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Wageningen Livestock Research

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Dit rapport beschrijft de resultaten van Feed4Foodure III, werkpakket 5: een modelstudie naar de potentiële effecten van verschillende scenario's op de emissie van broeikasgassen en ammoniak van melkveehouderijen. De effecten op het milieu (N en P verbruik, emissie van NH_3, CH_4, CO_2-equivalenten) zijn op bedrijfsniveau geanalyseerd. Het Koemodel is gekoppeld aan de KringloopWijzer. De gesimuleerde scenario's waren verhoogde vers grasopname, verhoogde weide-uren, kruidenrijk grasland, kruidenrijk grasland met verhoogde vers grasopname en vier laag-eiwitscenario's. Verhoogde vers grasopname en weidegang hadden beperkt effect op de emissie van broeikasgassen en ammoniak. Gebruik van kruidenrijk grasland zorgde voor een kleine reductie van de broeikasgasemissie. Uit de laag-eiwitscenario's bleek dat er potentie is om hiermee ammoniakemissie te verlagen al kan dit ten koste gaan van de melkproductie. De emissie van broeikasgassen werd ook lager, hoewel de enterische methaanemissie hoger werd.

The current report describes the results of Feed4Foodure III, work package 5: a modelling study to gain insight in the potential effects of different scenarios on greenhouse gas and ammonia emission from dairy cow farms. The environmental impact (N and P utilization, emissions of NH_3, CH_4, CO_2-equivalents) were analysed on farm level. A connection was made between the Dairy Cow Model and the Annual Nutrient Cycle Assessment model (KringloopWijzer). The simulated scenarios included increased fresh grass intake, increased grazing time, herb rich grassland, herb rich grassland with increased grazing time and four low protein scenarios. Increased fresh grass intake and increased grazing time had a limited impact on ammonia emissions and GHG emissions compared to the basic scenario. Herb rich grassland resulted in a minor reduction of GHG emissions. Low protein scenarios showed there is a high potential to reduce ammonia emissions although it may negatively influence milk yield. Total GHG emissions also decreased, however, enteric methane emissions increased.

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Foreword

Feed4Foodure (F4F) is a public private partnership between “Vereniging Diervoederonderzoek Nederland” (Dutch association for animal nutrition research) and Wageningen University & Research. The Dutch Ministry of Agriculture, Nature and Food Quality supports the research programme through the TKI Agri&Food. The partners focus on sustainable animal nutrition and livestock husbandry. This includes resource efficiency, reduction of the ecological footprint of animal production and healthy and robust animals.

The current report describes the results of work package 5: a modelling study to gain insight in the potential effects of different scenarios on greenhouse gas and ammonia emission from dairy cow farms. The prioritized scenarios included increased fresh grass intake, increased grazing time, herb rich grassland, herb rich grassland with increased grazing time and various low protein scenarios.

The authors thank all members of the VDN cattle cluster for their valuable input.

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Summary

In the transition towards more circular agriculture in the Netherlands, different approaches can be effective in reducing methane (CH_4) and ammonia (NH_3) emissions through animal feed. The current report describes the results of Feed4Foodure III, work package 5: a modelling study to gain insight in the potential effects of different scenarios on greenhouse gas (GHG) and NH_3 emission from dairy cow farms.

In this modelling study, the impact of different dairy cattle feed rations was composed on cow level; the related environmental impacts (N and P utilization, NH_3 emission, GHG emission) were analysed on farm level. The Dairy Cow Model (DCM) was connected to the Annual Nutrient Cycle Assessment model (ANCA, also known as KringloopWijzer in the Netherlands). Per scenario, the rations and farm characteristics were delivered by the DCM. This output, combined with an estimation of the milk production and chosen application levels of manure and fertilizers were used as input values for ANCA. The ANCA output was used to gain insight in the sustainability performance of farms in different scenarios in terms of GHG emission and NH_3 emission.

The prioritized scenarios included increased fresh grass intake, increased grazing time, herb rich grassland, herb rich grassland with increased grazing time and four different low protein scenarios: 90% DVE and -100 OEB; 90% DVE and -500 OEB; 100% DVE and -100 OEB; 100% DVE and -500 OEB with the basic scenario as a reference. In every scenario, several assumptions were made and, consequently, several input parameters changed.

Low protein scenarios showed high potential to reduce NH_3 emissions. Total GHG emissions also decreased, mainly due to a reduction in emissions from land use change (LUC). However, enteric CH_4 emissions increased due to different ingredients in concentrates.

Increased fresh grass intake and increased grazing time had a limited impact on NH_3 emissions and GHG emissions compared to the basic scenario. However crude protein (CP) level of these rations was also increased. Increasing only grazing time, while having the same CP levels of the rations did reduce NH_3 emissions. The impact on GHG emissions was minor.

Feeding herb rich grass to dry cows resulted in a minor reduction of GHG emissions. Total NH_3 emissions decreased (North-Western region) or increased (South-Eastern region). However, in this scenario more land was required and therefore expressing NH_3 emissions per hectare showed a high reduction in both regions.

Regardless of differences in milk production levels, the standard scenario, scenario with increased fresh grass intake, increased grazing time and herb rich grassland had similar GHG emissions in terms of CO_2 equivalents per kg FPCM for both NW and SE.

Although different scenarios showed the potential to reduce NH_3 emissions per hectare, this study also showed that there will be trade-offs. One important trade-off is that the NH_3 emission per hectare decreased in the low-protein scenarios, at the cost of milk production. Also, there was a decrease in GHG emissions per kg FPCM for the low protein scenarios, mainly as a result of lower land use emissions. However, enteric CH_4 emission per kg FPCM increased.

1 Introduction

Background

To be able to feed the growing world population in a sustainable manner, we need to create a food production chain with minimal environmental cost. This requires a transition from the current linear agricultural system to a more circular agri-food system.

By 2050, the Netherlands should have developed a climate neutral agricultural system and a climate neutral land use, as stated in the Climate Agreement[1]. In this agreement, the Dutch Ministry of Agriculture, Nature and Food Quality has set reduction targets to reduce the climate footprint of animal rations. In the transition towards more circular agriculture in the Netherlands, research and policies focus on various aspects. Dairy farmers play an important role in reaching the Climate Agreement's targets. The dairy sector (LTO, DZK, NZO) aims to reduce the emission of greenhouse gasses (GHG) by 1.6 MT CO_2-eq in 2030[2] (through feed, manure, energy use and energy generation). The main contributors to GHG emissions in the dairy sector are methane (CH_4) emissions from enteric fermentation (mainly in the rumen of the cow) and manure on farm and the CO_2 emissions related to production and transportation of feed ingredients. To reach this goal, one of the options is to further optimize dairy cow rations.

Besides the ambitions on GHG emissions, the ammonia (NH_3) and nitrogen oxide (NO_x) emissions need to be reduced on short notice in the Netherlands. In order to meet the goals set by the Dutch government, the deposition of nitrogen (N) should be below a certain critical deposition value (CDW). In 2030, 74% of all N-sensitive Natura-2000 areas should have a N deposition below this CDW[3]. Lowering dietary protein levels or increasing the utilization of dietary protein in dairy cow rations can reduce the excretion of N and thereby decrease the total emission of NH_3. Moreover, grazing strategies and manure management in the barn, external storage and field can mitigate the emission of NH_3.

