variation in milk production*
   TAN-excretion in the WUM model is not very sensitive to variation in milk production. In addition, the milk production is accurately monitored at this moment. Therefore, further investigation of the estimation of milk production has low priority.

7. *Sensitivity to variation in body weight and body composition*
   The excretion in the WUM model for dairy cows is not very sensitive to body composition. Therefore, further investigation of the body composition of dairy cows does have a relatively low priority because of the small impact, but may be interesting to have the most recent data included.

Conclusion

Based on this sensitivity analysis, it is recommended to start with an analysis of the accuracy of the estimation of the WUM input parameters with substantial effect on the total excretion. Subsequently, available new and improved data will be collected that can help in improving the following input values of the WUM model:

- Dairy cattle: N and P intake with feed, availability of maize silage, DCCP for young stock and beef cattle;
- Pigs: N and P intake with feed, N and P retention (body composition);
- Poultry: N and P intake with feed, N and P retention (body composition).

1 Introduction

This report is part of the project proposal 'Verbeteren systematiek en procedure N, TAN en P excretie volgens WUM' (june 2021), and deals with the first step of the project, the sensitivity analysis of the WUM method. WUM (in Dutch: Werkgroep Uniformering berekening Mest- en mineralencijfers) is a working group of experts with the task to establish uniformity in the calculation of manure and mineral data related to animal production.

The calculation of the national excretion of nitrogen (N), phosphorous (P) and total ammoniacal nitrogen (TAN) is based on the WUM method. This method forms the base for all subsequent steps in the calculation of ammonia emission from livestock farming in the Netherlands. The validity of the WUM method is crucial, because this calculated ammonia emission is the basis for monitoring the development in annual emission. It has significant consequences for governmental decisions on regulations to protect the environment. Because of this importance, the Dutch Ministry of Agriculture decided to fund the project BO-43-101-044-WLR Excretie verbetering modellen. This project focuses on improving the substantiation, transparency and quantification of the precision of the calculation of N, P and TAN excretion by WUM. Results of previous evaluations of the WUM method are used as a starting point for this project. Both the model itself, and the model as a part of NH3 emission calculations, have been reviewed earlier. These evaluations resulted in a number of suggestions. The suggestions included improvements regarding the robustness of the used data for the current situation, transparency of the data and quantification of the precision of the method (CDM, 2012, Sutton et al., 2015, Hordijk et al., 2020a, 2020b, Zom & Kasper, 2019). In their review of the NH3 calculation, Hordijk et al. (2020a and 2020b) advised to publish the used models and to discuss them in a stakeholder group. To address the points raised in these evaluations a workshop was organised with experts involved in several aspects of the data collection and modelling within the WUM model. The main conclusions and recommendations have been reported in the project's project proposal. The current project focuses on improving the WUM method based on the recommendations mentioned in the earlier evaluations and the workshop with experts (Appendix 1).

The governmental goals to reduce NH3-emission from livestock farming have made the magnitude of Dutch NH3 emission highly important. Feeding management to reduce NH3 emission is an important reduction route. Modification of feed composition can affect NH3 emission through the TAN excretion, which is calculated using the WUM method. The Dutch Nitrogen Knowledge Program (Nationaal Kennisprogramma Stikstof) aims to determine and research possible uncertainties within nitrogen emission calculations. The calculation method should be supported by recent and scientific knowledge and documented transparently. Moreover, the effects of crucial assumptions should be reported and quantified.

As mentioned, in the Netherlands, calculations of the annual excretion of N and P in manure and the excretion of TAN for farm animals are based on the WUM method. The TAN excretion is of great importance. The TAN excretion is used by the National Emission Model for Ammonia (NEMA) to calculate the ammonia emission in the Netherlands. In the model INITIATOR, the national ammonia emission is allocated to specific locations.
Moreover, a precise and accurate calculation of the absolute TAN excretion is essential for determining emission (factors) from different housing systems. N losses are used to determine mean excretion values (forfaits) for N, including N emission. A new calculation method to evaluate the predicted N emission was introduced by the Scientific Committee on Nutrient Management Policy (CDM) and elaborated by CBS (van Bruggen & Geertjes, 2019). This method is based on the reduction in N:P ratio between excretion in urine and faeces, as calculated by WUM and registered removal of the manure from the animal facility for which manure N and P composition has been analysed. The results of this new method are different from the emission factors that were determined earlier and used in the Dutch Regulation for Ammonia and Livestock Farming (RAV), especially for low-emission housing

systems. Therefore, an accurate evaluation of the N emission requires an accurate calculation of the P-excretion.

The N and P-excretion is the addition of the excretion in both faeces and urine, where the total N and P excretion equals the N and P intake minus N and P retention, respectively, in animal products. The TAN is the part of the N that is excreted via the urine, which is:

$$\text{EQ1: TAN} = (\text{N intake} * \text{N digestibility}) - \text{N retention in animal products}$$

The total project aims at improving the substantiation, transparency and quantification of the precision of N, P and TAN excretion calculations in the WUM method. The first step in the project, as described in working package 1 (WP1) of the project is to assess the sensitivity of the N, P and TAN excretion to variation in the model input. Sensitivity of the model to its input values will help in identifying potential next topics within the wider project. This will serve as a guideline for the activities in the rest of the project. For some animal species which, based on their low sensitivity and low quantitative importance, are not further studied in this project, it may still be relevant to refine starting values for the purpose of determining standard excretions (forfaits) specific for these species.

Description of the WUM method
A more extensive description of the WUM method can be found in Van Bruggen (2020). In short, the N, P and TAN excretion per animal is calculated yearly by WUM. Calculated excretion factors for N and P as stated in EQ1 are based on the mineral balance per animal (figure 1). The intake and retention are based on technical indicators, which provide data on feed consumption and animal production. Statistics and technical reports provide data for the technical indicators used by WUM (Appendix 1) These indicators are studied and updated regularly.

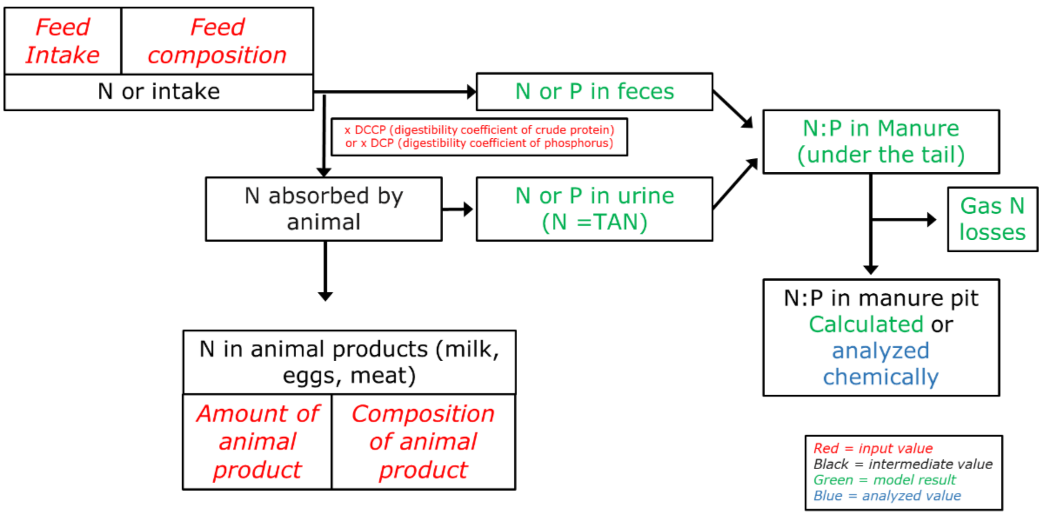

Figure 1 *Overview of excretion factor input values and model results according to WUM.*

The intake of N and P with feed per animal category is determined by the volume of feed consumed (concentrates, roughage and by-products) and the feed composition. In the Netherlands, feed suppliers are obliged to report the total amount and the N and P content of the supplied feed for different types of livestock categories. Roughage composition based on Eurofins data contain yearly average data on the composition of grass and maize silage. Intake of concentrates, grass silage and maize silage by cattle categories, with exception of dairy cows, is based on standardized quantities. These standardized quantities are multiplied by the number of animals and subtracted from the total amount of available feed. The remaining quantities of concentrates, grass silage and maize silage are then assigned to dairy cows. Finally the fresh grass intake by dairy cows is calculated from the total energy intake according to the Dutch Net Energy for Lactation (NEL) minus the energy intake from concentrates, grass silage and maize silage.

The retention of N and P in animal products (milk, eggs, animal growth, number of births) depends on the production level of milk, eggs and meat, and the mineral content of those products. The N content in milk is based on analyses of milk delivered to the dairy processing industry. The N content in live weight and eggs and the P content in all these animal products is based on mean values (forfaits) derived from scientific studies in which these products were analysed.

The N and P retention in animal products is subtracted from N and P intake with feed, resulting in the excretion of N and P. For the TAN excretion the total amount of digestible N is required and is calculated by multiplying N intake by an animal type-specific digestibility coefficient. The TAN excretion equals to the N digested minus the N retained in animal product.

2 Materials and method

What is a sensitivity analysis?
In a sensitivity analysis (SA), the effect of variation in an independent variable on the value of a dependent variable is calculated. SA is identified as a mathematical definition, with a differentiation of the output with respect to the input. This approach to sensitivity prevailed in the modelling community when the objective of the analysis was to ascertain the relative importance of input factors in the presence of finite ranges of uncertainties. For this reason, quantitative measures of sensitivity have been referred to in the literature as importance measures (Saltelli et al., 2006). Insight in the sensitivity is important when a model is based on a set of assumptions or input variables that are not precisely known, which may affect the conclusions and interpretation of the results.

2.1 Method

2.1.1 Sensitivity analysis

For all animal subgroups of the main animal categories (cattle, pigs, poultry, sheep, goat, and horses) according to the WUM method (CBS, 2019) the calculated N, P and TAN excretions were analysed for their sensitivity to variation in the input data. The analysis was done for each category and corresponding subcategories and is reported in separate paragraphs. For the sensitivity analysis, various scenarios were calculated using the 2020 input data (published by CBS; Dierlijke mest en mineralen 2020) as a basis (reference model). In each scenario, a single input parameter change of 10% relative to the reference situation was simulated, while all other input parameters were kept constant. The 10% itself is an arbitrary choice and used to compare the sensitivity of the output to a similar change in input value for a number of parameters. This allows comparison of the relative impact of the different input values on the excretions. The scenarios tested are shown in table 2. For all animal categories two basic scenarios were tested. The effect of variation in one input value on the excretion by the total animal category and on the total livestock excretion is also calculated and presented. It was tested how much excretion of N, P and TAN increased or decreased when: 1. the actual intake of N or P was 10% higher than adopted in the current model, or 2. the actual retention in animal product (meat, or meat and milk) was 10% higher than adopted in the current model. For ruminants a 10% increase in an additional set of input values was tested (see table 2), as the change in those input values were relevant for ruminants only. These analyses investigate the sensitivity to a 10% (upward) deviation in model input, while all other inputs were kept constant. This means that this does not describe the biological response to a change in either intake or retention, but merely the model behaviour if the actual input or retention was higher than in the current model. In the report, this is often referred to as an increase. The effect on digestibility of total ration was not considered in any of the scenarios.

Scenarios with a 10% increase in intake
The scenarios where the intake in N or P is increased by 10% reflect the sensitivity for a change in one of the two underlying input parameters: 1. It can represent a 10% deviation in the actual amount of feed consumed by the animal, while N or P content (and all other input parameters) remain the same. 2. It can represent a 10% deviation in the N or P content of the feed while feed consumed (and all other parameters) remain the same. It is important to realize that this 10% increase reflects an error in the estimation of the intake but is not a real biological error. Therefore, the animals will not grow more or produce more milk, which means that retention in N and P is kept constant. The underlying mechanism of the effect of an increase in intake is shown in figure 2.

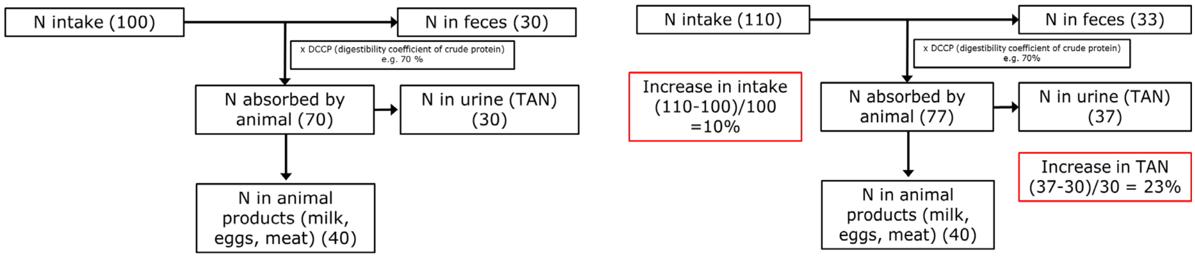

Figure 2 *The effect of a 10% increase in intake (right) on TAN excretion, compared to a reference situation (left).*

Scenarios with a 10% increase in retention

The scenarios with a 10% increase in N or P retention reflect the sensitivity for a possible change in different parameters: 1. In growing animals, it can represent either a 10% error in growth rate or body composition, i.e. N and P content in the body. 2. In lactating animals, it can represent either a 10% error from the combination of growth rate and milk production on the one hand, or milk composition on the other. For the first combination it is not specified from which source it actually is. This applies to dairy cows, dairy goats and lactating sows. 3. For laying hens, similar as for lactating animals, it can represent a 10% combined error in growth and egg production on the one hand, or egg composition on the other.

