NOTAT

Winter Feeding of Organic sows “WI-FI”

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Udarbejdet i projektet Winter Feeding of Organic Sows, som er finansieret af

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1. INTRODUCTION

Feed rations are typically based on specific nutritional needs of the animal and optimized, *inter alia*, for weight gain, weaning performance, animal health and anticipated slaughtering time. Feed ingredients are optimized based on their nutritional value and costs. In this context, relatively standard feed compounds can be purchased from feed suppliers as a function of the specific animal type and growing stage.

Research projects are currently testing the effects of feeding pregnant sows with relatively large amounts of grass silage or grass pulp (i.e., a byproduct of the grass-protein biorefinery). Our society is rich in various food-waste flows that can be retrieved from the market and used for feeding purposes: some examples are brewers' grains, bread, and fruit pulp. While feeding the animals with food-waste can be seen as cheap and positive from a circular economy point of view, the nutritional requirements of the animals should be met to avoid health problems.

Feeding the animals with food-waste or cheap and locally available alternatives, e.g., grass silage, should be done cautiously. While animal health should be seen as a priority, an effect of potentially unbalanced diets could be, inter alia, the inappropriate intake of crude protein. In particular, an excess of crude protein typically translates into a poor use of energy in the ration and therefore a decrease in feed efficiency. Excess of crude proteins can also induce an excess of nitrogen intake, and therefore excess of nitrogen in the urine and feces. On one hand, this excess of nitrogen can result in an increase in the ammonia, nitrous oxide (in the stable and tank as well as in soil applications, regardless of whether the manure is excreted by the animal while "grazing" or applied via injection) and nitrate emissions (from the manure on the field). On the other hand, the excess of nitrogen can be seen as a source of fertilizer.

In this study, the excess of nitrogen in the manure is a case example, as this is expected to be relevant in the case of feeding the sows with high levels of grass silage with abundant protein levels, and the potential climate change impacts and nitrogen leaching associated with this non-optimal diet are calculated. The effects are then compared with the alternative use of mineral fertilizer otherwise used as source of nitrogen - acknowledging that this practice is, however, not applicable in organic farming.

Climate change impacts are calculated using the characterization factors defined by the "IPCC 2013 GWP 100a" method (IPCC, 2013), where 1 kg $CH_{4\ biogenic}$ = 27.75 kg CO_{2eq}, 1 kg $CH_{4\ fossil}$ = 30.5 kg CO_{2eq} and 1 kg N_2O = 265 kg CO_{2eq}. The calculation of climate change impacts and nitrogen (via nitrates) leaching is based on the IPCC (2019) guidelines, Tier 1 approach, considering the parameters for "wet climate" conditions (see more details in the Appendix, A1).

2. MANURE WITH EXCESS OF NITROGEN

Assuming the case of a pregnant sow, which is outdoor during the whole pregnant period and therefore depositing 100% of its manure on the field plus and an additional 1 kg of N being excreted annually from a sow (because of the non-optimal diet):

> $F_{PRP,\ SO}$ = 1.0 kg N year^{-1}, where $F_{PRP,\ SO}$ represents the urine and dung N deposited on pasture, range and paddock by the grazing pigs;

Following common practice ("cut-off" system model approach in Life Cycle Assessment and considering manure as a residual material with no economic value) and in the interest of simplicity, it is considered that the manure receives no impact from the animal production system. Other approaches are available, but not herein considered. Therefore, the production of manure is associated with an impact equal to zero:

Climate change, production: 0 kg CO_{2eq} for the given $F_{PRP,\ SO}$

Based on the IPCC (2019) guidelines, and parameters in Table A1, direct and indirect N_2O emissions, and nitrogen leaching were calculated (Appendix, Section A2). The results are

Climate change impacts, from field: 4.82 kg CO_{2eq} for the given $F_{PRP,\ SO}$

Nitrogen leaching, from field: 0.24 kg N for the given $F_{PRP,\ SO}$

3. MINERAL FERTILIZER

The excess of N coming from the manure could be used for its fertilizing value, provided that the farmer is aware of it and therefore adjusts the amounts of manure to match the specific N crop needs. Manure is a constrained resource; if there was no excess of N in the manure and still a need of N from the crops, this N had to be applied via mineral fertilizers. It is therefore assumed that this excess of N in the manure could be substituting mineral fertilizer. The potential impacts coming from the otherwise used mineral fertilizer are estimated. It should however be noticed that mineral fertilizers are not a viable option for organic farming.