Lastly, conservation of biodiversity is an essential aspect in the development of a sustainable agri-food system. As the dairy sector uses 45% of all cultivated land in the Netherlands (CBS, 2022), investment in biodiversity on dairy farms can help bending the curve of biodiversity loss and provide habitats with high biodiversity. The land of dairy farms is used to produce feed (mostly grassland) but can also serve to increase biodiversity, or 'nature inclusive farming'. An example is the use of herb rich grasslands or the use of natural grassland for grazing.

Different approaches or a combination of different approaches can be effective in decreasing the emissions of dairy farming through animal feed. These approaches can also be region specific. It is also important to identify trade-offs with respect to N-emission and GHG. In this study, three important focal points are explored: the potential use of biodiverse roughages, three approaches are investigated: the use of biodiverse feeds, the effect of grazing time and the effect of lower dietary protein levels in dairy cow nutrition.

Region-specific strategies

In 2022, region-specific targets for GHG and NH_3 emission reduction were defined by the Dutch government. These targets were established to reduce further deterioration and to improve the status of maintenance of nature in Natura-2000 areas. The current condition and characteristics of nature reserves vary in different regions of the Netherlands. Region characteristics such as the distance between dairy farms and Natura-2000 areas, the source of emissions and soil type formed the basis for the targets.

Farms in the Netherlands are located on different types of soil. The type of soil relates to multiple factors, such as the use of grassland and maize land on farms as well as legislation on manure application. The Netherlands can be roughly divided in two regions, based on their soil type.

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[1] https://www.klimaatakkoord.nl/landbouw-en-landgebruik
[2] https://www.duurzamezuivelketen.nl/themas/klimaatneutraal-ontwikkelen/
[3] Kamerstuk Tweede Kamer 35600 nr. 14

As shown in Figure 1, the North-Western (NW) part of the Netherlands is dominated by clay and peat soils, while the South-Eastern (SE) region is mostly based on sandy soils.

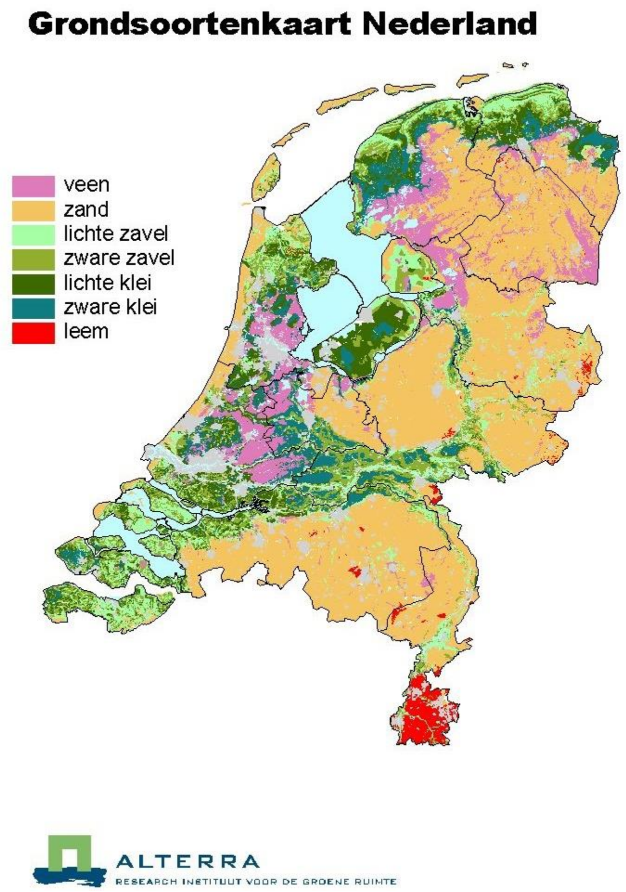

***Figure 1** Soil map of the Netherlands: peat (veen), sand (zand), light sabulous clay (lichte zavel), heavy sabulous clay (zware zavel), light clay (lichte klei), heavy clay (zware klei), loam (leem) (Wageningen Environmental Research, 2006[4]).*

Strategies to reduce emission of N and GHG need to be tailor-made for each region in order to achieve maximum results. Therefore, depending on region characteristics, region-specific strategies were developed. Also, possible strategies in other domains (focusing on water and soil quality, for example) but which apply in the same region need to be taken into account to ensure strategies do not compete but reinforce each other.

Low protein rations

Nitrogen is an essential building block for protein in plants and animals. Nitrogen-containing protein enters the cow through its feed and is found in milk and meat, or released in manure and urine. When urea from urine is combined with faeces, NH_3 is formed. This NH_3 evaporates and is deposited in natural areas which can lead to eutrophication. Through leakage of NO_3^-, H^+ in the soil can lead to acidification of the soil, which subsequently can negatively affect biodiversity.

Lower protein levels in animal diets lead to lower excretion of N in animal manure and urine and potentially, but not necessarily, in milk. These low protein diets will need to minimize N excretion without compromising animal health, and maintain an acceptable potential income level for the farmer (milk performance). This means that dairy cow diets will need to be balanced in various dietary aspects. Protein content in dairy cow nutrition is based on supplying sufficient protein on rumen level as well as on small intestinal level. For this purpose, the nutritional values of degraded protein balance (OEB; rumen) and protein digested in the intestine (DVE; small intestine) are used. In the Dutch protein evaluation system, the OEB value shows the (in)balance between microbial protein synthesis possible from available rumen degradable crude protein (CP) and that possible from the available energy during anaerobic fermentation in the rumen.

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[4] https://www.wur.nl/nl/show/grondsoortenkaart.htm

When positive, the OEB-value indicates a loss of N from the rumen, however, when OEB is negative, microbial protein synthesis may be impaired because of a shortage of N in the rumen. This, in turn, may reduce the dry matter intake (DMI).

According to this protein evaluation system, the optimum OEB-value in a ration is (slightly above) zero. Ammonia emission is highly related to OEB (Van Duinkerken et al., 2005). Reduction in OEB levels will result in most potent reductions in N excretion, especially in urine. Therefore, reducing protein levels in the diet (e.g. concentrates) is a potential strategy in mitigating NH_3 emission from dairy cow manure, as studied in this modelling approach.

Grazing strategies

Although the Dutch landscape is characterized by cows in the pastures, the number of grazing cows has decreased over the years as an effect of upscaling and intensification. A Grazing Agreement (Convenant Weidegang[5]) was introduced by the members of the Dutch Dairy Association and LTO Netherlands in 2012, to sustain and promote grazing practices. As from 2017, the Dutch government has started stimulating grazing in the Netherlands as well (TK, 2017Z17332). As a result, the number of grazing dairy cows has increased again over the past six years. In 2021, 75% of all cows on 83% of all dairy farms spent at least 120 days per year and 6 hours per day outside in the pasture (CBS, 2022).