Scenarios with a 10% increase in DCCP

In the scenarios with a 10% increase in digestion coefficient of crude protein (DCCP), retention and intake are fixed. Hence, the scenarios with a 10% increase in DCCP reflect a reduction in efficiency of utilisation of absorbed N for retention in products, e.g. because the animals are fed above their requirements. The scenarios with a 10% increase in DCCP lead to a shift from N in faeces to N in urine (TAN). These scenarios are calculated for dairy cows only and for other cattle (including other grazing livestock), pigs, poultry, sheep, goats, horses and ponies.

Additional sensitivity analysis dairy cattle

Scenario with a 10% increase in NEL requirement

In this scenario, the NEL requirement is increased by 10% for the animals in the categories: male and female dairy young stock, female beef young stock, dairy cows, suckling, fattening and grazing cows. This scenario determines how sensitive the model is to the estimated feed intake based on the NEL system. This change mainly affects the total intake of the diet. The retention remains the same. The intake model for dairy cows is based on the NEL system and uses the fresh grass intake to fill the NEL gap between requirement and estimated concentrate, grass silage and maize silage intake. An increased NEL requirement will increase the NEL gap and it is likely that this scenario will result in a relatively higher proportion of fresh grass in the diet.

Scenario with a 10% increase in milk production

In this scenario the cows' milk production is increased by 10%. This will have two consequences for the model. Firstly, the increased milk production implies a higher retention of N and P in milk. Second, the higher milk production will also increase the energy requirement of the cows, which leads to a 10% increase in feed intake. As discussed for scenario NEL requirement, increased feed intake will result in a proportional increase in fresh grass intake. Therefore, the results of this scenario reflect the balance of the increase in both N and P retention (less N and P excretion) as well as N and P intake (more N and P excretion).

Scenario with a 10% increase in body weight

In this scenario there is a 10% increase in the body weight of the adult dairy cow. This has two consequences in the model. First, the increased body weight will result in higher retention of N and P. Second, a higher body weight results in a higher energy requirement, leading to a 10% increase in feed intake (see also scenarios with increased NEL requirement and milk production for effects).

Scenarios with a 10% increase in availability of feed components

In three different scenarios, we evaluate the sensitivity to a 10% increase in the availability of either maize silage, grass silage and the total amount of concentrates, respectively. In each of these scenarios, the availability of one of the three feeds increases by 10%, while the others remain constant. The intake of all feed components for all cattle categories are based on standardized quantities, except for dairy cows. This means that the increase in either concentrates, grass silage or maize silage will reduce the NEL gap that is filled with fresh grass, and therefore causes a change in diet composition towards less fresh grass intake. The difference in NEL to N and NEL to P ratio between concentrates, grass silage and maize silage, relative to the same ratios in grass silage will cause a change in N or P content of the total diet. For instance, a 10% increase in maize silage with a lower N to NEL ratio, will likely, when there is a lower NEL gap to close with grass silage, cause a reduction in N content of the total dairy cow diet.

Table 2 *Overview of the scenarios, used to calculate the sensitivity of the WUM method, used for national N and P excretion calculations. Scenarios imply a 10% variation in the indicatedparameter and were calculated for different animal categories. For each scenario, the relevance for the sensitivity analysis is indicated. The effect on digestibility of total ration was considered in none of the scenarios.*

Varied parameter	**Relevance**
Intake with feed +10%	Increased intake with feed will lead to a higher excretion in manure and urine.
Retention in animal products +10%	An increase of the retention will decrease the excretion, especially in urine.
Digestibility coefficient of crude protein (DCCP), ration other beef cattle, sheep, goats and horses: DCCP of all feed materials except milk and milk replacers + 10%	With DCCP the N excretion will decrease in manure and increase in urine.
Feed requirement of dairy cattle: milk production per cow +10%	An increase in milk production will lead to an increased NEL-requirement. This will result in a higher feed intake with, possibly, a different feed composition, and increased N and P intake. This might be balance by an increased N and P retention because of the higher milk production.
Feed requirement of other cattle: Dutch Net Energy for Lactation (NEL)-requirement of female and male young cattle in dairy farming, female young cattle for beef production, of dairy cows and of suckling, fattening and grazing cows +10%	An increase in NEL-requirement will result in a higher feed intake with, possibly, a different feed composition or increased N intake.
Body weight dairy cow +10%	An increase in body weight leads to an increased NEL-requirement. This will result in a higher feed intake with, possibly, a different feed composition, and increased N uptake. The higher body weight may also lead to increased N and P retention.
Availability feed materials: maize silage +10%	The increased portion of corn silage will be compensated with a smaller portion of fresh grass in the ration of dairy cows.
Availability feed materials: grass silage +10%	The increased portion of grass silage will be compensated with a smaller portion of fresh grass in the ration of dairy cows.
Availability feed materials: concentrates +10%	The increased portion of concentrates will be compensated with a smaller portion of fresh grass in the ration of dairy cows.
DCCP ration dairy cows: +10%	The increased DCCP will reduce the excretion in manure and increase the excretion in urine. This will lead to a higher TAN excretion for dairy cows.

3 Results and discussion

3.1 Reference data

Table 3 presents an overview of the results of the calculation of the reference data. These reference data for 2020 are the calculated by CBS according to the WUM method. The total N, P and TAN excretion is shown per animal category. This table helps in interpreting the results from the scenarios regarding the impact of input parameter changes on the excretions of the total Dutch Livestock level. Categories that have a large absolute excretion will have a large impact in the sensitivity analysis, and therefore are relatively more important to calculate accurately, purely based on total excretion.

Table 3 *Results of the analysis of the reference data: N, P and TAN excretion per animal category in million kg per year.*

Animal category	**N (million kg)**	**% of total N excreted by livestock**	**P (million kg)**	**% of total P**	**TAN (million kg)**	**% of total TAN**
Female young stock <1 year	14.9	3.0	3.2	2.1	9.1	3.1
Male young stock <1 year	1.3	0.3	0.3	0.2	0.8	0.3
Female young stock ≥1 year	32.1	6.6	7.8	5.2	20.4	6.9
Male young stock and breeding bulls ≥1 year	1.2	0.2	0.3	0.2	0.8	0.3
Lactating and dry dairy cows	236.9	48.4	62.1	41.2	131.6	44.3
Total dairy cattle	286.4	58.5	73.7	48.9	162.7	54.7
Calves for white veal production	10.8	2.2	2.7	1.8	6.4	2.2
Calves for rose veal production	9.5	1.9	3.0	2.0	5.1	1.7
Female young stock <1 year	1.1	0.2	0.2	0.1	0.7	0.2
Male young stock <1 year	1.4	0.3	0.3	0.2	0.7	0.2
Female young stock ≥1 year	3.7	0.8	0.9	0.6	2.4	0.8
Male young stock (incl. bullocks) ≥1 year	2.3	0.5	0.7	0.5	1.3	0.4
Suckling cows incl. fattening/grazing ≥2 years	4.8	1.0	1.3	0.9	3.1	1.0
Total beef cattle	33.7	6.9	9.2	6.1	19.6	6.6
Total cattle	320.1	65.4	82.8	55.0	182.3	61.3
Sheep	7.1	1.4	1.9	1.3	5.2	1.7
Goats	8.8	1.8	2.6	1.7	5.3	1.8
Horses	4.9	1.0	1.8	1.2	3.4	1.1
Ponies	0.9	0.2	0.3	0.2	0.7	0.2

Animal category	N (million kg)	% of total N excreted by livestock	P (million kg)	% of total P	TAN (million kg)	% of total TAN
Total sheep, goats, horses, ponies	21.7	4.4	6.6	4.4	14.6	49
Fattening pigs	61.8	12.6	22.9	15,2	40.8	13.7
Gilts and boars	3.3	0.7	1.5	1.0	2.3	0.8
Sows	26.8	5.5	12.1	8.0	16.9	5.7
Young boars ≥50 kg	0.0	0.0	0.0	0.0	0.0	0.0
Boars for service	0.1	0.0	0.1	0.1	0.1	0.0
Total pigs (incl. piglets)	92.1	18.8	36.6	24.3	60.1	20.2
Broilers	18.3	3.7	5.2	3.5	11.6	3.9
Broiler breeders <18 weeks	0.9	0.2	0.5	0.3	0.7	0.2
Broiler breeders ≥18 weeks	4.6	0.9	2.4	1.6	3.6	1.2
Laying hens <18 weeks	4.0	0.8	1.9	1.3	3.1	1.0
Laying hens >18 weeks	25.5	5.2	13.2	8.8	19.6	6.6
Ducks	0.5	0.1	0.3	0.2	0.3	0.1
Turkey	0.9	0.2	0.4	0.3	0.7	0.2
Total poultry	54.8	11.2	24.0	15.9	39.6	13.3
Total livestock	489.8		150.6		297.4	

3.2 Sensitivity analysis cattle

Table 4 presents an overview of the results of the sensitivity analysis in the scenarios calculating the effect of a 10% increase in N and P intake with feed or a 10% increase in N and P retention on N, P and TAN excretion, compared with the reference data (table 3).

Table 4 *Results of sensitivity analysis for scenarios for cattle: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either intake with feed or a 10% higher retention.*

	Relative change in excretion with +10% intake with feed			Relative change in excretion with +10% retention		
	N	**P**	**TAN**	**N**	**P**	**TAN**
Animal category						
Female young stock <1 year	11.9%	16.3%	12.8%	-1.9%	-6.3%	-2.8%
Male young stock <1 year	12.7%	19.3%	14.3%	-2.7%	-9.3%	-4.3%
Female young stock ≥1 year	10.8%	12.6%	11.2%	-0.8%	-2.6%	-1.2%
Male young stock and breeding bulls ≥1 year	10.5%	11.4%	10.8%	-0.5%	-1.4%	-0.8%
Lactating and dry dairy cows	13.5%	15.5%	16.2%	-3.5%	-5.5%	-6.2%
Total dairy cattle	13.1%	15.2%	15.4%	-3.1%	-5.2%	-5.4%

	Relative change in excretion with +10% intake with feed			Relative change in excretion with +10% retention		
	N	P	TAN	N	p	TAN
Animal Category						
Calves for white veal production	16.4%	25.5%	19.8%	-6.4%	-15.5%	-9.8%
Calves for rose veal production	13.9%	17.1%	16.5%	-3.9%	-7.1%	-6.5%
Female young stock <1 year	11.9%	16.5%	12.9%	-1.9%	-6.5%	-2.9%
Male young stock <1 year	13.8%	19.5%	16.4%	-3.8%	-9.5%	-6.4%
Female young stock ≥1 year	10.8%	12.6%	11.2%	-0.8%	-2.6%	-1.2%
Male young stock (incl. bullocks) ≥1 year	11.9%	14.3%	13.0%	-1.9%	-4.3%	-3.0%
Suckling cows incl. fattening/grazing ≥2 years	11.3%	12.2%	11.9%	-1.3%	-2.2%	-1.9%
Total beef cattle	13.8%	18.3%	15.8%	-3.8%	-8.3%	-5.8%
Total cattle	13.1%	15.6%	15.4%	-3.1%	-5.6%	-5.4%
Total livestock	8.6%	8.6%	9.4%	-2.1%	-3.1%	-3.3%

Increase in intake

The effect of a 10% increase in intake on total N, P and TAN excretion for the different animal categories is in the range of 10.5% (male young stock and breeding bulls) to 16.4% (calves for white veal production) for N; 11.4% (male young stock and breeding bulls) to 25.5% (calves for white veal production) for P and 10.8% (male young stock and breeding bulls) to 19.8% (calves for white veal production) for TAN. A 10% increase in excretion means that the increase in excretion equals the increase in intake. The higher values for the increase in excretion, such as 16.4%, 25.5% and 19.8% for N, P and TAN, respectively, indicate that the excretion is more sensitive to intake for some animal categories than for others.

The lowest values are for male and female animals older than 1 year. These animals grow slower and have a low retention of N and P relative to fast-growing animals. Because the retention of N and P in body tissue is low, most of the ingested N and P is excreted, thus a 10% increase in intake remains close to a 10% increase in excretion.

The highest values in response are for veal calves and male beef calves younger than one year. This reflects that in these animals with a high growth rate, a relatively high proportion of the N and P is retained in body tissues, which results in a lower excretion. Therefore, for these animals a 10% increase in intake that is subsequently excreted is a relatively higher proportion of excretion than for animals with a lower retention.

Dairy cows have the highest absolute excretion for all parameters according to table 3. Therefor the sensitivity for dairy cows is important. For dairy cows the sensitivity was 13.5%, 15.5% and 16.2% for N, P and TAN, respectively. It indicates that especially TAN is rather sensitive to a change in N intake. This means that correct feed intake and N content estimation are relatively important factors in this case for dairy cows, but actually for most of the animal categories.