Denmark uses a variety of mineral fertilizers containing N. IFAstat contains data on annual consumption of mineral fertilizer for different countries, and it was used to retrieve the Danish consumption of N mineral fertilizers in 2020. These values were used to calculate the average formulation of 1 kg N from mineral fertilizer in 2020 (more details in Section A3).

Given a specific N crop need, the farmer will make some adjustments in the amounts of N being applied depending on the source of N being used. In the case of mineral fertilizers, the amounts of N will be matched 1:1 (i.e. 1 kg N needed for the crop: 1 kg N applied via mineral fertilizer); in the case of manure, the farmer will tend to apply a 25% additional N because of the slower N mineralization which makes it less plant available (i.e. 1 kg N needed for the crop: 1.25 kg N applied via manure). Because of these differences in the amounts of N being applied given a specific crop, it was assumed that 1 kg N applied via manure corresponds to 0.75 kg of N applied via mineral fertilizers. Accordingly,

F_{SN} = 0.75 kg N year^{-1}, where F_{SN} is mineral fertilizer N applied to soils

The impacts from the production of the average N mineral fertilizer were estimated based on Agri-footprint 5 (van Paassen et al. (2019)):

Climate change impacts, from production: 4.67 kg CO_{2eq} for the given F_{SN}

Based on the IPCC (2019) guidelines, and parameters in Table A1, direct and indirect N_2O emissions, and nitrogen leaching were calculated (Appendix, Section A3). The results are

Climate change impacts: 6.74 kg CO_{2eq} for the given F_{SN}

Nitrogen leaching: 0.80 kg N for the given F_{SN}

4. DISCUSSION AND CONCLUSIONS

Table 1 summarizes the results calculated above and considers that the excess of nitrogen in the manure can be used for fertilizing purposes. In this context, the environmental impacts related to the excess of nitrogen in the manure are compared with the otherwise used mineral fertilizer (assuming that manure is a limited resource and therefore the additional N can only be supplied by mineral fertilizer). Mineral fertilizer cannot however be used in organic farming, so the comparison should be done cautiously.

For each additional kg N excreted coming from the excess of protein intake, there is a climate impact of 4.82 kg CO_{2eq}, against the 11.41 kg CO_{2eq} coming from the use of mineral fertilizer. In other words, it would be environmentally favorable to use the excess of N coming from manure, rather than apply mineral fertilizer: by using manure, there would be a saved emission of GHG emissions of (11.41-4.82 =) 6.59 kg CO_{2eq} per kg N (already considering the 25% correction factor between manure and mineral fertilizer). The presented values are very dependent on the methodological assumption that manure has no burdens associated to its production, but the overall conclusion is expected to be valid also in the case of other approaches, given the relatively large difference in the impacts.

According to the latest regulations for keeping sows outside, a maximum of app. 10,5 sows on yearly basis per ha are allowed (Landbrugsinfo, 2019).

Diet calculations (Vestjysk Andel) show that for each 10% exchange of compound feed with clover-grass silage, an additional 0.7 kg of N is excreted. Considering the 10.5 annual sows per ha, a surplus of 7,4 kg N is excreted. In average, organic farmers feed their sows (average of pregnant and weaning) with 20% clover-grass, which would lead to app. 15 kg of excess nitrogen, compared to a balanced compound feed.

Eutrophication by nitrate leaching increases if organic farming would use the same amounts of N fertilizer as calculated as optimum for conventional agriculture. This is due to slower availability of the (manure) organic nitrogen, which must mineralize to ammonia and nitrate to be plant available. Some nitrogen will become available after the growing season, and it will be susceptible for leaching. This can especially be a challenge, as the grazing pastures for the sows and weaning piglets, are part of a special rotation in the organic system. As fencing is expensive, most farmers tend to have a narrow rotation alternating grazing pasture with cereals every second year. The challenge lies in the amount of nitrogen that is deposited by the sows, and the risk of “hot spots” with large amounts of manure, where feeding stations have been situated.

The lower climate impact of excessive nitrogen excretion contra balanced fertilization, could well be annihilated if no precautious measures are taken to:

a) Shift feeding deposits regularly
b) Ensure crop coverage of grazing pasture in the autumn
c) Manage the following crop carefully, securing optimal Nitrogen intake
d) Preferably enlarge the rotation from 50% pasture to 33% (every third year).

The field impacts reported in this study are calculated based on the IPCC (2019) Tier 1 approach, which is a relatively generic and simplified approach. Site specific impacts may be different.