Further increasing grazing practices could potentially contribute to lower emissions. Hoving et al. (2015) modelled the effects of grazing on NH_3 emission. The results showed a strong negative relation between grazing hours and NH_3 emission. This effect is expected because NH_3 emission is mostly related to housing, manure storage and spreading of organic manure. During grazing, NH_3 emission is very low. In the pasture, urea in the urine and manure are separated, which prevents NH_3 from being formed. Ammonia emission could therefore be reduced by increased grazing time, resulting in lower NH_3 emission from housing systems. Additionally, less liquid manure is spread (Hoving et al., 2015). Similarly, enteric CH_4 emissions can be reduced by 10-30% by day and night grazing when compared to grass silage feeding (Klootwijk et al. 2021; Koning et al., 2022). The level of reduction depends on season and growing circumstances which influence the quality and intake of fresh grass (Klootwijk et al., 2021). A potentially integrated approach of simultaneous reduction NH_3 and CH_4 emission with the use of grazing is still being investigated. Moreover, grazing can serve biodiversity in the field because it serves habitat diversity.
Increasing fresh grass intake or increasing the time spent outside in the pasture could be a potential mitigation strategy to reduce emission of NH_3 and CH_4, which is investigated in this modelling study.

Biodiverse grassland

As mentioned before, the topic of biodiversity and biodiverse grasslands in livestock production systems has gained more attention by dairy farmers in the past years. Two types of biodiverse grasslands are known: semi-natural grasslands and agro-biodiverse grasslands. Semi-natural grasslands play an important role in nature conservation. It concerns lowly fertilized or non-fertilized grassland with a relatively low yield (<5 000 kg dry matter/ha/year), which is not primarily intended for intensive livestock farming or agricultural production. These grasslands are managed by mowing, by disposing biomass and by grazing. Another type of biodiverse grassland are agro-biodiverse grasslands: agricultural grasslands consisting of a mixture of grass and herb species. This type of grassland is primarily intended for agricultural production and often need to be re-seeded.

Biodiverse grasslands may not only provide primary production; it is suggested that they also serve other ecosystem services such as increased biodiversity, carbon sequestration, climate adaptation, underground N fixation and reduction of emissions. The level of primary production and of other secondary functions may depend on the land use intensity (Kleijn et al. 2009).

The use of grasslands with pluriform cultivars, herb rich grasslands, and flowery field borders are gaining more interest from dairy farmers as part of the grassland management. The effects of including biodiverse forages in the diet of youngstock and dry cows on GHG and NH_3 emissions were modelled in this study.

Aim and approach

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[5] https://www.clm.nl/uploads/nieuws-pdfs/convenant-weidegang.pdf

Considering the complexity and urgence of the transition towards a more circular agri-food system, it is important to investigate and quantify the effects of strategies mitigating NH_3 and GHG emissions. In this modelling study, the effect of changes in dairy cattle feed rations was analysed on cow level using the Dairy Cow Model. The related environmental impacts of a given herd (N and P utilization, emissions of NH_3 and GHG) were analyzed on farm level using Annual Nutrient Cycle Assessment model.

The three focal points, low protein rations, increased grazing and biodiverse grassland (all relative to a standard scenario) formed the basis for our scenarios to calculate the effect of various feeding strategies on the emission of GHG and NH_3. Regional differences were accounted for by defining specific scenarios for the NW and SE regions.

2 Methods

In the PPS Feed4Foodure, scenarios for integral sustainable diet formulation and feeding concepts were identified and evaluated to enable a win-win situation for biodiversity and animal nutrition practices. Various dairy cattle feed rations (diets formulated on cow level) were analyzed for their impact on milk production, N and P utilization and emissions of NH_3 and GHG on farm level. In this modelling study, the Dairy Cow Model (DCM) was connected to the Annual Nutrient Cycle Assessment model (ANCA, also known as KringloopWijzer in the Netherlands). A visual representation of the different models and input/output parameters used for the scenario calculations in this modelling study is shown in Figure 2.

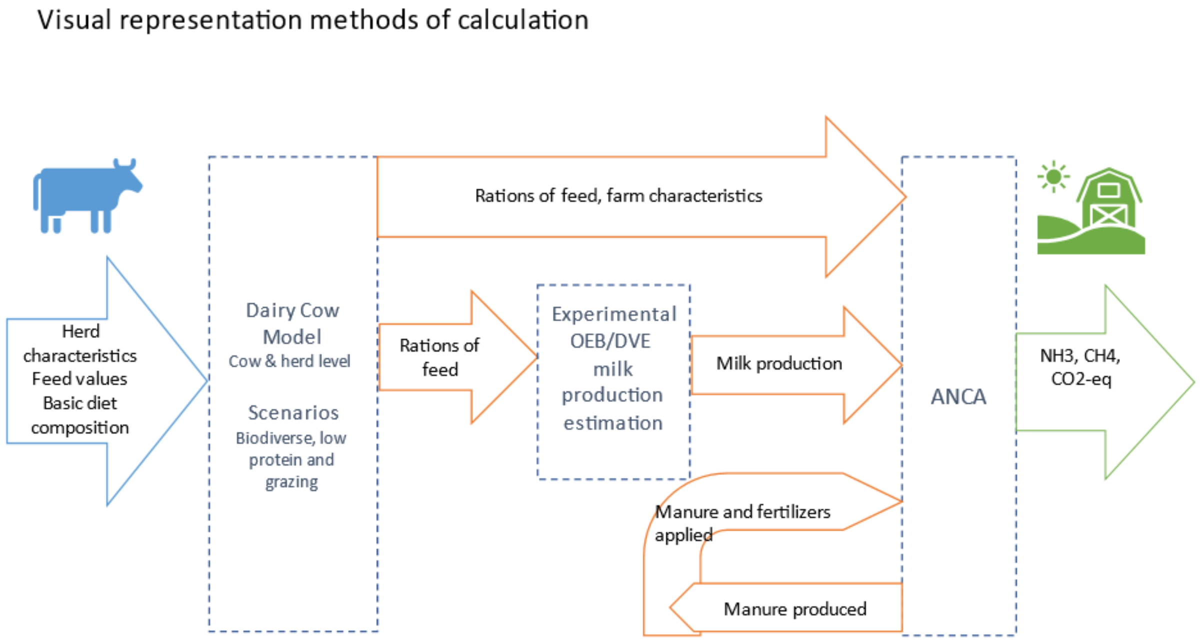

Figure 2 A visual representation of the different models and input/output parameters used for the scenario calculations in this modelling study.

The DCM is an energy-based model (2014) designed to predict feed intake and performance of dairy cows. The model consists of two models: a feed intake model and an energy partitioning model. The feed intake model predicts the dry matter intake (DMI) from cow and feed characteristics. The energy partitioning model predicts the partitioning of ingested net energy to milk energy and body reserves. Per scenario, the rations and farm characteristics were delivered by the DCM. The estimated milk yield however also depends on protein nutrition. Therefore output of the energy-based DCM, combined with an estimation of the milk production based on degradable protein balance (OEB) and application levels of manure and fertilizers based on Dutch legislation were used as input values for ANCA. As part of the low protein scenarios, a quantitative meta-analysis was done. This meta-analysis focused on the effects of manipulating OEB by changing protein degradability on fat and protein corrected milk (FPCM) production. The results of the meta-analysis were used to estimate the effect of intestine-digestible protein (DVE) supply and the OEB level on milk yield. A description of the methods and results of this analysis can be found in Appendix 1. As part of the scenario calculations which included biodiverse forages, Dutch were was collected to obtain nutritional values of biodiverse forages. The method and results can be found in Appendix 2. The results of this data collection were used in the diet calculations with the biodiverse forages.