It must also be noted that the sensitivity of TAN is generally greater than that of N. Because the overall N digestibility of feed dairy cow ration is 68.4%, most of the extra intake will be absorbed by the animal and subsequently be excreted in urine, making the TAN response the most prominent. The P response is in the same range or higher than the TAN response. Thus also the P excretion is very sensitive to the P intake.

The overall effect of a 10% increase in intake on the excretion for the categories of dairy cattle together and beef cattle together were similar with for N excretion 13.1% for dairy versus 13.8% for beef, for P excretion 15.2% for dairy and 18.3% for beef and for TAN excretion 15.4% for both dairy and beef. The difference in P excretion response shows a relative higher importance of P intake in beef versus dairy animals.

When expressed relative to the total livestock the 10% change in intake for all the cattle results in a 8.6% increase in excretion for N and P and a 9.4% increase for TAN excretion.

Increase in retention
An increase in retention has the opposite effect of a 10% increase in intake. When retention increases there is a lower excretion. The effect of the decrease in excretion depends on the amount of retention relative to the excretion in the starting situation. When the retention increases with 10% the change in excretion for N, P and TAN ranges from -0.8% (female young stock ≥ 1 year) to -6.4% (calves for white veal production) for N, -1.4% (male young stock and breeding bulls) to -15.5% (calves for white veal production) for P and -0.8% (male young stock and breeding bulls) to -9.8% (calves for white veal production) for TAN. Again, like for intake, the lowest values are for the relatively slower growing and heavier male animals and animals older than 1 year. The highest values are for the relatively fast-growing and lighter white veal calves. For dairy cows, a 10% higher retention results in a decrease in excretion of N, P and TAN with, respectively, -3.1%, -5.2% and -5.4%. These values are mostly (not all) lower than the 10% increase in retention, showing that a percentual error in retention is mostly not fully translated into the same percentual error in excretion.
As for an increase in intake, a 10% increase in retention has a larger effect on TAN than compared to N excretion. This is because TAN equals the part of N intake that is digested minus the N retention. The N excretion is equals N intake minus N retention. Generally, the effect of P excretion was the highest, showing the relative importance of a correct P retention estimate. The intake/retention ratio is lower for P, which means cattle feed is more accurately adjusted to the P requirement than for the N requirement.
The overall effect of a 10% increase in retention on the excretion for the categories of dairy cattle together and beef cattle together were similar with for N excretion -3.1% for dairy versus -3.8% for beef, for P excretion -5.2% for dairy and -8.3% for beef and for TAN excretion 5.4% for both dairy and beef.
When expressed relative to the total livestock the 10% increase in retention for all cattle results in a -2.1% change in N excretion, a -3,1% change in P excretion and a -3.3% change in TAN excretion.

Implications for scenarios with increased intake and retention
Dairy cows contribute about 72-74% to the total N, P and TAN excretion of total cattle. Therefore, they are by far the most important cattle category even though the relative change in excretion was not the highest compared with other cattle categories. The next biggest animal category in absolute excretion with about 9-11% of the total cattle excretions is female young stock of one year and older. However, female young stock of one year and older showed a low sensitivity to model errors and may not be the first focus for improvement. The following most significant categories in excretion are that of dairy cows young stock younger than 1 year and calves for white veal and rose veal production, each around the 3-5% relative importance. The relatively high sensitivity to intake and retention especially for the two categories of veal animals, might warrant extra attention to the correctness of the model input values for these animal categories.

3.3 Sensitivity analysis sheep, goats, horses and ponies

Table 5, 6 and 7 present an overview of the results of the sensitivity analysis for the scenarios calculating the effect of a 10% increase in N and P intake with feed or a 10% increase in N and P retention on N, P and TAN excretion from sheep, goat and horses, compared with the reference data (table 3).

Table 5 *Results of sensitivity analysis for scenarios or sheep: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either intake with feed or a 10% higher retention.*

	Relative change in excretion with +10% intake with feed			**Relative change in excretion with +10% retention**		
	N	**P**	**TAN**	**N**	**P**	**TAN**
Animal Category						
Sheep	11.7%	12.7%	12.3%	-1.7%	-2.7%	-2.3%
Total sheep, goats, horses and ponies	3.8%	3.6%	4.4%	-0.5%	-0.8%	-0.8%
Total livestock	0.2%	0.2%	0.2%	0.0%	0.0%	0.0%

Table 6 *Results of sensitivity analysis for scenarios for goats: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either intake with feed or a 10% higher retention.*

	Relative change in excretion with +10% intake with feed			**Relative change in excretion with +10% retention**		
	N	**P**	**TAN**	**N**	**P**	**TAN**
Animal Category						
Goats	12.9%	15.3%	14.8%	-2.9%	-5.3%	-4.6%
Total sheep, goats, horses and ponies	5.2%	5.9%	5.4%	-1.2%	-2.1%	-1.7%
Total livestock	0.2%	0.3%	0.3%	-0.1%	-0.1%	-0.1%

Table 7 *Results of sensitivity analysis for scenarios for horses and ponies: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either intake with feed or a 10% higher retention.*

	Relative change in excretion with +10% intake with feed			**Relative change in excretion with +10% retention**		
	N	**P**	**TAN**	**N**	**P**	**TAN**
Animal Category						
Horses	10.2%	10.2%	10.2%	-0.2%	-0.2%	-0.2%
Ponies	10.1%	10.2%	10.1%	-0.1%	-0.2%	-0.1%
Total sheep, goats, horses and ponies	2.7%	3.3%	2.8%	0.0%	-0.1%	0.0%
Total livestock	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%

Overall, the N and P intake with feed has a large effect on N, P and TAN excretion from sheep and goats in particular with the response for horses almost equal to the 10% increase. The largest effect is observed in goats.
The effect of a 10% increase in N and P retention in body and milk on N, P and TAN excretion is much smaller compared to the effect of feed intake.
Because of the relatively low total excretion of sheep, goats, horses and ponies, the impact of potential errors in these animal categories on the total livestock excretion is very small.

3.4 Sensitivity analysis pigs

Table 8 presents an overview of the results of the sensitivity analysis in the scenarios for pigs: the effect of a 10% increase in N and P intake with feed or a 10% increase in N and P retention in body on N, P and TAN excretion, compared with the reference data (table 3).

Table 8 *Results of sensitivity analysis for scenarios for pigs: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either intake with feed or a 10% higher retention.*

	Relative change in excretion with +10% intake with feed			**Relative change in excretion with +10% retention**		
	N	**P**	**TAN**	**N**	**P**	**TAN**
Animal Category						
Fattening pigs	16.8%	19.0%	20.4%	-6.8%	-9.0%	-11.1%
Gilts and boars	13.8%	14.6%	15.5%	-3.8%	-4.6%	-5.2%
Sows	16.7%	17.3%	22.2%	-6.7%	-7.3%	-9.6%
Young boars ≥50 kg	13.8%	14.6%	15.5%	-3.8%	-4.6%	-5.2%
Boars for service	11.4%	11.3%	11.4%	-1.4%	-1.3%	-1.4%
Total pigs (incl. piglets)	16.7%	18.3%	20.7%	-6.7%	-8.3%	-10.4%
Total livestock	3.1%	4.4%	4.2%	-1.3%	-2.0%	-2.1%

Feed intake has a large effect on N, P and TAN excretion from both pigs and poultry. In pigs, the increase in excretion varies from 11.4% in boars for service to over 20.4% for TAN in fattening pigs and sows, with other categories in between. Breeding boars have a low N and P retention, most of the ingested minerals are excreted. Hence, the extra excretion induced by the higher intake is about equal to the extra intake (depending on the intake/excretion ratio). Likewise, a relative increase of 10% in retention has little effect on the excretion.
In contrast, fattening pigs and sows, including piglets up to 25 kg, retain a high proportion of ingested N and P. Hence, the increase in intake causes a relatively high increase in excretion due to the ratio of intake/excretion. Likewise, a 10% increase in mineral retention is quite substantial and thus causes a relative large reduction in their excretion. In both scenarios, the effect on the excretion of TAN is more significant than the effect on N since digestibility of N (DCCP) is close to 80%. Hence, most surplus N is digested and excreted via the urine, and a lower portion via the faeces.
Overall, the contribution of pigs to the total excretion is relatively small. Nonetheless, the sensitivity to variation in intake and retention in pigs is high. Taking into account the sensitivity and the contribution of specific animal categories (table 3), more attention for the input of fattening pigs and sows would be warranted. Excretion calculations are also relevant for pigs, regardless of their contribution to the total excretion. This is because these calculations are used in determining the mean excretion values (forfaits).

3.5 Sensitivity analysis poultry

Table 9 presents an overview of the results of the sensitivity analysis in the scenarios for poultry: the effect of a 10% increase in N and P intake with feed or a 10% increase in N and P retention in body on N, P and TAN excretion, compared with the reference data (table 3).

Table 9 *Results of sensitivity analysis for scenarios for poultry: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either intake with feed or a 10% higher retention.*

	Relative change in excretion with +10% intake with feed			**Relative change in excretion with +10% retention**		
	N	**P**	**TAN**	**N**	**P**	**TAN**
Animal Category						
Broilers	24.1%	27.7%	32.0%	-14.1%	-17.7%	-22.3%
Broiler breeders <18 weeks	15.6%	13.4%	17.2%	-5.6%	-3.4%	-8.2%
Broiler breeders ≥18 weeks	13.3%	11.8%	13.3%	-3.3%	-1.8%	-4.5%
Laying hens <18 weeks	13.2%	13.1%	14.7%	-3.2%	-3.1%	-4.5%
Laying hens ≥18 weeks	14.3%	11.8%	15.8%	-4.3%	-1.8%	-5.6%
Ducks	21.3%	17.7%	26.7%	-11.3%	-7.7%	-16.6%
Turkeys	19.0%	17.0%	22.2%	-9.0%	-7.0%	-12.7%
Total poultry	17.6%	15.6%	20.4%	-7.6%	-5.6%	-10.5%
Total livestock	2.0%	2.5%	2.7%	-0.8%	-0.9%	-1.4%

Feed intake has a large effect on N, P and TAN excretion from poultry. The relative effects in poultry are particularly high in broilers, ducks and turkeys. These birds are characterised by a high efficiency and retention of minerals and a low excretion. Consequently, a 10% increase in intake makes a large contribution to the excretion, while a 10% increase in retention causes a substantial reduction in excretion. Young broiler breeders (< 18 weeks) realise higher mineral retention than young laying hens (< 18 weeks). Therefore, effects are somewhat higher in the broiler breeds than in laying hens. In contrast, adult laying hens have higher retention in eggs than broiler breeds. Hence the effects in adult animals are higher for laying hens than for broiler breeders. Overall, the contribution of poultry to the total excretion is relatively small. Nonetheless, the sensitivity to variation in intake and retention in poultry is high. Taking into account the sensitivity and the contribution of specific animal categories (table 3), more attention for the input of laying hens would be warranted. Since the input data for laying hens are more reliable, improvement of data for broilers is prioritized, however laying hens may be a topic for further study later. Moreover, excretion calculations are relevant for poultry as well, regardless of their contribution to the total excretion. This is because these calculations are used in determining the mean excretion values (forfaits).

3.6 Additional sensitivity analysis dairy cattle

Table 10 presents an overview of the results of the sensitivity analysis in the scenario with a 10% increase in NEL-requirement on N, P and TAN excretion from cattle, compared with the reference data (table 3).

Table 10 *Results of sensitivity analysis for scenario for cattle: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in NEL-requirement.*

	Relative change in excretion with +10% NEL-requirement		
	N	**P**	**TAN**
Animal category			
Female young stock <1 year	11.9%	16.2%	12.7%
Male young stock <1 year	16.3%	20.7%	21.3%
Female young stock ≥1 year	10.6%	12.3%	10.9%
Male young stock and breeding bulls ≥1 year	10.5%	11.4%	10.8%
Lactating and dry dairy cows	15.3%	14.0%	19.1%
Total dairy cattle	14.5%	13.9%	17.7%
Calves for white veal production	0.0%	0.0%	0.0%
Calves for rose veal production	0.0%	0.0%	0.0%
Female young stock <1 year	12.0%	16.3%	12.8%
Male young stock <1 year	0.0%	0.0%	0.0%
Female young stock ≥1 year	10.6%	12.3%	10.9%
Male young stock (incl. bullocks) ≥1 year	0.0%	0.0%	0.0%
Suckling cows incl. fattening/grazing ≥2 years	11.4%	12.2%	11.9%
Total beef cattle	3.2%	3.3%	3.6%
Total cattle	13.3%	12.8%	16.2%
Total livestock	8.7%	7.0%	9.9%

An increased NEL requirement has a large effect on the total N, P and TAN excretion in cattle. The ration of female young stock is based on a constant composition of the ration with fixed percentage of concentrates and roughage in relation to the NEL requirement. This approach implies that with a 10% increase in NEL requirement a larger part of the available concentrates and preserved roughage is used by young stock, leaving less for dairy cows. As a result, and due to the higher NEL requirement, the share of fresh grass in the ration of dairy cows is increasing substantially. The combination of the higher intake because of the increase in NEL and the increase in fresh grass intake leads to a response in TAN of 19.1 %, which is higher than the 16.2% from a straight increase in N intake alone (table 4). The adopted DCCP of the total ration is based on the DCCP of the Tier-3 model of the ration in the reference situation and is therefore constant. N-intake and digested N increases while the retention remains unchanged. As a result, the TAN excretion increases. The Tier-3 model is specifically applicable for dairy cows but its numbers are also the basis for correcting the digestibility of other ruminant species. The Tier-3 model could be run with the adjusted ration for a correct effect on TAN. The DCCP will then probably be higher, as the DCCP of fresh grass is generally higher than for the other forage ingredients. This would mean that TAN excretion would increase even more sharply than reported here, underlining the importance of a correct NEL requirement estimate.
For male young stock, fixed amounts of rearing milk, concentrates, silage maize and grass silage are used, so that the higher NEL requirement is fully accounted for by fresh grass. Due to the relatively high DCCP of fresh grass, the increase in TAN excretion is larger than the increase in N excretion. Female young stock beef cattle is treated the same as female young stock dairy cattle. Male beef cattle is a different category compared to male cattle on dairy farms. Therefore, for male cattle, feed

intake is not regulated through NEL intake, and no effect can be modelled. Hence, the 0.0% output values for male young stock.