Table 1. Summary of the results: climate change impacts, expressed as kg CO_{2eq}, and nitrates' leaching, expressed as kg N. Emissions from transport and field applications are not considered.

		1 kg N from manure	0.75 kg N from fertilizer
Climate change impacts			
Production	kg CO_{2eq}	0	4.67
Field emissions	kg CO_{2eq}	4.82	6.74
Tot (excl. transport)	kg CO_{2eq}	4.82	11.41
Nitrates leaching			
Field emissions	kg N	0.24	0.18

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APPENDIX

A1. General

Table A1 reports the parameters used for the calculation of the climate change impacts and nitrates' leaching, based on the IPCC (2019) guidelines, Tier 1 approach. The IPCC (2019) guidelines defines aggregated default values and disaggregated values for dry and wet climates: "*Wet climates occur in temperate and boreal zones where the ratio of annual precipitation: potential evapotranspiration > 1, and tropical zones where annual precipitation > 1000 mm. Dry climate occur in temperate and boreal zones where the ratio of annual precipitation: potential evapotranspiration < 1, and tropical zones where annual precipitation < 1000 mm (cf. Figure 3.A.5.1 in Chapter 3 of Vol. 4 provides a map subdividing wet and dry climates based on these criteria)*.". According to this figure, Denmark is generally classified as a "Cool temperate moist" region. The section of emission factors reflected the generally moist/wet climate. In practice, some areas in Denmark may be classified as "Cool temperate dry", but for the sake of simplicity and using a conservative approach, the chosen parameters reflect "wet climate" conditions. An alternative approach could have been the use of the aggregated emissions factors (column "alternative value" in Table 1), which in turn consider conditions between wet and dry.

Table A1. Parameters used for the calculation of climate change impact and nitrate leaching in the case of manure. Wet climate parameters were selected, when available. Alternative values are only presented for comparison purpose. Source: IPCC (2019), chapter 11, volume 4.

Parameter	Value	Unit	Source: IPCC (2019), chapter 11, volume 4	Alternative value (aggregated climate)
$EF3_{PRP,\ SO}$	0.006	kg N_2O-N / kg N	wet climate, Table 11.1	0.004 aggregated climate, Table 11.1
$Frac_{GASM}$	0.21	(kg NH_3–N + NO_x–N) (kg N applied or deposited)$^{-1}$	Table 11.3	
EF4	0.014	kg N_2O–N (kg NH_3–N + NO_X–N volatilised)$^{-1}$	wet climate, Table 11.3	0.010 aggregated climate, Table 11.3
$Frac_{LEACH-(H)}$	0.24	kg N (kg N additions or deposition by grazing animals)$^{-1}$	Table 11.3	
EF5	0.011	kg N_2O–N (kg N leaching/runoff)$^{-1}$	wet climate, Table 11.3	
EF1	0.016	kg N_2O–N / kg N input	wet climate, Table 11.1	0.01 aggregated climate, Table 11.1

A2. Manure with excess of nitrogen

Assuming the case of an additional 1 kg of N being excreted annually from a sow, and based on equation 11.1 from IPCC (2019), volume 4, Chapter 11,

$\underline{F_{PRP,\,SO} = 1.0 \text{ kg N year}^{-1}}$

Direct and indirect N_2O emissions can be calculated based on equation 11.1 (direct emissions) and equations 11.9 and 11.10 (indirect emissions) from IPCC (2019), volume 4, Chapter 11.

Direct soil N_2O emissions:

$N_2O\text{-}N_{PRP} = F_{PRP} \times EF3_{PRP,\,SO} = 0.0060 \text{ kg } N_2O\text{-N year}^{-1}$

Indirect soil N2O emissions:

Volatilization: $N_2O_{ATD}\text{-N} = F_{PRP,\,SO} \times Frac_{GASM} \times EF4 = 0.0029 \text{ kg } N_2O\text{–N yr}^{-1}$

Leaching: $N_2O_{ATD}\text{-N} = F_{PRP} \times Frac_{LEACH\text{-}(H)} \times EF5 = 0.0026 \text{ kg } N_2O\text{–N yr}^{-1}$

The total (direct + indirect) N_2O emissions corresponds to:

$TotN_2O\text{–N} = 0.0116 \text{ kg } N_2O\text{–N yr}^{-1}$, which converted into CO_{2eq} corresponds to