The ANCA is a tool developed to provide an overview of the cycle and losses of N, phosphorus (P) and carbon (C) on a dairy farm. These insights are useful to optimize farm management. In this project, the DCM was used to obtain input parameters for ANCA (version 2021).

The ANCA output was used to give insight in the sustainability performance (GHG emission in terms of CO_2-equivalents and NH_3 emission) of rations on farm-level in different scenarios.

2.1 Scenarios for modelling

The following scenarios were selected for calculations in DCM and ANCA (also shown in Table 1). The DVE and OEB values refer to the DVE/OEB system 2007 (CVB, 2007).

1. Standard: current scenario; calculations based on CBS data for average farms in the North-West (NW) and South-East (SE) of the Netherlands in 2019 (published 2020)
2. Increased fresh grass intake for the NW and SE scenarios
3. Increased grazing time for the NW and SE scenarios
4. Decreased protein levels (100% DVE, 0 OEB) for the NW and SE scenarios by using biodiverse forages for the youngstock and dry cows.
5. Decreased protein levels (100% DVE, 0 OEB) for the NW and SE scenarios by using biodiverse forages for the youngstock and dry cows, with additionally increased fresh (perennial rye) grass intake
6. Low protein rations with current grazing intake, but a decrease in protein to 100% DVE coverage and -100 OEB (compared to standard scenario, both as a minimum, depending on diet situation the actual DVE coverage and OEB level during lactation may be higher)
7. Low protein rations with current grazing intake, but a decrease in protein to 100% DVE coverage and -500 OEB (compared to standard scenario, both as a minimum, depending on diet situation, the actual DVE coverage and OEB level during lactation may be higher)
8. Low protein rations with current grazing intake, feeding below DVE requirement (90%) and -100 OEB (compared to standard scenario, both as a minimum, depending on diet situation the actual DVE coverage and OEB level during lactation may be higher)
9. Low protein rations with current grazing intake, feeding below DVE requirement (90%) and -500 OEB (compared to standard scenario, both as a minimum, depending on diet situation the actual DVE coverage and OEB level during lactation may be higher)

Table 1 *Modelled scenarios and their characteristics. Indicated numbers correspond with the text above.*

	Scenario name	**Forage type**	**Protein intake (DVE/OEB system 2007)**	**Concentrate type**
1	Standard	According to CBS (2020)		
2	Increased fresh grass intake	Increased fresh grass intake, only supplemental maize silage during grazing season	Minimize N intake from concentrate with 100%DVE coverage, increased CP from grazed grass	Standard concentrate
3	Increased grazing time	Increased fresh grass intake with increased grazing hours, only supplemental maize silage during grazing season	Minimize N intake from concentrate with 100%DVE coverage, increased CP from grazed grass	Standard concentrate
4	Herb rich grassland	Only supplemental maize silage during grazing season; during dry period grass silage semi-natural	Minimize N intake from concentrate with 100%DVE coverage, increased CP from grazed grass	Standard concentrate
5	Herb rich grassland with increased fresh grass intake	Increased fresh grass intake, only supplemental maize silage during grazing season; during dry period grass silage semi-natural	Minimize N intake from concentrate with 100%DVE coverage, increased CP from grazed grass	Standard concentrate
6	100%DVEmin100OEB	According to CBS (2020)	Minimize N intake from concentrate with 100%DVE coverage; OEB threshold -100 OEB	Alternative concentrate composition
7	100%DVEmin500OEB	According to CBS (2020)	Minimize N intake from concentrate with 100%DVE coverage; OEB threshold -500 OEB	Alternative concentrate composition
8	90%DVEmin100OEB	According to CBS (2020)	Minimize N intake from concentrate with 90%DVE coverage; OEB threshold -100 OEB	Alternative concentrate composition
9	90%DVEmin500OEB	According to CBS (2020)	Minimize N intake from concentrate with 90%DVE coverage; OEB threshold -500 OEB	Alternative concentrate composition

2.2 Diet formulation

Two basal rations were formulated, one ration being representative for the NW region and one for the SE region based on the annual inventory of the CBS (2020). Both rations (and variations) are described in detail in Appendix 4. The DVE and OEB values refer to the DVE/OEB system 2007 (CVB, 2007). Additionally, DVE and OEB 1991 are presented as DVE91 and OEB91 in Appendix 4.

2.3 Dairy Cow Model and Young Stock model simulations

Simulations were performed with the DCM (Koemodel; Zom, 2014). The simulations were performed for 144 individual animals (lactation 1-6, pregnant and non-pregnant cows and 12 months of calving per lactation number per year). An even calving spread over the year was assumed. For each of the 144 animals, the cow model simulated feed and nutrient intake, FPCM production, mobilization and energy input on a daily basis. The cow model estimates the production response based on net energy intake (VEM). Per scenario one feed allocation strategy was applied. Feed intake and growth of young stock was simulated with the Young Stock model based on currently available information (Mandersloot, 1989).

2.3.1 General assumptions

The general assumptions were made regardless of the simulated feeding or diet strategy. The general assumptions involved:

- Breed: in all simulations it was assumed that the cows were average Dutch Holstein Friesians.
- Replacement rate/culling rate: according to the CBS (2020), annually 28% of the cows from the herd are culled. It was assumed that culled cows were non-pregnant and were on average 180 days in milk at culling.
- Age distribution: herd consisted of 28%, 24%, 18%, 14%, 10% and 6%, 1st, 2nd, 3rd, 4th, 5th and 6th parity cows, respectively.
- Young stock per dairy cow (Van Bruggen, 2020): the number of female young stock per dairy cow was assumed to be 0.7, from which 0.37 were calves younger than 1 year and 0.33 were rearing heifers older than 1 year.
- Calving and calving interval: an evenly distributed calving pattern was assumed throughout the year. The calving interval was 420 days.

2.3.2 Feedstuff composition and feeding values for basic scenarios

For the NW and SE regions, the basic scenario rations for lactating dairy cows in the DCM simulations consisted of five feedstuffs: grass silage, maize silage, grazed grass, compound concentrates and moist by-products. An overview of the ingredients of the high and low protein concentrates used in the standard scenarios is shown in Table 2. The feeding values of all feedstuffs in the basic scenarios, as well as their corresponding GHG emissions and emission factors, are given in Table 3. It should be noted that it was not the aim to change the CO_2eq values but that these were based on the current composition. An overview of the nutrient composition of the total diets as calculated by the DCM are presented in Appendix 3. The emission factors (EF) for both concentrates and roughages were obtained from Nevedi data (unpublished).

Concentrates

For model simulations of the scenarios standard, increased fresh grass intake, increased grazing time, herb rich grassland and herb rich grassland with increased fresh grass intake were simulated according to the inventory of CBS (2020): dairy cow rations were supplemented with a low protein (LP; 24.9 g N/kg; 156 g CP/kg) and a high-protein concentrate (HP; 34.6 g N/kg; 216 g CP/kg; Table 2). These concentrates contained 950 VEM/kg. The ingredient composition of these rations were formulated on the basis using a least-cost linear programming method. The available ingredients and average prices of the year 2022 were obtained from Voederwaardeprijzen-Rundvee. The composition of the ingredients was obtained from the CVB-table values[6] (CVB, 2019).