Table 11 presents an overview of the results of the sensitivity analysis in the scenario with a 10% increase in milk production on N, P and TAN excretion from cattle, compared with the reference data (table 3).

Table 11 *Results of sensitivity analysis for scenario for cattle: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in milk production.*

	Relative change in excretion with +10% milk production		
	N	**P**	**TAN**
Animal Category			
Lactating and dry dairy cows	6.9%	4.4%	6.7%
Total dairy cattle	5.7%	3.7%	5.4%
Total cattle	5.1%	3.3%	4.8%
Total livestock	3.3%	1.8%	3.0%

The higher milk production leads to a higher energy requirement, consequently a higher feed and therefore higher N intake. Then N-excretion increases due to this higher N intake. As fresh grass is the forage that fills the energy gap, this increase in N intake is from fresh grass, while other ingredients stay the same. The DCCP of the total ration is equal to the DCCP of the Tier-3 model of the ration in the reference situation and is therefore constant. Due to the higher milk production, the retention also increases, this is likely why the increase in TAN in this case, contrary to the tables before, is equal and not higher than the increase in total N excretion.

Table 12 presents an overview of the results of the sensitivity analysis for the scenario for cattle: the effect of a 10% increase in body weight on N, P and TAN excretion, compared with the reference data (table 3).

Table 12 *Results of sensitivity analysis for scenario for cattle: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in body weight.*

	Relative change in excretion with +10% body weight		
	N	**P**	**TAN**
Animal Category			
Lactating and dry dairy cows	3.5%	2.8%	4.2%
Total dairy cattle	2.9%	2.3%	3.4%
Total cattle	2.6%	2.1%	3.0%
Total livestock	1.7%	1.1%	1.8%

The sensitivity of the calculated excretion to an 10% increase in bodyweight is low, between 2.8-4.2%. The N and P excretion does however increase due to a higher intake of N and P, because with a higher bodyweight the cows need more energy and therefore more feed. As stated before in the WUM this higher feed intake comes from fresh grass intake, whereas the consumption of other feed remains the same. Fresh grass contains more N and P than the average ration, which is why the increase in feed intake results in an increase in excretion of N, P and TAN. The DCCP of the total ration is equal to the DCCP of the Tier-3 model of the ration in the reference situation and is therefore constant. N-uptake, digested N and retention increase.

Table 13 presents an overview of the results of the sensitivity analysis in the scenarios with a 10% increase in the availability of either maize silage, grass silage or concentrate on N, P and TAN excretion, compared with the reference data (table 3). The effects on lactating and dry dairy cows are shown only, because this is the only animal category that is affected by these scenarios.

Table 13 *Results of sensitivity analysis for the scenarios for cattle: numbers reflect the relative change (percent) in N, P, or TAN excretion with an increase of 10% in either maize silage availability, grass silage availability or concentrate availability.*

	Relative change in excretion with +10% maize silage			**Relative change in excretion with +10% grass silage**			**Relative change in excretion with +10% concentrates**		
	N	**P**	**TAN**	**N**	**P**	**TAN**	**N**	**P**	**TAN**
Animal Category									
Lactating and dry dairy cows	-2.1%	-1.5%	-2.7%	0.3%	1.2%	-0.1%	-0.4%	1.7%	-0.7%
Total dairy cattle	-1.8%	-1.2%	-2.2%	0.3%	1.0%	-0.1%	-0.4%	1.4%	-0.5%
Total cattle	-1.6%	-1.1%	-2.0%	0.2%	0.9%	-0.1%	-0.3%	1.2%	-0.5%
Total livestock	-1.0%	-0.6%	-1.2%	0.2%	0.5%	0.0%	-0.2%	0.7%	-0.3%

In lactating and dry dairy cows, changes in the availability of feed components have an effect on N, P and TAN. The largest effect, although still very small, is observed when the availability of maize silage increases. The effect on TAN is -2.7%. The ration of all cattle categories, except for dairy cows is based on standardized shares of concentrates and roughage in relation to the NEL requirement. Changes in the availability of feed components while assuming constant NEL requirements are therefore only expressed in the excretion of dairy cows. In this case, more maize silage will be available for dairy cows, reducing fresh grass intake. The DCCP of the total ration is assumed equal to the DCCP of the Tier-3 model of the ration in the reference situation and is therefore constant. The Tier-3 model is specifically applicable for dairy cows but its numbers are also the basis for correcting the digestibility of other ruminant species. For a correct effect on TAN, the Tier-3 model could be run with the adjusted ration. The DCCP will then probably be lower, as maize silage has a lower DCCP than other forage, and consequently the TAN excretion will therefore fall more than indicated now. However the effect would still be relatively small.
In the scenario with higher grass silage availability for dairy cows, fresh grass intake will be reduced. A small increase is observed in N (+0.3%) and P (+1.2%) excretion and a small decrease in TAN (-0.1%) excretion. The N content of grass silage is lower than the N content of fresh grass, but the NEL content of grass silage is also lower, so when fresh grass is replaced by grass silage, the dry matter intake must increase to meet the feed requirement. On balance, the effect on excretion is negligibly small. The effects on P excretion are generally so small that they are negligible.

Table 14 presents an overview of the results of the sensitivity analysis in the scenario calculating the effect of a 10% increase in DCCP in dairy cows on TAN excretion or a 10% increase in DCCP in beef cattle, sheep, goats and horses, compared with the reference data (table 3).

Table 14 *Results of sensitivity analysis for the scenarios for dairy cattle and for beef cattle, sheep, goats, horses and ponies: numbers reflect the relative change (percent) in TAN excretion with an increase of 10% in DCCP in dairy cows and in other cattle.*

	Relative change in excretion with +10% DCCP dairy cows	Relative change in excretion with +10% DCCP other cattle
	TAN	**TAN**
Female young stock <1 year	-	12.3%
Male young stock <1 year	-	13.8%
Female young stock ≥1 year	-	11.2%
Male young stock and breeding bulls ≥1 year	-	10.8%
Lactating and dry dairy cows	16.2%	-
Total dairy cattle	13.1%	2.2%
Calves for white veal production	-	10.3%
Calves for rose veal production	-	15.7%
Female young stock <1 year	-	12.4%
Male young stock <1 year	-	15.8%
Female young stock ≥1 year	-	11.2%
Male young stock (incl. bullocks) ≥1 year	-	13.0%
Suckling cows incl. fattening/grazing ≥2 years	-	11.9%
Total beef cattle	-	12.5%
Total cattle	11.7%	3.3%
Sheep	-	12.3%
Goats	-	14.5%
Horses	-	10.0%
Ponies	-	9.9%
Total sheep, goats, horses, ponies	-	12.5%
Total livestock	7.2%	2.6%

In both scenarios, TAN excretion increases with increased digestibility while retention remains the same. Due to the higher DCCP digested, N excretion in TAN increases, but total N excretion (not shown) remains the same. As absorbed N increases and retention remains the same, this leads to an increase of TAN. An increased DCCP of dairy cow feed has the largest effect on TAN excretion from livestock in total compared to an increased DCCP other cattle feed. The increased DCCP increases the TAN excretion with 10 to 15% for all calculated animal categories. Currently, the DCCP in dairy cows, as mentioned before, is modelled with the Tier 3 model. However, for other cattle categories, the DCCP of the other cattle species is extrapolated from this value from the Tier 3 model. Seeing that the TAN for all cattle species is sensitive to this change extra effort to further substantiate the exploration of DCCP from Tier 3 dairy cattle to other cattle species might be warranted.

Table 15 and 16 present an overview of the results of the sensitivity analysis for the scenario for pigs: the effect of a 10% increase in DCCP in pigs on N, P and TAN excretion, compared with the reference data (table 3).

Table 15 *Results of sensitivity analysis for scenario for pigs: numbers reflect the relative change (percent) in TAN excretion with an increase of 10% in DCCP.*

	Relative change in excretion with +10% DCCP
	TAN
Fattening pigs	19.7%
Gilts and boars	15.7%
Sows	22.2%
Young boars ≥50 kg	15.7%
Boars for service	12.5%
Total pigs (incl. piglets)	20.2%
Total livestock	4.1%

Table 16 *Results of sensitivity analysis for the scenario for pigs: numbers reflect the relative change (percent) in TAN excretion with an increase of 10% in DCCP.*

	Relative change in excretion with +10% DCCP
	TAN
Broilers	31.7%
Broiler breeders <18 weeks	18.1%
Broiler breeders ≥18 weeks	14.1%
Laying hens <18 weeks	14.1%
Laying hens ≥18 weeks	15.6%
Ducks	26.9%
Turkeys	21.9%
Total poultry	20.3%
Total livestock	2.7%

The results demonstrate that the TAN excretion is highly sensitive to the variation in DCCP. With a 10% increase TAN excretion increase anywhere from 12.5% for breeding boars to 22% in sows and from 14.1% in broiler breeders and young laying hens to 31.7% for broilers. The relative effect is largest in those animal categories that have a high efficiency of retention of digested N. For these animals the TAN excretion is low, hence a change in DCCP has a relatively large impact. This includes in particular fast-growing animals as weaned pigs (included in the sow category) fattening pigs, and poultry for meat production. Hence, adequate input of the DCCP is particularly important for these animal categories. In addition, despite the somewhat smaller effect in laying hens, this category is equally relevant because of the relatively high contribution to the total TAN excretion (table 3).

4 Interpretation and conclusions

This report describes a sensitivity analysis of the calculated excretion of N, P and TAN to variation in input parameters for the most relevant animal categories. The results showed that the sensitivity to a change in an input parameter is different between the various input parameters that have been investigated. However, some general conclusions can be drawn that give direction of the next steps in the project. At the end of this chapter the priority for further investigation into specific animal categories is suggested, based on the current evaluation of the sensitivity, the estimated reliability of the input values, and their contribution to the present excretion of N, P and TAN (table 17).

4.1 Sensitivity to changes in intake

In general for most species the excretion of N, P and TAN is sensitive to especially a change in the intake of N and P. An increase of N and P intake of 10% generally enhances the excretion of N, P and TAN by more than 10%. This is especially the case in animals with a high efficiency of utilization (retention) of N and P, and thus a low excretion of N, P and TAN. In this situation, the extra intake of N and P, that is fully excreted, is a relatively large part of the basal excretion. This conclusion is supported by Zom & Kasper (2019). Similarly, according to the uncertainty analysis performed in by CBS, feed intake and feed composition are relatively uncertain components as it depends not only on animal production levels, but also on the type of farming system (Van Bruggen & Gosseling, 2012). Therefore, a correct estimation of total N and P intake is relevant for all species and should be addressed in the next step in the project, to evaluate the correctness. This means special focus for dairy cows (also see below at In-depth analyses of dairy cow scenarios), fattening pigs, sows, broilers and laying hens. Depending on specific interest or relevance, other categories may be addressed.

4.2 Sensitivity to changes in retention

In general, the sensitivity to changes in retention was lower than the sensitivity to intake. A change in retention may be caused by either a change in growth rate, production or in composition of the body gain. The N and P content of the body gain is presently based on data from 2010, and older data. For growing animals in which retention in body tissues is important (e.g. fattening pigs and broilers), it is advised to further investigate availability of more recent data. This conclusion is supported by the uncertainty analysis by CBS (Van Bruggen & Gosseling, 2012). Appendix 2 gives results of a brief literature scan of the potentially available data for establishing updated body composition of pigs, based on which it seems feasible to study this further. For broilers it is equally relevant to investigate body composition, or at least conduct a similar literature scan. For dairy cows the main retention is in milk, for which N and P are fairly accurately analysed. Therefore, further research in N and P retention has low priority for this animal category.

4.3 Sensitivity to DCCP

The sensitivity for TAN to DCCP is generally high for all species and could merit further investigation. For pig and poultry species DCCP is a parameter that is generally well documented , as it is important for determining digestible protein which is used in ration optimization for these species. For dairy cows DCCP is based on the well substantiated Tier 3 model, however for other cattle species DCCP is estimated by extrapolation from dairy cattle. Therefore a more in depth analysis of DCCP for other cattle species may be warranted. Important to note is that it remains uncertain whether the composition of compound feed and total ration used in the WUM model are representative for all Dutch livestock. The literature scan in Appendix 3 regarding this topic indicates that there may be enough data to conduct further literature review in this area.