$CO_{2eq} = TotN_2O\text{–N} \times 44/28 \times 265 = \underline{4.82 \text{ kg } CO_{2eq} \text{ y}^{-1}}$

(where $N_2O = N_2O\text{–N} \times 44/28$)

Nitrates leaching:

$Tot\ NO^{-}_3 = F_{PRP} \times Frac_{LEACH\text{-}(H)} \times 62/14 = \underline{1.06 \text{ kg } NO^{-}_{3-} \text{ yr}^{-1}}$

(where $NO^{-}_3 = N \times 62/14$)

A3. Mineral fertilizer

IFAstat contains data on annual consumption of mineral fertilizer for different countries, and it was used to retrieve the Danish consumption of N mineral fertilizers in 2020. These values were used to calculate the average formulation of 1 kg N from mineral fertilizer in 2020.

The mineral fertilizers from IFAstat were matched with the ones in Agri-footprint 5 (van Paassen et al. (2019)) to the extent possible. The "unmatched" mineral fertilizers (which corresponded to ~12% in weight) were redistributed across the matched ones. Table A2 presents the considered composition of the average N fertilizer.

Table A2. Considered composition of N mineral fertilizers in Denmark based on IFAstat 2020 and after some simplifications, expressed per kg N being applied on the soil.

	%
Ammonium nitrate (N)	2.5%
Ammonium sulphate (N)	2.9%
Calc. amm. nitrate (N)	63.5%
Nitrogen solutions (N)	9.6%
Urea (N)	0.3%
Ammonium phosphate (N)	0.8%
N P K compound (N)	20.5%

The calculated climate change impacts related to the production of 1 kg N mineral fertilizer with a composition equal to the one presented in Table A2 was based on Agri-footprint 5 (van Paassen et al. (2019)), and resulted into 6.23 kg CO_{2eq} / kg N. It is regular practice, however, that given a specific N crop need, the farmer will make some adjustments in the amounts of N being applied depending on the source of N being used. In the case of mineral fertilizers, the amounts of N will be matched 1:1 (i.e. 1 kg N needed for the crop : 1 kg N applied via mineral fertilizer); in the case of manure, the farmer will tend to apply a 25% additional N because of losses of N via nitrates (i.e. 1 kg N needed for the crop : 1.25 kg N applied via manure). Because of these differences in the amounts of N being applied given a specific crop, it was assumed that 1 kg N applied via manure corresponds to 0.75 kg of N applied via mineral fertilizers.

$\underline{F_{SN} = 0.75 \text{ kg N year}^{-1}}$

Accordingly, the climate change impacts related to the production of 0.75 kg N via mineral fertilizers are $\underline{4.67 \text{ kg } CO_{2eq}}$.

With regards to the direct and indirect N_2O emissions from fertilizer on the field, direct and indirect N_2O emissions can be calculated based on equation 11.1 (direct emissions) and equations 11.9 and 11.10 (indirect emissions) from IPCC (2019), volume 4, Chapter 11

Direct soil N_2O emissions:

$N_2O\text{-}N_{SN} = F_{SN} \text{ x } EF1 = 0.0120 \text{ kg } N_2O\text{-N year}^{-1}$

Indirect soil N2O emissions:

Volatilization: $N_2O_{ATD}\text{ -N} = F_{SN,\ SO} \text{ x } Frac_{GASM} \text{ x } EF4 = 0.0022 \text{ kg } N_2O\text{–N yr}^{-1}$

Leaching: $N_2O_{ATD}\text{ -N} = F_{SN} \text{ x } Frac_{LEACH\text{-}(H)} \text{ x } EF5 = 0.0020 \text{ kg } N_2O\text{–N yr}^{-1}$

The total (direct + indirect) N_2O emissions corresponds to:

$TotN_2O\text{–N} = 0.0162 \text{ kg } N_2O\text{–N yr}^{-1}$, which converted into CO_{2eq} corresponds to

$CO_{2eq} = TotN_2O\text{–N x } 44/28 \text{ x } 265 = \underline{6.74 \text{ kg } CO_{2eq} \text{ y}^{-1}}$

(where $N_2O = N_2O\text{–N x } 44/28$)

Nitrates leaching:

$Tot\ NO^-_3 = F_{SN} \text{ x } Frac_{LEACH\text{-}(H)} \text{ x } 62/14 = \underline{0.80 \text{ kg } NO^-_3 \text{ yr}^{-1}}$

(where $NO^-_3 = N \text{ x } 62/14$)