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[6] www.cvbdiervoeding.nl

For the alternative scenarios with lower protein content, four lower protein concentrates (85-127 g CP/kg) and one high protein concentrate (275 g CP/kg) (Appendix 3) were formulated after consultation of the Association for Animal Nutrition Research (VDN) steering board. The selected ingredients with lower protein content were ingredients from European origin. The concentrate feeds that were used in the simulated rations were formulated using linear programming. The linear programming optimized concentrate feeds with a fixed energy level (950 VEM/kg) and fixed OEB levels (OEB intakes of -100 and -500 OEB/day) as close as possible with a minimized CP content by linear programming.

Grass and maize silage

The feeding values of grass silage and maize silage were based on average values over the period 2015-2019 as published by Eurofins. See Table 3 for feeding values and nutrient composition. For dairy cows, one single standard grass silage was used for the model simulations. The feeding values and nutrient composition of the standard grass silage was calculated as the weighted mean composition from the feeding values of spring, summer and autumn cut silage and their relative proportions of total available grass silage. It was assumed that the available grass silage in the rations of dairy cows consisted of 55%, 30% and 15% of spring (April-May), summer (June-August) and autumn (September and later) silage respectively. This assumption was based on variation in grass growth rates and grass supply during the growing season as calculated with the VoederVoorzieningsWijzer (VVW; integrated simulating grass growth and grass silage production; Van der Kamp et al. 2003).

In scenario 4 and 5, herb rich forages were fed to youngstock and dry cows. In this study, 20% of herb rich grass from nature conservation areas was included, corresponding with key performance indicators from Friesland Campina (Van Doorn et al., 2019). At this moment, the relation between feeding of herb rich grass and CH4 emission is still being researched. In our simulations, the EF for herb rich grass was therefore similar to the EF of fresh grass (17.2 CO_2 eq/kg DM).

Fresh grass

The feeding values of fresh grass were obtained from fresh grass monitoring programs of VDN members in which fresh grass samples were analysed on a weekly basis for their feeding value and chemical composition. Weekly averages of the feeding values and chemical composition were calculated from data which consisted of the feed analysis of 1483 weekly fresh grass samples collected during the growing season of 5 consecutive years (2017-2021). The weekly feeding values were used as inputs for the DCM. It was assumed that the nutritional value of fresh grass was similar in the NW and SE region, and that the grazing season lasted for 175 days, starting at day 105 (April 15; week 15) until and 280 (October 7; week 40). Volumes of fresh grass are presented in Figure 4.

Moist by-products

It was assumed that moist by-products consisted of 43% pressed beet pulp, 32% wet brewer's grains and 25% pressed potato pulp on a dry matter basis, according to assumptions in the Dutch National Inventory Report based on the IPCC Tier 3 approach (Bannink et al., 2011). Feeding values were obtained from the CVB feedstuffs table (CVB, 2020). It was assumed that moist by-products were fed to the dairy cows at a flat rate during the entire lactation, and during the close-up period.

Table 2 *Ingredients and GHG emissions of feed production (CO_2-equivalents) and enteric CH_4 emission emission factors (EF) with different maize silage levels (SM) of the high protein (HP) and low protein (LP) concentrates (% of fresh weight) used in the standard scenarios. Emission data were obtained from ANCA and VDN data (land use change).*

	HP concentrates	LP concentrates	CO_2-eq	LUC	EF CH_4	EF CH_4	EF CH_4
Table name ANCA	**%**	**%**	**g/kg**		**0% SM**	**40% SM**	**80% SM**
Beet pulp	39.8	5	477	0	25.8	25.8	28.3
Corn	8.5	28	576	135	21.2	19.7	17.8
Rapeseed meal (bypass)	15.5	3	635	103	17.9	17.9	18.6
Soy hulls	1.3	10	1272	1003	23.3	23.0	23.6
Soybean meal (bypass)	4.4	0	4469		20.4	19.3	18.9
Soybean meal	21.4	0	2990	2434	21.1	20.5	22.4
Wheat	1.6	0	513	14	23.4	23.0	22.5

Table name ANCA	HP concentrates %	LP concentrates %	CO_2-eq g/kg	LUC	EF CH_4 0% SM	EF CH_4 40% SM	EF CH_4 80% SM
Vegetable oil	1.9	0	3801	979	-11.8	-11.0	-11.2
Molasses (beet)	2	2	266	0	30.0	28.7	30.7
Calcium carbonate	0.8	0	518	0	0.0	0.0	0.0
Magnesium oxide	1	0	1119	0	0.0	0.0	0.0
Salt	1	0	511	0	0.0	0.0	0.0
Premix	0.8	2	1115	0	0.0	0.0	0.0
Rapeseed meal	0	11	555	95	18.9	19.4	22.7
Barley	0	16	532	18	22.8	22.1	20.7
Palm kernel expeller	0	10	796	194	16.9	17.4	18.6
Wheat gluten feed	0	5	652	9	20.8	20.4	19.8
Vinasses (beet)	0	4	402	0	21.8	22.8	27.0
Sunflower meal	0	4	558	54	17.9	18.4	21.2

Table 3 *Greenhouse gas emissions (until feed mill; emission from processing and transport to farm excluded), enteric CH_4 emissions factors (EF), nutrient composition, and feeding values of the roughage (g/kg DM) and low (LP) and high (HP) protein concentrates (g/kg) used in the standard scenarios. Emission data were obtained from ANCA and Nevedi data (land use change).*

Feed	Grass Silage g/kg DM	Fresh grass g/kg DM	Maize Silage g/kg DM	Straw g/kg DM	Moist by-products g/kg DM	LP g/kg	HP g/kg
CO2-eq (g/kg)	241	76	52	245	6.43	766	1640
Land use change (CO_2-eq)						308	679
EF_CH_4 0% maize silage	20.1	17.2*	18.5	17	21.6	21.8	20.6
EF_CH_4 40% maize silage	20.1	17.2*	17.6	17	21.6	21.5	20.3
EF_CH_4 80% maize silage	21.6	17.2*	16.3	17	22.7	22.3	21.1
Dry matter (g/kg)	460	161	370	902	224	891	876
Crude protein total	176	227	72	44	138	155	218
Ether extract	41	44	32	12	40	25	35
Sugar	84	97	15	0	32	50	110
Starch	0	0	362	0	58	267	66
NDF	477	445	364	745	453	250	220
VEM (/kg)	909	1006	982	418	1019	951	962
DVE	64	100	50	-4	110	103	155
OEB	49	69	-35	-17	-27	-2	12

*Based on Koning et al. (2022)

2.3.3 Feed stuffs nutrient composition and feeding values for low protein scenarios

In the NW and SE low protein scenarios, the rations for lactating dairy cows in the DCM simulations consisted of five feedstuffs: grass silage, maize silage, grazed grass, concentrates and moist by-products. An overview of nutrients, feeding values and emission factors of the high and low protein concentrates used in the low protein scenarios is shown in Table 4. A complete overview of the feeding values and nutrient composition of both the roughages and the concentrates for the low protein scenarios calculated by the DCM can be found in Appendix 3.