4.4 In-depth analyses of dairy cow scenarios

Scenarios that are more specific for dairy cows deal with the sensitivity to the NEL requirement, to the availability of the feedstuffs (maize silage, grass silage and concentrates), to body weight and to body composition of dairy cows.

NEL requirement
A change in NEL requirement has a large impact on the excretion of N, P and TAN, for the important category of dairy cows. In the WUM method, the NEL requirement is used to calculate feed intake (for male cattle, feed intake is not regulated through NEL intake, and no effect could be modelled). This approach is also the basis for instance the KLW. Furthermore, this approach is supported by, for example, Oenema et al. (2017). As concluded in the uncertainty analysis (Van Bruggen & Gosseling, 2012), the inaccuracy of the Dutch NEL system results in an overall uncertainty in NEL requirement of dairy cows of 2%, which is also supported by other research (e.g. Bannink, 2010; Hollander et al., 2014). It was recommended earlier to improve the calculations for VEM requirements (Zom & Kasper, 2019). Since the development of the NEL system, other models have been developed with the aim of estimating feed intake, such as e.g. the satiety value model by Zom (2014).
In conclusion, the current estimation error of 2% is fairly good for a model. However, because of the existence of specific feed intake models, the importance of feed intake for the calculation of excretion of N, P, and TAN, as well as the advice of Zom & Kasper (2019), it is prudent to further investigate potential improvement of the estimation of intake in the WUM for this important animal category.

Availability of feed components
For the availability of grass silage, maize silage and concentrates the sensitivity to a change in availability was quite low. Both concentrates and maize silage have been indicated before by CBS (Van Bruggen & Gosseling, 2012) as input values with relatively high uncertainty. Since the highest sensitivity was found for the availability of maize silage, attention for availability of maize silage should have priority above availability of grass silage and concentrates.

Milk production
The VEM requirement increases as the milk production increases, thus increasing intake of feed, N and P. However, the TAN excretion in the WUM model is not very sensitive to variation in milk production. Due to a higher milk production, the retention increases. The increase in TAN excretion does, therefore, not exceed the increase in N excretion. Moreover, the milk production is accurately monitored at this moment. Likewise, the uncertainty in milk production levels plays a minor role in the overall uncertainty of the TAN excretion (Van Bruggen & Gosseling, 2012). Therefore, further investigation of the estimation of milk production has low priority.

Body composition and body weight
The excretion in the WUM model for dairy cows is not very sensitive to variation in body composition. The same conclusion was drawn earlier by Zom & Kasper (2019). Nonetheless, the data for body composition is quite outdated (Appendix 4). Further investigation of the body composition of dairy cows does have a relatively low priority, because of the small impact, but may be interesting to have the most recent data included. Similar to body composition, the impact of body weight in dairy cows is relatively small, but because of the large contribution of dairy cows to total excretion still interesting. Variation in body weight leads to variation in NEL requirement, for which body weight is an important starting value. Improvement of body weight input values will therefore also contribute to improvement of NEL requirement calculations. CVB has recently updated their estimate of body weight for modern Dutch dairy cows based on recent data, as shown in Appendix 5. Therefore, it is advised to evaluate the suitability of these CVB values for body weight in dairy cows and not to further investigate body weight itself.

4.5 Priorities for further research

Based on previous advices an reviews a research project has started to improve the calculation of the national excretion values for farm animals as done by the WUM model. This report is the first step of this project, a sensitivity analysis of variation in the input values on the change of the output values of the WUM model. Accurate and validated input values are of high importance for national excretion calculations in the Netherlands. In order to prioritize the different potential topics for follow up research an overview (table 17) was made combining the proportional contribution of the total TAN excretion in the Netherlands, the results from this sensitivity analysis and the (estimated) reliability of the different input parameters. This overview serves as a tool to prioritize input parameters for further research.

Table 17 *Overview of the sensitivity of the WUM-method for different input parameters and corresponding priorities for improvement*.*

Animal category	**Share total TAN excretion (% of total)**	**Input parameter**	**Sensitivity TAN**	**Reliability input data**	**Priority**	
Young stock (0-2 yrs)	10	Intake	++	+++	+	
		Retention	+	++	+	
		DCCP	++	+	+++	
Dairy cows	48	Intake	++	++	+++	
		Retention	+	+++	0	
		NEL requirement	++	+++	+	
		Milk production	+	+++	0	
		Body weight	+	++	0	finished (WP1)
		Availability maize silage	+	+	++	
		Availability grass silage	+	++	0	
		Availability concentrates	+	+++	+	
		DCCP	++	+++	0	
White veal calves	2	Intake	++	++	+	combined with forfaits project
		Retention	+	++	+	combined with forfaits project
		NEL requirement	0	++	+	combined with forfaits project
		DCCP	++	++	+	combined with forfaits project
Rose veal calves	2	Intake	++	++	+	combined with forfaits project
		Retention	+	++	+	combined with forfaits project
		NEL requirement	0	++	+	combined with forfaits project
		DCCP	++	++	+	combined with forfaits project
Young stock (0-2 yrs)	2	Intake	++	++	0	
		Retention	+	++	0	
		NEL requirement	++	++	0	

Animal category	Share total TAN excretion (% of total)	Input parameter	Sensitivity TAN	Reliability input data	Priority	
		DCCP	++	++	0	
Suckling cows	1	Intake	++	++	0	
		Retention	+	++	0	
		NEL requirement	++	++	0	
		DCCP	++	++	0	
Sheep, goats, horses, ponies	4	Intake	++	++	+	check input values
		Retention	+	++	+	check input values
		DCCP	++	++	0	
Fattening pigs	13	Intake	+++	+++	0	
		Retention	++	++	+++	update body composition
		DCCP	++	++	++	feed optimalisations for DCCP
Gilts	1	Intake	++	++	+	check input values
		Retention	+	++	+	check input values
		DCCP	++	++	0	
Sows	5	Intake	+++	+++	+	check input values
		Retention	+	++	+	check input values
		DCCP	+++	++	0	
Young boars	<1	Intake	++	+	+	check input values
		Retention	+	+	+	check input values
		DCCP	++	++	0	
Boars for service	<1	Intake	++	+	+	check input values
		Retention	+	+	+	check input values
		DCCP	++	+	0	
Broilers	4	Intake	++++	+++	+++	specify input parameters for concept animals
		Retention	+++	++	+++	specify input parameters for concept animals
		DCCP	++++	++	0	
Broiler breeders	1	Intake	++	++	+	check input values
		Retention	+	++	+	check input values
		DCCP	++	++	0	
Laying hens	7	Intake	++	+++	0	
		Retention	+	+++	0	
		DCCP	++	++	0	
Ducks, turkey	<1	Intake	+++	+	0	
		Retention	++	+	0	
		DCCP	+++	++	0	

The degree of sensitivity, reliability and priority in the table above is presented as follows:

0	*not sensitive*	*least reliable*	*no priority*
+	*somewhat sensitive*	*less reliable*	*low priority*
++	*sensitive*	*reliable*	*high priority*
+++	*very sensitive*	*very reliable*	*highest priority*
++++	*extremely sensitive*	*most reliable*	

Similar to the sensitivity of the modelled excretion to input parameters, the uncertainty of input parameters differs substantially between animal categories. In the uncertainty analysis performed earlier by CBS (Van Bruggen & Gosseling, 2012), it was concluded that the uncertainty in excretion factors is mainly determined by uncertainty in feed intake and composition, manure production level, N and P content of animal products. Combining the results of the uncertainty analysis and the results of this sensitivity analysis, it is observed that the most sensitive input parameters are also among the more uncertain parameters (table 17). Improving the certainty of these parameters will, therefore, improve the accuracy of the excretion calculations according to the WUM method.

Based on the results of both this sensitivity analysis and the uncertainty analysis performed earlier (Van Bruggen & Gosseling, 2012), it is recommended to analyse the accuracy of the estimated WUM input parameters that have a substantial effect on the total excretion as a first step. Table 17 shows the sensitivity, reliability and corresponding priority for future research for each input parameter per animal category. Subsequently, based on table 17, it is recommended to collect available new and improved data that could help in improving the following input values of the WUM model:

Dairy cattle

In the Netherlands, dairy cattle are the largest contributors (48%) to the total TAN excretion. Therefore, in further research, specific attention should be paid to the most sensitive and less reliable input parameters for dairy cows. As the WUM model is sensitive to variation in N and P intake with feed and these intake data are among the less reliable input data, it should be investigated whether the input of N and P intake can be improved. Although sensitivity for the availability of maize silage was low, the input data are very uncertain and further improvement is needed.

The animal categories of white veal calves and rose veal calves have a relatively small contribution to total TAN excretion (2%) with low to moderate sensitivity and moderate reliability of the input data. However these animal categories have recently been studied in another project that was aimed at determining excretion forfaits for these animals categories. We will first evaluate the results of that project before investigating these categories.

Pigs and poultry

For pigs and poultry, the input data for N and P intake with feed are uncertain. This sensitivity analysis showed that the WUM method is also sensitive to variation in the intake of N and P for pigs and poultry (especially broilers). Therefore, it should be further investigated whether this input parameter can be improved. For both pigs and poultry, it should be investigated whether input data for N and P retention (body composition) can be improved, as table 17 shows a relatively high sensitivity and uncertainty for this input parameter.

There are a number of animal categories which have a small contribution to the total TAN excretion, such as: sheep, goats, horses and ponies, gilts, sows, young boars, boars for service, and finally broiler breeders. These categories do not warrant a full investigation, however because their input values are relatively uncertain a check on the correctness of the current input values is warranted.

The input parameters (N & P intake and retention) for laying hens are estimated to be quite reliable and the sensitivity of these parameters is moderate (2 or 1 plus). Therefore laying hens has for now not been prioritized for further investigation.

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Appendix 1 Outcome expert workshop

Samenvatting expert workshop – excretieberekeningen t.b.v. ammoniakemissie.

Deelnemers: Cor van Bruggen (CBS), André Bannink (WLR-DV), Leon Sebek (WLR-DV), Roselinde Goselink (vz, WLR-DV), Harmen van Laar (WLR-DV), Gerard Velthof (WEnR), Jan van Harn (WLR-DV), Karin Groenestein (WLR-D&O), Izak Vermeij (WLR-D&O), Harry Luesink (WEcR), Ronald Zom (WLRDV), Jan Dijkstra (WU-diervoeding), Paul Bikker (WLR-DV).
Verhinderd: Oene Oenema (WEnR), David van Doorn (UU-diergeneeskunde), Arjan Wisman (WEcR)

Inleiding
Op maandag 9 November is een virtuele workshop gehouden om te komen tot ideeën hoe de berekening van de NH3 emissie in Nederland te verbeteren met als uiteindelijk doel tot een projectvoorstel te komen op welke onderwerpen werk dient te gebeuren om het huidige systeem van excretie- en emissieberekeningen te verbeteren. Roselinde Goselink was voorzitter van de discussie/workshop en startte met een overzicht van hoe de excreties van N (en P) en de uiteindelijke NH3 emissie berekend worden. Daarna vond discussie plaats om verbeterpunten naar boven te krijgen. Deze samenvatting wil deze punten weergeven op basis van het (sterk vereenvoudigde) schema van de berekening van de excretie en emissies (Figuur 1). Hierbij zal per onderdeel aandacht besteed worden aan de verschillende diersoorten. Dit is anders dan de indeling van de discussie waarbij veel meer per diertype gewerkt werd.
Naast de punten passende in het huidige systeem, werden nog een aantal aandachtspunten aangedragen die op een meer algemeen niveau liggen deze zullen eerst besproken worden.

Samenvatting discussie: Algemeen
De discussie richtte zich vooral op omissies/verbetermogelijkheden van het huidige systeem van berekening. Er werd terecht opgemerkt en door eenieder onderschreven dat het ook goed zou zijn om eerst na te denken of de huidige manier van berekenen ook het ideaal plaatje is. Zouden we wanneer we op dit moment het systeem opnieuw gingen opzetten het zelfde model bouwen. Het is goed om aandacht voor deze overweging in het projectvoorstel op te nemen. Een van de overwegingen zou kunnen zijn om te verkennen in hoeverre het mogelijk is een model te ontwikkelen wat niet de totale TAN excretie voorspelt, maar ook de TAN-concentratie. Dit is van belang aangezien de NH3-excretie nu wordt berekend op basis van de totale TAN-excretie met een constante NH3-emissiefactor (als % TAN). Echter deze emissiefactor is (lineair) afhankelijk van de TAN-concentratie, mogelijke verschillen in TAN concentratie worden dus nu niet meegenomen. Het zou goed zijn eerst te evalueren in hoeverre het realistisch is een TAN-concentratiemodel te bouwen, en vervolgens te zien of dit past in het projectvoorstel.
Gedurende de discussie kwam verschillende keren de vraag naar voren betreffende de nauwkeurigheid op regionale schaal versus de nauwkeurigheid op Nederlandse schaal. Op Nederlandse schaal worden heel veel zaken “platgeslagen”. Deze vraag is tweeledig, aan de ene kant moet men er voor waken dat model berekeningen op dierniveau niet een detaillering vragen die niet relevant is voor Nationaal niveau. Aan de andere kant is het met betrekking tot regionale berekeningen van belang dat input data en modellen specifiek genoeg zijn. Voor nationaal doel spelen kleine diersoorten wellicht geen wezenlijke rol, regionaal misschien wel als een bedrijf op een gevoelige plek ligt. Maar individuele excretie is voor een bedrijf met kleine diersoort net zo belangrijk. Er werd nog opgemerkt dat we nog wel terug naar LNV terug moeten om uit te leggen aan Team Mest dat we kleine sectoren meenemen t.b.v. excretieforfaits, dit om de relevantie aan te geven.