Table 4 *Nutrients, feeding values, carbon footprint and emission factors (EF) of concentrates used to simulate the protein scenarios (until feed mill; emission from processing and transport to farm excluded). Emission data were obtained from ANCA and Nevedi data (land use change).*

	Low protein				**High protein**
Region	**NW**	**NW**	**SE**	**SE**	**NW, SE**
OEB scenario	**OEB-100**	**OEB-500**	**OEB-100**	**OEB-500**	
CO_2-eq feed (CO_2/kg)	421	431	644	431	802
Land use change (CO_2-eq)	40	46	34	35	137
EF_CH4_0_SM	22.4	23.8	21.8	23.6	18.7
EF_CH4_40SM	22.2	23.3	21.7	23.4	18.8
EF_CH4_80SM	23.6	24.2	23.1	25.1	20.5
Dry matter (g/kg)	880	880	882	885	879
CP (g/kg)	112	85	127	93	275
Ether extract* (g/kg)	42	15	47	28	59
Sugar (g/kg)	70	68	70	78	71
Starch** (g/kg)	149	210	99	99	49
NDF (g/kg)	289	261	314	310	241
VEM (/kg)	960	960	960	960	955
DVE (%)	93	93	89	89	190
OEB	-30	-59	-12	-48	33

*determined by extraction with petroleum ether (ISO 6492, 1999)
**determined by enzymatic analysis (amyloglucosidase) (ISO/DIS 15914, 2004)

2.3.4 Simulations and calculations

Dairy cows

The DCM calculates feed intake on a daily basis from animal and feed characteristics[7]. The feed intake capacity is expressed in satiety units per day and is determined by the animal factors parity, days in milk and days pregnant. The feed factors are expressed in the satiety value of feed (SV/kg DM) and are calculated with feed specific equations using dry matter content, crude protein, crude fibre, ash and digestibility of organic matter as inputs. The net energy intake (VEM/day; Van Es, 1978) is calculated from the dry matter intake and VEM concentration. On a daily basis, the ingested VEM is partitioned among maintenance, pregnancy, developmental growth, milk production (FPCM, 3.05 MJ NE/kg) and mobilisation and restoration of body reserves. The yields of fat and protein are calculated from the FPCM yield (kg/day) and default curves of milk fat and protein concentrations.

Young stock

Feed intake and growth was simulated with the Young Stock model (Mandersloot, 1989). The simulated rations and growth were identical in all scenarios. The assumed birth weight was 38 kg, with an age at first calving of 24 months and weight 580 kg (excluding calf and maternal tissues) and 645 kg (including calf and maternal tissues).

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[7] CVB Veevoedertabel, CVB Tabellenboek Voeding Herkauwers 2022

Table 5 *Rearing scheme, body weight youngstock.*

Rearing phase	Body weight excl. calf and maternal tissues	Body weight incl. calf and maternal tissues	Growth (kg/d)
0- 10 weeks	92	92	0.81
10 weeks t/m 12 months	345	345	0.85
12-15 months	416	416	0.76
15 months - calving	577	628	0.61
Close-up	580	645	0.22

Rearing calves
In all scenarios, the same ration was used for young cattle <1 year. It was assumed that calves received colostrum during day 1-3 and milk replacer powder from day 3 to 70 days of age, with a total intake of 55 kg milk replacer powder per calf. In the period from 1 June to 31 August, young stock >5 months and younger <1 year were grazed without restriction. Outside the grazing season, the ration consisted of unlimited grass silage of the same quality as that provided to dairy cows (see grass silage Table 3). This ration was supplemented with low protein compound feed (see Table 2 and 3) up to the CVB requirement standard for VEM and DVE.

Rearing heifers >1 year
In all scenarios, the same ration was used for young stock >1 year, with the exception of the scenario with herb rich grassland. Young stock >1 year were grazed without restriction for 180 days. In addition, the ration consisted of unlimited grass silage of the same quality as that provided to dairy cows (see grass silage Table 3).

Dry cows
In both regions and all scenarios, identical rations were simulated for dry cows during 50-11 days before calving. Within the NW and SE regions, dry cows in the close-up group (10-1 days before calving date) received 1 kg of concentrate and a basal ration (i.e. grass silage: maize silage ratio on DM basis) that was identical to the rations of lactating cows in all scenarios (see Table 6).

2.3.5 Rations

Concentrates
For both regions NW and SE, three different scenarios were calculated with different amounts of low-protein and high-protein concentrates as supplementary feeding. The nutrient and raw material compositions are given in Table 2 and 3. All scenarios assumed an intake of 2060 kg compound feed and 348 kg DM moist by-products in accordance with CBS (2019). The simulated dose of the moist by-products was a constant amount of 1.1 kg DM per animal per day from 10 days before calving to 5 days before dry-off. The distribution of the compound feed over the lactation can have an effect on the predicted milk production, the mobilized amount of body reserves and feed intake. The amount of compound feed was simulated such that it roughly follows the milk production curve (see Figure 3).

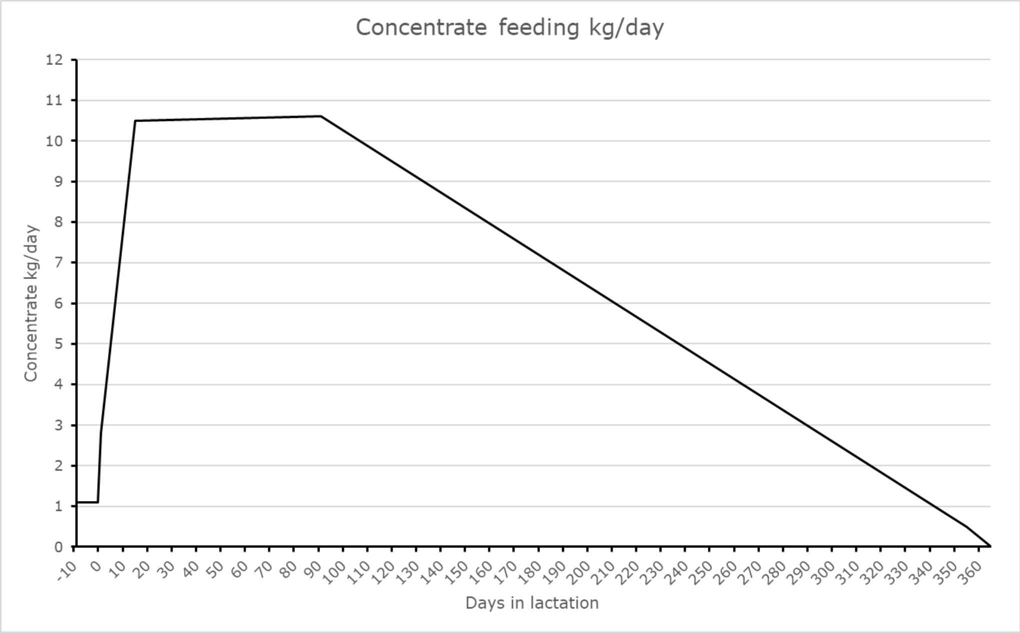

Figure 3 *Distribution of compound feed over lactation days.*

Roughage

The NW ration was characterized by a relatively large proportion of grassland products (grass silage and grazed grass) and a relatively small proportion of silage maize. The SE ration had a relatively large proportion of maize silage. Calculated over the entire year, in all scenarios the ratios between grass silage, grazed grass and maize silage in the entire ration, as reported by the CBS for NW and SE, were approached as closely as possible. Within one year (indoor and grazing season) and within animals (start of lactation (1-120 days in milk; DIM), end of lactation (121-365 DIM), dry period (50-11 days before calving date), close-up (10-0 days before calving date) the ratios between grass silage, grazed grass and maize silage for the different stages of the lactation cycle are shown in Table 6. In the simulations, only during the barn season (calendar days 1 to 104 and 280 to 365) a distinction was made between rations for cows in early lactation (1-120 DIM) and end lactation (121-365 DIM). For both NW and SE, supplementary feeding with the same grass silage/maize silage ratio was simulated for cows regardless of the lactation stage during the grazing season.