Afstemming BEX/KLW – WUM/NEMA
De regionale versus Nationale discussie bracht ook de vraag naar voren in hoeverre de BEX/Kringloopwijzer en WUM/NEMA gesynchroniseerd worden. De berekeningswijzen zijn in principe gelijk (met als enige verschil hoe het VEM-gat bij melkvee gevuld wordt). Ontwikkeling in

berekeningsmethodiek vinden in verschillende projecten plaats, echter tijdens de workshop werd 12 gesteld dat er voldoende overleg is tussen de projecten. De verschillende projecten kunnen daarom aparte ontwikkeltrajecten volgen, waarbij geborgd is dat de uiteindelijke toepassing wordt gesynchroniseerd.

Validatie

Naast ideeën hoe het model zelf verbeterd kan worden is ook aandacht nodig voor de validatie van de modellen. Er moet worden nagedacht over hoe de modellen te valideren zijn. Op basis van het verschil in N:P verhouding "onder de staart" zoals berekend met het model, en de N:P verhouding van afgevoerde mest is een validatie van de NH3 emissie gemaakt (Groenestein et al., 2015; van Bruggen en Geertjes, 2019). Er zijn hier nog gaten tussen voorspeld en gemeten. Echter het gebruik van N:P verhouding houdt dus in dat zowel de N als de P goed voorspeld moet worden. Verdere validatie van de onder de staart voorspelde N:P verhouding zou goed zijn, echter hierbij komt het probleem dat mest in de put zeer lastig homogeen is te bemonsteren naar voren. Bemonstering van mest in de put verdient aandacht.
Een van de ideeën die naar voren kwamen om uitscheiding en emissie beter te valideren is het gebruik van additionele merkers, bijvoorbeeld kaliumconcentratie in mest. Ook werd het bepalen van droge stof in de mest genoemd (ook in relatie met het idee naar een concentratie model te gaan). Evaluatie van additionele metingen om de modellen te valideren is nuttig.

Documentatie

Alhoewel niet direct in de workshop bediscussieerd, werd op basis van de evaluaties van het berekeningssysteem (CDM, 2012, Sutton et al., 2015, Hordijk et al., 2020a, 2020b) de vraag naar voren gebracht of het mogelijk zou zijn alle rekenregels (en aannames) van het excretiesysteem (dus t/m N, P in mest en TAN) transparant te documenteren. Vorig jaar is hiernaar gevraagd bij het bekend maken van de excretieforfaits.

Toekomst

Er was reeds een actie genoemd, waarbij niet alleen naar verbeteringen in het huidige model gekeken dient te worden, maar ook naar hoe een ideaal model er uit zou zien. Daarnaast is het van belang toekomstige trends te identificeren welke impact hebben op de excretie en emissie van dieren en bij gebruik in de praktijk in het model meegenomen dienen te worden. Hierbij valt te denken aan additieven die de N en P verteerbaarheid beïnvloeden. Ook zijn er additieven die zowel in het dier, alsook via aanzuring van de urine (eg. Benzoëzuur) effect kunnen hebben op excretie en emissie. Voor melkvee (wellicht ook bij andere dieren) kan het type TAN van belang worden wanneer naar de toekomst toe het eiwit in het rantsoen naar beneden gaat. Bij een lager eiwit in het rantsoen is het de verwachting dat de TAN voor een kleiner deel uit ureum bestaat waardoor de NH3 emissie factor mogelijk veranderd. Het is goed te inventariseren wat de impact van deze ontwikkelen en producten is en welke toepassingen in de toekomst van belang kunnen worden.

Verbetering van huidige model onderdelen

De beschrijving van de algehele principes waarop de berekeningen in WUM en NEMA gebaseerd zijn staat weergegeven in Figuur 1. Het lijkt vrij simpel, per diersoort wordt voor een gemiddeld dier de totale uitscheiding van N en P in de mest en urine samen berekend, door de (gemiddelde) N en P uitscheiding in product (totale dier, melk, eieren) af te trekken van de (gemiddelde) N en P opname met het voer. Voor N wordt deze totale mest en urine uitscheiding op basis van een diersoort specifieke N verteringsmodel verdeeld in een uitscheiding in de mest en een uitscheiding in de urine (TAN voor N). Voor ammoniakemissie wordt op basis van verschillende stalsystemen een emissiefactor als percentage van de TAN gebruikt om de absolute hoeveelheid ammoniak emissie per dier(plaats) uit te rekenen. Uiteindelijk wordt dan de Nationale uitscheiding en emissie berekend door het totale aantal dieren per diersoort te vermenigvuldigen met de diersoort specifieke excreties en emissies.
Dit klinkt vrij simpel, echter, afhankelijk van de diersoort zijn niet alle inputgegevens beschikbaar voor de betreffende diersoort. Voor sommige diersoorten zijn inputgegevens alleen op een hoger aggregatieniveau beschikbaar, bijvoorbeeld hoeveelheid rundveevoer en moet de input voor diersoorten berekend worden op basis van verschillende aannames. Hieronder wordt per input type de tijdens de workshop genoemde punten van aandacht weergegeven.

Dieraantallen

Dieraantallen vormen naast de excretie- en emissiefactoren de basis van de totale excretie en emissieberekeningen. De groepen dieren in de excretieberekeningen worden weergegeven in Figuur 2. De betrouwbaarheid van de gebruikte dierkengetallen verschilt sterk per diercategorie. Voor de veel voorkomende dieren zijn de dierkengetallen betrouwbaarder dan voor de kleinere diercategorieën waarvoor een deel van de informatie veelal afkomstig is van schattingen en "expert judgement" uit "het netwerk". Het zou goed zijn een gevoeligheidsanalyse uit te voeren om duidelijk te krijgen hoe groot het effect van fouten in dierkengetallen in de minder betrouwbare diercategorieën is voor de totale excretie- en emissieberekeningen. Hoewel kleine diercategorieën wellicht (afhankelijk van gevoeligheidsanalyse) een kleine invloed hebben op de totale emissies kunnen deze lokaal wel degelijk een groot effect hebben. Verder dient er aandacht te zijn of de getallen m.b.t. speciale "concept dieren" goed vertegenwoordigd zijn. Bijvoorbeeld het aandeel traag groeiende dieren, bij vleeskuikens. Hierbij is het goed te evalueren wat de status is van eigendom van data.

Voeropname

Voor de meeste diersoorten wordt voor de voeropname met vaste inschattingen gewerkt en is de inschatting voor graasdieren in het algemeen lastiger dan voor staldieren. Uitzondering hierop kan het gebruik van brijvoeders bij staldieren zijn, waardoor voeropnameschatting ook complexer wordt. Het meest complex is de schatting van de voeropname van melkvee. Deze wordt berekend aan de hand van de VEM-behoefte van melkvee en de VEM in de hoeveelheid geschatte opname van krachtvoer, grassilage, maïssilage en vers gras. Hierbij wordt de hoeveelheid krachtvoer opgenomen door melkvee berekend op basis van de totale hoeveelheid krachtvoer voor rundvee, gecorrigeerd voor de opname van bijvoorbeeld jongvee en vleesvee. Uiteindelijk wordt de hoeveelheid vers gras opname geschat door het VEM-gat dat ontstaat door de VEM-behoefte van de koe te verminderen met de VEM-opname uit krachtvoer, grassilage en maïssilage, te vullen met VEM uit vers gras. Hierbij accumuleren fouten in de onderliggende aannames in de vers gras opname. Opmerkelijk hierbij is dat de grassilage productie uit de cijfers van de kringloopwijzer (KLW) berekend wordt, maar dat de opbrengst van maïssilage (per hectare) uit gegevens van het Bedrijven Informatie Netwerk (BIN) komt (de totale oppervlakte mais komt uit de landbouwtelling). Dit aangezien de KLW gegevens tot onwaarschijnlijk hoge opnames aan maïssilage leiden. Het is goed de bepaling van de maïssilage oogst en uiteindelijk opname te evalueren en zo nodig en wanneer mogelijk aan te passen. De juistheid van het VEM model is dus van belang voor een juiste voeropname schatting, het is goed deze toepassing te evalueren. Verder blijkt dat de data zoals in KLW grondig filtering vereist voordat deze toegepast kunnen worden. Vanaf januari 2020 zijn de automatische invoer en filtering van KLW verbeterd hetgeen tot minder foute invoer zou moeten leiden.
Voor melk-rundvee wordt gerekend met Nevedi-afzet en samenstelling van RVO. Voor vleesvarkens en fokzeugen wordt gerekend met verbruik op basis van agrovision-kengetallen en voor leghennen en vleeskuikens op basis van BIN-kengetallen. Voor overige categorieën wordt gerekend met verbruik uit KWIN-kengetallen (indien aanwezig). De samenstelling van alle voeders is gebaseerd op RVO-data uitgezonderd sommige categorieën graasdieren (schapen, paarden). De voercategorieën van rundvee, varkens en pluimvee zijn geaggregeerd, daarom is het nodig deze opname verder te verdelen over onderliggende diercategorieën. Door aannames voor de voeropname van geselecteerde diercategorieën wordt door "afpellen" de samenstelling van krachtvoer voor andere diercategorieën berekend. Ook dit leidt tot onzekerheden.

Samenstelling voeders

Krachtvoeders

De N en P samenstelling van de krachtvoeders wordt door de mengvoer leveranciers aan RVO doorgegeven. Dit is voldoende voor de berekening van de totale N en P excretie. Echter voor de berekening van de TAN is het voor de meeste diersoorten nodig om ook het verteerbaar ruw eiwit (VRE) gehalte van de voeders te weten (op basis van CVB (2019) getallen). Voor melkvee wordt de krachtvoersamenstelling voor het zelfde doel gebruik (TAN berekening), echter wordt daarvoor het Tier III model van Bannink et al. (2018) gebruikt. Op dit moment wordt dit niet doorgegeven en wordt dit berekend door op zichzelf staande voeroptimalisaties, het is onbekend hoe goed deze optimalisaties aansluiten bij de daadwerkelijk gevoerde krachtvoeders. Het doorgeven van krachtvoersamenstelling door mengvoer bedrijven ligt gevoelig, dit zal niet makkelijk zijn. Wellicht is het mogelijk dat naast de N en P gehaltes die mengvoerbedrijven doorgeven aan RVO het ook mogelijk is dat een VRE gehalte doorgegeven wordt. Dit zou voor stal dieren een oplossing zijn. Voor het Tier III model voor melkvee blijft voersamenstelling van belang. Hierbij wordt ook aangegeven te kijken naar andere bronnen. Er is een organisatie Stigevo genaamd, die getallen over grondstof import en export weergeeft met een verdeling naar diersoort. Vroeger werd Stigevo-data gebruikt maar dit gaf onvoldoende weer welke grondstoffen in welk mengvoer terecht kwamen.

Ruwvoeders
Voor ruwvoerder wordt gewerkt met de gemiddelde samenstelling zoals geanalyseerd door Eurofins. Vooral voor vers gras wordt er betwijfeld of deze samenstelling representatief is voor het echt door melkvee gevreten vers gras. Ten eerste omdat de grassamenstelling veranderd gedurende het seizoen, met een verschillende grasopname per seizoen. Hierdoor is de samenstelling van het gevreten gras waarschijnlijk anders dan de nu gebruikte gemiddelde samenstelling. Ten tweede omdat er getwijfeld wordt of de geanalyseerde monsters (categorie vers gras) het gevreten gras goed representeren, waarschijnlijk omdat er ook monsters genomen worden van gras voordat het ingekuild wordt. Er zijn andere (private) initiatieven in Nederland (bv gras meetnet) waar wellicht betrouwbaarder informatie beschikbaar is (zolang deze initiatieven lopen).

Product hoeveelheid en samenstelling
Melk
De enige opmerking met betrekking tot de input gegevens voor melk had betrekking op de berekening van de energie waarde van melk (wat weer gebruikt wordt in de berekening van de voeropname voor melkvee). In de huidige systematiek wordt daar alleen het vet en eiwit gehalte voor gebruikt, mogelijk dat lactose aanvullend van waarde kan zijn.

Vlees/karkas/lichaam
De lichaamssamenstelling (N en P) van de grootste groepen mono-gastrische dieren is gebaseerd op relatief recent onderzoek. Hierbij wordt nog niet meegenomen dat voor varkens het gehalte aan P in het lichaam gerelateerd is met het gehalte in het voer. Goed om na te gaan wat de impact hiervan kan zijn en te zien in hoeverre de lichaamssamenstelling voor mono-gastrische dieren aanpassing behoeft. Verder is ook de samenstelling van "concept kuikens", d.w.z. langzaam groeiende vleeskuikens niet bekend.
Voor rundvee werd genoemd dat de lichaamssamenstelling gebaseerd is op erg oud onderzoek (jaren 30 vorige eeuw) met andere rassen van dieren. Gezien de ontwikkeling van de melkkoe de afgelopen 50 jaar dient hier een revisie van de lichaamssamenstelling van melkvee (en wellicht ook vleesvee) plaats te vinden. (zie ook andere punten uit review van Zom en Kasper (2019)).