Table 6 *Simulated feeding strategy and roughage allocation for NW and SE.*

	Region	**Standard**	**Increased fresh grass and increased grazing time**	**Herb rich**	**Herb rich +increased fresh grass intake**
Non grazing ration (lactations and dry cows close-up group)					
Maize silage/grass silage ratio	NW	0.17/0.83	0.17/0.83	0.17/0.83	0.17/0.83
	SE	0.48/0.52	0.48/0.52	0.48/0.52	0.48/0.52
Grazing ration					
Maize silage/grass silage/fresh grass	NW	0.17/0.27/0.56	0.17/0/0.83	0.17/0.27/0.56	0.17/0/0.83
Maize silage/grass silage/fresh grass	SE	0.48/0.26/0.26	0.48/0/0.52	0.48/0.26/0.26	0.48/0/0.52
Dry period far-off (% of DM)					
Wheat straw/maize silage/grass silage	NW, SE	0.17/0.27/0.56	0.17/0.27/0.56		
Grass silage/conservation area hay	NW, SE			0.08/0.92	0.08/0.92

Fresh grass

For the basic scenarios, the rations of NW and SE were simulated with a different fresh grass allowance. Grazing started at day 105 when an allowance of 3 kg DM fresh grass for NW and 2 kg DM fresh grass for SE could be realized. Based on the grass growth model it was assumed that the maximum fresh grass allowance could be realized in May and June, with a steady decrease in fresh grass allowance until day 280 (Figure 4). In addition to fresh grass, additional feeding with maize silage and grass silage was simulated (Table 4).

For the scenarios with increased fresh grass and increased grazing time, in addition to the standard pasture ration, rations were simulated for NW and SE in which supplemental grass silage was replaced by an increased fresh grass intake. The supplementary feed with maize silage was similar to the standard pasture rations. For the scenarios with increased grazing time the grazing hours were increased to 2455 for NW and to 2620 hours for SE based on grazing hours for unrestricted grazing in these regions (CBS, 2022).

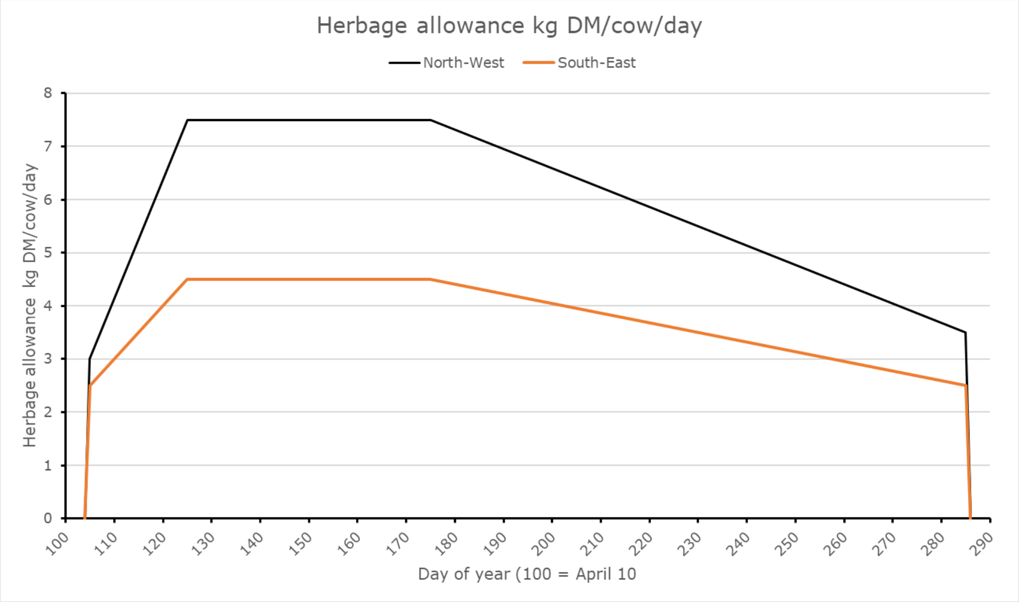

Figure 4 *Fresh grass allowance over days of the year.*

2.4 Intermediate steps to connect DCM to ANCA

The connection of the DCM to ANCA was done in different steps and required two runs of ANCA. Most input for ANCA was available from DCM (Table 7). Herd composition was the same for each scenario, namely 100 dairy cows, 33 youngstock >1 year, and 37 youngstock <1 year. Because herd size was the same in each scenario, the amount of hectares per farm can change per scenario to produce sufficient roughage. ANCA normally calculates the fresh grass intake (based on the gap between production and other feed input). For this study, ANCA (version 2021.17) was adapted to make fresh grass intake a fixed input based on DCM. Calculations were needed to obtain the required input parameters for ANCA that were not available from DCM. This was mainly related to total roughage production on farm and the application of manure and fertilizers. The calculations are described in the following chapter. With these calculated parameters, ANCA was run for a second time to obtain the final results.

Table 7 *Output parameters used to obtain input parameters for ANCA.*

Output from DCM to ANCA	Output from ANCA used for calculated input parameters	Calculated input parameters
Net feed consumption (herd level)	Total volume of manure production	Area of grassland
Milk production	N and P content in animal manure	Area of forage maize
Fat and protein content milk		Gross feed consumption (herd level, corrected for losses)
Herd composition		Maximum limit of K2O in slurry

		Maximum level of N and P from animal manure
		Level of active N
Output from DCM to ANCA	**Output from ANCA used for calculated input parameters**	**Calculated input parameters**
		Surplus of N and P
		Amount of N from artificial fertilizer
		Maximum amount of animal manure to meet the N or P limit per hectare
		K requirement
		Application amount of different artificial fertilizer components
		Usage of diesel, (green) electricity and gas

Areas of grassland and forage maize and on farm roughage production

The net feed consumption of the herd was calculated by the DCM. Based on the total feed intake of on-farm produced feedstuffs, the total hectares required to provide for the total feed intake was calculated. The assumed net yield of grassland (grazing and silage) was 12,300 kg DM/ha the net yield of maize silage was 15,600 kg DM/ha (CBS, 2019). In order to obtain input values for ANCA, the gross feed intake of grass and maize silages was corrected for feeding losses (feed spoiled at the bunk and feed out) and ensiling losses (silage fermentation losses) to obtain net feed intake. Feeding losses at feed bunk were assumed to be 5%, ensiling losses were assumed to be 10% for grass silage and 5% for maize silage (Van Dijk et al., 2022). The area of grassland was calculated from the gross consumption of grass silage and grazed grass. The gross consumption of grass silage and grazed grass was calculated from the net grass silage intake corrected for feeding losses (i.e. feed spoiled at the feed bunk) and ensiling losses (i.e. fermentation losses, effluent losses). As grazing losses occur in the field and these nutrients remain at the field, these were not taken into account. The gross intake of grass silage was calculated as net grass silage intake * 1.05 * 1.1. and the gross intake of maize silage was calculated as net maize silage intake * 1.05 * 1.05.