Eieren
Samenstelling van eieren is niet ter sprake gekomen.

Excretie N en P in mest en urine
De excretie van N en P in mest en urine wordt berekend zoals hierboven aangegeven. Zie ook Van Bruggen en Gosseling (2019). Validatie van deze uitscheiding evt. op bedrijfsniveau zou goed zijn. Echter het blijkt erg lastig om op bedrijven representatieve mest monsters uit de mestput te verkrijgen (zie ook hierboven beschreven).

Ammoniak vervluchtiging en validatie
Berekening van de ammoniak emissie naar de lucht wordt berekend met NEMA, en is gebaseerd op het percentage TAN wat vervluchtigd in de stal, tijdens opslag en tijdens uitrijden. Er is kort gesproken of deze verliezen voor vleeskuikens nadere studie behoeft. Hier zijn geen nadere conclusies over getrokken (was ook geen doel van deze workshop).

Conclusies
Er zijn verschillende punten aangedragen voor het invullen van een werkplan ter verbetering van de modellering van NH3 emissie. Puntsgewijs zijn dit:
1. Gevoeligheidsanalyse op het effect van datastromen (o.a. vanuit KWIN) op de uiteindelijke excretie berekening, waarbij ook rekening wordt gehouden met de variatie in bedrijfstypen

(concepten).
2. Evaluatie mogelijkheden extra informatie over mengvoersamenstelling te verkrijgen (uitsplitsen voertypen en voerparameters).
3. Evaluatie en mogelijke revisie van de berekening van de voeropname bij melkvee en voor diersoorten die gebruikt worden om voeropname en voersamenstelling van andere diercategorieëen door "afpellen" te berekenen. Speciale aandacht voor beschikbaarheid snijmaïs.
4. Evaluatie van impact kwaliteit van informatie Nationaal versus Regionaal.
5. Wat zou nu het ideale model zijn, ook in verband met eventueel concentratie model.
6. Opname van toekomstige ontwikkelingen, bijvoorbeeld voer additieven effecten van laag P op lichaamssamentelling, en van Laag N op TAN samenstelling.
7. Aandacht voor validatie van excretie voorspelling "onder de staart" en hoe mest representatief te meten.
8. Evaluatie noodzaak volledige systeem transparant te rapporteren.

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Appendix 2 Data sources for calculating TAN

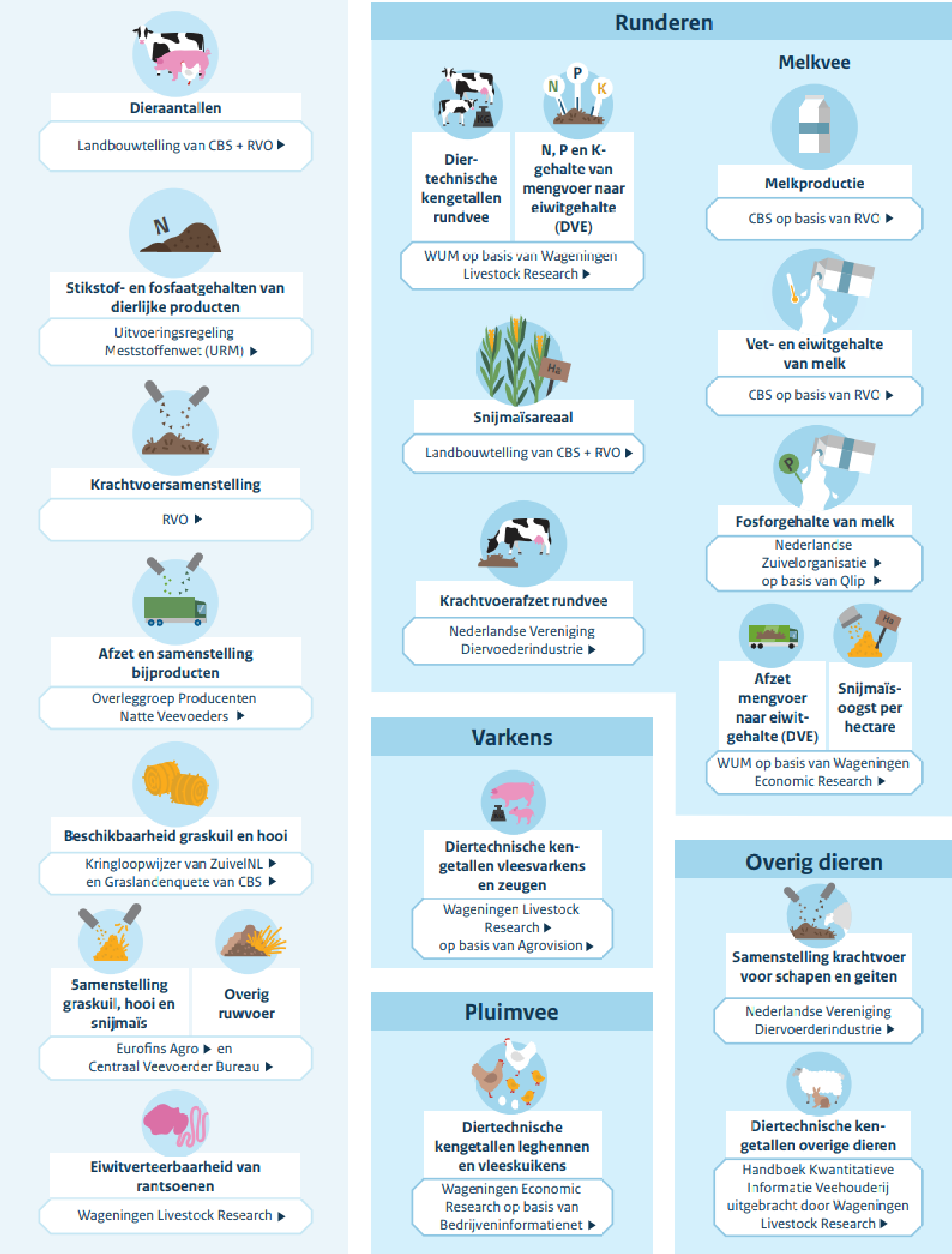

Figure 1 *Data sources used for calculating TAN emission from livestock farming in the Netherlands. These data are used according to WUM, and then used to calculate ammonia emission with NEMA. Source: https://www.wur.nl/nl/show/Data-voor-het-berekenen-van-ammonia.*

Appendix 3 Body composition of pigs (nitrogen)

Forewords
Approximately 60% of the ingested protein in pigs is excreted via manure [1], with potential nitrogen (N) losses to the environment. N excretion in the pig farming sector was 91.8 million kg (19% of total animal production) in 2020 in the Netherlands [1]. Excretion of N and TAN in the Netherlands is calculated using the WUM model. These data are further used for calculating the ammonia emission from livestock farming. The output of the WUM model plays a key role in evaluating progress in emission reduction, and the validity of the WUM model is imperative for unbiasedly determining government decisions on regulations to protect the environment. Since in the WUM model, TAN is calculated as follows:

TAN = (N intake * N digestibility) – N retention in animal products

For pigs N retention in the body is a significant part of the N retention in animal products. The last update for the proximate composition of the body figures in the WUM model is from 2010. This document aims to provide an introduction to the proximate composition of the empty body and its importance, available techniques for measuring it, and the availability of more recent data for updating the WUM project.

Introduction
The proximate composition of the body (percentage protein, moisture, lipid, and ash) serves as a helpful tool for studying nutritional influences and nutrient requirements of growing animals, including pigs[2]. Body protein accretion rates most closely define the animals' protein (or amino acid) requirements and can be used as a guiding measure towards optimal protein allowances for maximum body or lean tissue gain and efficiency. Proximate composition of the body in pigs can be influenced by several factors including but not limited to: sex [3], genetic background [4] and selection [5], growth stage [6] and body weight [7], health status[8], heat stress [9, 10] and in utero heat stress [11], dietary protein [12], amino acid balance [13], and hormonal status [14].

Body composition measurement techniques
Slaughtering, dissection, and chemical analysis have traditionally been used as the standard method for determining body composition. However, these procedures are expensive, laborious, and destructive (i.e., an animal can be used only once). Besides being complicated and costly, preparing a representative sample from the body is difficult.

Non-destructive techniques are often required to analyse valuable animals or when a sequential study of the animals is necessary or desirable [15]. The search for non-destructive methods of estimating body composition or meat traits has led to the development of numerous techniques. A number of these techniques have been used to study body composition in pigs such as dual-energy X-ray absorptiometry[16, 17], bioelectrical impedance[18, 19], magnetic resonance imaging[20, 21], computed tomography images[22, 23], visual image analysis[24, 25] and dilution techniques [20, 26, 27]. It should be noted that despite all the disadvantages of the slaughter/dissection method, it is still the standard method and is often used to calibrate non-destructive techniques[28].

Availability of more recent data
A better understanding of the body protein deposition and the process of protein partitioning between body deposition and excretion is fundamental to defining an optimum feeding strategy to minimize N excretion to the environment. Studies that provide information on protein deposition not only improve the body of knowledge that ideally can lead to strategies for reducing N excretion without affecting protein deposition but also offer insight into environmental aspects of pig farming[29]. Compiling a dataset with the proximate body composition for pigs representing pig farming circumstances in the Netherlands will provide constructive information related to N excretion in the pig farming chain. A

quick search in google scholar restricted to the results from 2010 onwards with keywords: pig AND growing AND finishing AND body composition. In the first two pages of the results, nine studies had protein or N composition of the body obtained by direct measurement techniques[11, 30-37], and it's possible that with a more thorough search, more studies with data on body protein or N content obtained by direct measurement techniques can be found.

On the other hand, not all the mentioned studies may be suitable for updating the WUM model. This will depend on the defined criteria for data to be included in the dataset. Also, we are unaware of the magnitude of possible differences between current figures in the WUM project and data from more recent papers.

Recapitulate

There seem to be a considerable number of studies with direct measurements on the proximate body composition of pigs available in the literature published since 2010. A potential dataset on the proximate body composition in pigs can be expanded by adding data from studies that used indirect techniques. Although these techniques are calibrated and therefore secondary to the slaughter technique, specific datasets may be relevant when representing groups of pigs without slaughter data. A critical step towards collecting and analyzing data would be assessing the target animal characteristics such as sex and breed, body weight, physiological state, etc.

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Appendix 4 The effect of parity (youngstock vs. primiparous vs. multiparous) on nitrogen digestibility in cows

Forewords

In dairy cows, the major part of the ingested protein is excreted via manure, with potential nitrogen (N) losses to the environment. N excretion in the dairy cow farming sector was 281 million kg in 2019 in the Netherlands[1]. Excretion of N and TAN in the Netherlands is calculated using the WUM model. These data are further used for calculating the ammonia emission from livestock farming. The output of the WUM model plays a key role in evaluating progress in emission reduction, and the validity of the WUM model is imperative for unbiasedly determining government decisions on regulations to protect the environment. In the WUM model, TAN is calculated as follows:

TAN = (N intake × N digestibility) – N retention in animal products

A key parameter for calculating TAN is the N-digestibility, also known as the digestion coefficient of crude protein (DCCP or VCRE in Dutch). The previous inventory of N emission from cow excreta relied on fecal N digestibility data in Dutch feeding tables, assuming additivity of dietary ingredients to obtain diet values (CVB model,[2]). Currently the DCCP for dairy cows is estimated with the Tier-III model that results in an approximately 10% lower TAN excretion compared to the previous calculation method. The Tier-III model is a dynamic, mechanistic model describing the fermentative and digestive processes in the gastrointestinal tract of dairy cattle. This model uses Dry matter intake (kg/d) Feed, Roughage proportion (%) RP, Dietary composition of Sugar, starch, NDF, total and Crude fat with some rumen fermentation and dynamics parameters for prediction of apparent fecal N digestibility[3]. The DCCP for other subgroups of cattle is estimated by extrapolation from this Tier-III value for dairy cattle. The TAN excretion of the other cattle categories is still yearly calculated with the standard DCCP (old method) and then the resulting TAN-excretion is lowered by 10%.

However this extrapolation may merit further investigation to improve the substation of the estimate of DCCP of cattle other than dairy cows. This document aims to provide an introduction to digestibility, its importance, and the availability of more recent data for potentially updating the WUM project.

Introduction

A clear and unbiased definition of the relationship between N (and all other nutrients) input from intake and output as affected by digestibility is crucial for any model or system trying to provide information on retention for physiological, nutritional or environmental purposes. The literature scan has not found data that directly compare the digestibility of young stock and older dairy cows. Bannink et al., [3] generated an independent dataset of rather recent observations on apparent fecal N digestibility in dairy cows documented in peer-reviewed literature to evaluate and reported that average apparent nitrogen digestibility in dairy cows is ≃ 70%. Many studies reported the average apparent nitrogen digestibility in weaned non lactating heifers to be constantly higher than 70% anywhere from 5 to 15 percent [4-10]. In 2008, Zanton et al., [11] did a metanalysis on data from10 papers from 1900 to 2007 reporting the effect of differing levels of dietary N intake on N utilization and excretion in weaned calves. They reported that true digestibility of dietary N was 96.4% for and basal fecal N excretion values of was 6.51 g of N/kg of dry matter intake for weaned heifers. Although the high true N digestibility reported by [11] points out at the direction of higher DCCP for young stock, the extent might not be realistic because their dataset was very limited due to their study selection criteria.

Rumen dynamics is a key player in determining the ruminal digestibility of N and has been implemented in the Tier-III model for predicting apparent fecal N digestibility[3]. The current understanding of the relationship between digestibility and passage in ruminants is based on the dietary-digestive-metabolic interactions described by [12]. Briefly in ruminants digestibility can be increased if ruminal passage rate is decreased or degradation rate is increased. To the extent of our knowledge, only two studies directly investigated the rumen dynamic related parameters in relation to the parity. Maekawa et al., [13] studied the effects of parity on chewing activity, saliva production and, ruminal pH of lactating dairy cows in 2002. They reported that saliva output while eating (L/d), Rumen digesta weight (kg), Rumen liquid volume (L), Liquid outflow (L/h), and Liquid turnover rate (%/h) were significantly different for primiparous and multiparous cows. Increased liquid outflow rates, as was observed for multiparous cows compared with primiparous cows is thought to be related to the passage of small particles. The passage of small particles may be delayed if they are trapped in the rumen mat layer, which would consequently extend ruminal retention time and digestibility[14]. More recently, Azizi et al., [15] investigated the relationship between the parameters of feeding behavior and feed intake in 70 lactating dairy cows (23 primiparous and 47 multiparous) from the 2nd to 15th week of lactation. They reported that meal frequency, daily mealtime (min/day), meal size (kg/meal), daily DMI (kg/day) and, feeding rate (g DM/min) was different for first lactation and older cows. This means that in this study primiparous cows ate less (≃4kg/d) at a slower rate (≃24 gDM/min) would consequently extend ruminal retention time[14] and increase feed digestibility [16].

Besides the rumen dynamics, there are other factors with the potential to change nutrient digestibility in young and old animals, such as age-dependent differences in rumen bacterial communities [17-21] or differences in digestive enzymes activity [22-24], which will not be further mentioned here due to lack of sufficient quantitative data.

Altogether, it seems that there are differences in nutrient digestibility between youngstock and cows due to age-dependent variation in parameters related to rumen dynamics, BW, DMI and, diet specifications.

Availability of more recent data

Previous meta-analyses have focused on dietary and animal characteristics to model digestibility in lactating dairy cows. However, these meta-analyses didn't directly investigate the effect of age or parity on digestibility. Instead, they emphasized on the effect of DMI and BW on protein digestibility which can be greatly influenced by parity [25-27]. Total tract nutrient digestibility is a part of many production experiments, a large number of studies in young stock with protein digestibility information are available in the literature both from before [28-39]and after [4, 5, 40-49] the year 2000. Since old data was not used for youngstock, they can enrich the digestibility dataset. These data can be used to provide further insight to DCCP in young stock.

Recapitulate

Based on a quick search for available data in the literature, there are two options available to study the differences in nutrient digestibility between youngstock and cows:

1- Compiling a dataset of digestibility trials in only for youngstock to investigate DCCP.
2- In addition to option number 1, an existing dataset of digestibility trials in cows can be updated in order to look into the parity differences in DCCP between cows and compare them to youngstock.

With a thorough search for proper studies, probably more data can be found.

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Appendix 5 Body composition of dairy cows (nitrogen)

Forewords
In dairy cows, the major part of the ingested protein is excreted via manure, with potential nitrogen (N) losses to the environment. N excretion in the dairy cow farming sector is 281 million kg in 2019 in the Netherlands[1]. Excretion of N and TAN in the Netherlands is calculated using the WUM model. The TAN is used for calculating the ammonia emission from livestock farming. The output of the WUM model plays a key role in evaluating progress in emission reduction, and the validity of the WUM model is imperative for unbiasedly determining government decisions on regulations to protect the environment. In the WUM model, TAN is calculated as follows:

TAN = (N intake × N digestibility) – N retention in animal products

N retention in the body is part of the N retention in animal products, where for dairy cows the retention in milk is the major factor. Milk N composition is measured routinely and considered accurate. Body N composition in dairy cows is not analyzed routinely and the WUM system uses literature based values. In order to assure the accuracy it is useful to consider the most recent literature for body N content. For cattle, sheep goats and horses the currently used N and P content of body tissue have been determined in the years 2000 – 2005, based on information before that. For specifically dairy cows the information was compiled in 2000.

This document aims to provide an introduction to the proximate composition of the body and its importance, available techniques for measuring it, and the availability of more recent data for updating WUM calculations.

Introduction
Proximate composition of the body (percentage of protein, moisture, lipid, and ash) serves as a useful tool for genetics, nutrition and, physiology studies[2]. A complete understanding of the composition of tissue being accreted or mobilized is necessary to determine dietary protein needs. The body composition of cows, specifically the N content of the body, depends on many factors, including but not limited to genetics [3], age [4], environmental factors[5], nutrition [6], and the physiological stage of the animal[7]. Amongst the mentioned factors, the physiological stage of the animal is well studied. Vast changes in body protein reserves occur in two distinctive physiological stages for dairy cows. One occasion is when animals change from a gestational non-lactating to a non-gestational lactating state in a period that spans through 3 weeks after parturition, and muscle protein can be mobilized to compensate for the energy deficit [7, 8]. Protein mobilization occurs in advance of fat mobilization in most cows [11] and ends approximately 4 wk after parturition[6, 9, 10]. The other occasion is during the final third of gestation when the developing gravid uterus and the mammary gland receive a more significant partitioning of nutrients to maintain their demand for tissue growth and accelerated metabolic rate, even at the cow's expense [12, 13]. The extent of muscle mobilization of a cow exceeds 13% of body protein in well-fed transition dairy cattle and 25% in N-limiting diets; however, there appears to be a considerable variation in the extent of protein that is mobilized [14]. Information about dairy cow body proximate composition should be comprehended having in mind the big variation caused by physiological state of the animal.

Body composition measurement techniques
Slaughtering, dissection, and chemical analysis have traditionally been used as the standard method for determining N composition. However, these procedures are expensive, laborious, and destructive (i.e., an animal can be used only once). Besides being difficult and costly, preparing a representative sample from the body is difficult.

Non-destructive techniques are often required to test valuable animals or when a sequential study of the animals is necessary or desirable[9]. The search for non-destructive methods of estimating body composition or meat traits has led to the evaluation of numerous techniques such as real-time ultrasound, computer tomography, magnetic resonance imaging (MRI), dual-energy X-ray absorptiometry (DXA), total body electrical conductivity, dilution techniques, bioelectrical impedance, and neutron activation analysis. It should be noted that despite all the disadvantages of the slaughter/dissection method, it is still the standard method and is often used to calibrate non-destructive techniques [10-14].

There are also equations developed to predict dairy cow body composition [15]. For example, Martin and Sauvant [16]developed an empirical model of dairy cow chemical body composition that aimed at predicting the concentrations of fat, protein, water, and minerals in empty body weight in relation to body condition score on a 0-5 scale. More recently, Martin and Sauvant [17] and Martin and Sauvant [18] described a teleonomic model of individual performance during growth and over repeated reproductive cycles throughout the lifespan of dairy cattle. The operating sub-model describes body weight and composition changes, fetal growth, and other important physiological and performance parameters.

Availability of more recent data

A better understanding of the body protein deposition and the process of protein partitioning between body deposition and excretion is fundamental to defining an optimum feeding strategy to minimize N excretion to the environment. Studies that provide information on protein deposition not only improve the body of knowledge that ideally can lead to strategies for reducing N excretion without affecting protein deposition but also offer insight into environmental aspects of dairy cow farming[30]. Compiling a dataset with the proximate body composition for dairy cows representing dairy cow farming circumstances in the Netherlands will provide constructive information related to N excretion in the dairy cow farming chain. A quick search in google scholar restricted to the results from 2005 onwards with keywords: Cow AND body composition was conducted. Results showed that there are a number of publications with body composition information measured with direct [6, 25-29] and indirect [19-24] measurements.

On the one hand, it's possible that with a more thorough search, more studies with data on body protein or N content can be found, and on the other hand, not all the mentioned studies may be suitable for updating the WUM model. This will depend on the defined criteria for data to be included in the dataset. Also, we are unaware of the magnitude of possible differences between current figures in the WUM project and data from more recent papers.

Recapitulate

Compiling a dataset with more recent studies containing the proximate composition of the carcass information for a particular group of animals (i.e., dairy cows, heifers, calves) that are of interest for dairy cow farming circumstances in the Netherlands will provide constructive information to N excretion in cow milk production chain. A potential dataset on the body composition can be expanded by adding data from other breeds (i.e., Jersey cows, Beef cattle breeds), bulls, heifers, and data from studies that used indirect techniques. A critical step towards collecting and analyzing data would be assessing the target animal characteristics such as breed, age, physiological state, etc.

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Appendix 6 Body weight of dairy cows

Forewords
In dairy cows, the major part of the ingested protein is excreted via manure, with potential nitrogen (N) losses to the environment. N excretion in the dairy cow farming sector is huge and came to 281 million kg in 2019 in the Netherlands[1]. Excretion of N and TAN in the Netherlands is calculated using the WUM model. These data are further used for calculating the ammonia emission from livestock farming. The output of the WUM model plays a key role in evaluating progress in emission reduction, and the validity of the WUM model is imperative for unbiasedly determining government decisions on regulations to protect the environment. In the WUM model, TAN is calculated as follows:
TAN = (N intake × N digestibility) – N retention in animal products
In the WUM model, an increase in the body weight (BW) of the adult dairy cow will result in an increase in energy requirement. Subsequently, higher energy requirements will lead to increased feed intake and higher intake retention of N and P on the one hand, but a higher retention of N and P in body tissue on the other hand. Economic importance of non-production traits has led to the implementation of genetic plans based on the total merit index. Different countries include different traits in the total merit indices used in their countries[2]. Differences in the genetic plan have led to significant variation in body weight change curves [3]. BW figures in the WUM system have not been updated for more than a decade, and the effect of the continuum of the genetic plan in the Netherlands on BW has not been investigated.
This short document aims to provide an introduction to the importance of BW and its dynamics through lactation and the availability of more recent data for updating the WUM project.

Introduction
The dairy cow's BW and its changes during lactation are important parameters for making management and nutritional decisions[4] at the herd level[5] and the individual cow level[6]. The BW profile of different strains of dairy cattle usually follow a similar pattern; there is a sharp fall in BW at parturition coinciding with the expulsion of the fetus and uterine contents; this is followed by a decline in BW due to the catabolism of body reserves to supply energy for milk production, and there is a subsequent rise until the following parturition as new tissue reserves are built up, and the fetus begins to enlarge[7]. BW and its changes during lactation are affected by physiological and environmental conditions. BW in dairy cows is affected by animal size (skeletal development), degree of fatness, and gut fill [8, 9], all of which are dependent on the stage of pregnancy, stage of lactation, and age-dependent growth[10]. Standard BW curves could be used to monitor management and nutrition and identify production groups, and assess if a specific group is prone to suffering from maladaptation to NEB[4, 11, 12]. With the advent of the dynamic computer model to describe biological systems, there has arisen the potential to predict an animal's response over time to various interventions[13]. In lactation models, DMI prediction equations typically require daily milk production and BW as inputs[14, 15]. Models that describe the dairy cow's energy balance using mathematical formulas must include BW and food intake as components[16]. Models exist for BW prediction, which describe the cow's BW from calving until maturity, based on growth curves. These models predict BW changes during different lactation periods without the inclusion of parameters of physiological nature [17-19]. Also, Several models are available to predict BW changes during different lactation periods that have physiological parameters in them as predictors [9, 12, 15, 20-23].

Availability of more recent data
Studies that investigated BW change in dairy cows are abundant. In many studies related to NEB and dairy cows' metabolic health, the BW change has been mostly monitored for the first weeks to months of lactation[5, 24]. There are also many studies that looked into BW change for a longer time or through lactation, mostly in relation to milk production, DMI, or reproduction[16, 25-29].

Recently in a CVB project, a dataset has been compiled from 1 Belgian and 4 Dutch research farms. Cow-week observations were collected, during which BW in almost all cases was measured daily and in all cases directly after milking. These daily BW measurements were afterward averaged per week. Thus, the BW of the cows was analyzed on a week-in-lactation (WIL) basis. In addition, they proposed a series of reference values for BW/lactation weeks for cows in different parities in TC-CVB-275document [30].

Recapitulate

There are four options available to study the BW change in dairy cows:

1- Construct a dataset and further analyze the newly compiled dataset

2- Adapt one of the currently developed models from the literature

3- Use the recent model developed by CVB

4- Evaluate the performance of some of the existing models in the literature against the CVB dataset and select the model based on the outcome

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To explore the potential of nature to improve the quality of life

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