Farms may produce more roughages than required to fulfil the intake of the herd. Therefore we first estimated the total hectares to fulfil the intake of the farm. Subsequently, we compared these total hectares with the average total hectare per dairy farm in Agrimatie[8]. For the reference situation, if total hectares per farm in Agrimatie was higher than calculated for our modelled farm, total hectares were taken from Agrimatie to match average production intensity. This correction was done for all NW scenarios and it was assumed that the feed that was not fed was stocked.

The areas of grassland and forage maize used for each of the scenario calculations can be found in Table 25 of Appendix 6.

Manure production and application of fertilizers

Based on the feed composition and intake, the milk production and composition, and body weight increase of the animals, ANCA calculates the volume of manure produced and the total amount of N and phosphorus (P) excreted in milk and manure and N and P retained in the body. Based on the national norms of manure application, the total application of (artificial) fertilizer was calculated. Amount of N application through animal manure for both NW and SE was based on derogation[9], although dairy farms in SE did not fulfil to the requirements. This was chosen because in practice most farms in SE do also have derogation. In the coming years, derogation will be phased out, influencing emissions on farm level.

In relation to manure production and application of fertilizers the following assumptions and model settings were applied:

1. Based on the grazing time and milk production the total volume of manure production and N and P content in animal manure were estimated by ANCA.

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[8] https://www.agrimatie.nl/PublicatiePage.aspx?subpubID=2523&sectorID=2245&themaID=2753&indicatorID=2761

[9] https://www.rvo.nl/onderwerpen/mest/derogatie

2. To calculate K_2O content of manure, the total volume of manure was multiplied by the average K_2O levels in slurry, at a level of 5.4 g/kg manure (Handboek bodem en bemesting, 2014).
3. The maximum level of P fertilization of grass and maize was calculated using the maximum limit for grassland (95 kg/ha for both NW and SE) and for maize forage (70 kg/ha for both NW and SE[10]).
4. The maximum application level of N from animal manure was calculated by applying the maximum limit of N (with derogation), which is 250 kg/ha for NW and 230 kg/ha for SE.
5. The level of available N was calculated using the maximum limits for different regions, considering the forage grass-maize ratio of the pasture (Mestbeleid 2019-2021). The maximum limits for usage of N for different crops, regions and soil types can be found in table 23 in Appendix 6. Although SE did not have enough grassland for derogation norms, it was assumed that NW and SE had derogation.
6. The amount of N from artificial fertilizer was calculated by the difference between the maximum level of active N/ha and the maximum level of N/ha from animal manure (correcting with a factor 0.45 for the level of active N in slurry manure[11]).
7. The maximum level for either N or P per hectare was the limiting factor for animal manure application in our different scenarios. Consequently, animal manure was applied to meet the N or P limit per hectare.
8. It was assumed that the K output was equal to the K input, which was calculated using the maximum levels for K: 158 kg K/ha maize forage leaving the field and 356 kg K/ha grassland. These amounts were based on the average amount of K leaving the farm and the average total hectares of grassland and maize land in the Netherlands (Agrimatie[12]; Appendix 6, Table 29).
9. K requirement and K excretion from manure were used to calculate the K requirement from artificial fertilizer. The required application of K_2O from artificial fertilizer was calculated using the K requirement from artificial fertilizer and applying a 47/39 ratio.
10. To calculate the application amount of different artificial fertilizer components, the distribution of the components as mentioned in IFASTAT[13] (2021) were used (Table 30, Appendix 6). The total amount of kg K_2O from artificial fertilizer and the total amount of kg N from artificial fertilizer were calculated in kg product of ammonia phosphate, kg product of calcium ammonium nitrate (CAN), kg product of urea, kg product of triple phosphate, kg potassium oxide (K_2O).
11. For all scenarios, the surplus of animal manure in kg N was calculated using the actual manure production in kg N and the maximum limit of 250 kg N/ha, or the maximum kg N that could be applied up to the P limit.
12. The surplus of animal manure in kg P was calculated using the actual manure production in kg P and the maximum limit of 95 kg P/ha grassland and 70 kg/ha maize forage, or the maximum kg P that could be applied up to the N limit.
13. The outcome of -12- was used to calculate the removal or supply of animal manure in tons of manure, used as input data for ANCA.

Final input information
Other input values for ANCA needed for scenario calculations were usage of diesel, (green) electricity and gas. These were calculated based on standard values per 1000 kg produced milk. These standard values can be found in Table 31 in Appendix 6.

Emission sources
Altogether, this input was used to obtain information on GHG and NH_3 emission as calculated by ANCA. The emission of GHG is presented per FPCM and on farm level. Different sources of emission contributed to the total GHG emission: emission from inputs (such as purchased feed and fertilizer), usage and production of energy, on-farm feed (roughage) production, barn and manure storage and rumen fermentation. The total NH_3 emission consisted of emissions from crop residues from harvesting, from crop residues from grazing, from manure during pasturing, from artificial fertilizer on arable land and on grassland, from animal manure on arable land and on grassland, and from barn and manure storage.

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[10] Fosfaatdifferentiatie table 1 and 2 (rvo.nl)
[11] Tabel 3 Werkingscoëfficiënt dierlijke en andere organische meststoffen 2014-2017 (rvo.nl)
[12] https://www.agrimatie.nl/PublicatiePage.aspx?subpubID=2523&sectorID=2245&themaID=2753&indicatorID=2761
[13] IFASTAT | IFA Fertilizer Converter (ifastat.org)

3 Results

3.1 Dairy Cow Model and Young Stock model simulations

3.1.1 Diet composition

Rations were simulated using the DCM and Young Stock model. For the NW scenarios, the results simulated by the DCM can be found in Table 8. In the scenarios with increased fresh grass intake and increased grazing time, the amount of grazed grass increased from 3.6 to 5.5 kg DM/d. This was compensated for by a decrease in grass silage from 7.0 to 5.4 kg DM/d. In the low protein scenarios, the share of low protein concentrates increased from 4.0 to 4.8 (100% DVE) and 5.0 kg DM/d (90% DVE). Based on the model calculations, the milk yield (FPCM) increased for grazing and did not change in the biodiverse scenario. Herb rich forage was fed to rearing young stock >1 year and to dry cows.. Herb rich forage replaced grass silage from the >3 cuts and straw in the rations of dry cows. For the low protein scenarios, the change in FPCM ranged from +1.0% to -5.2%, depending on the scenario. FPCM levels are representative for an average dairy farm in the Netherlands (8843 in 2021; 8968 in 2022) (CBS, 2023).

Table 8 *Average daily feed intake per cow and milk yield of the dairy cows (including dry period) on an annual basis for different feed strategy scenarios in the North West (NW) region as simulated by the Dairy Cow Model.*

Region	**NW**	**NW**	**NW**	**NW**	**NW**	**NW**	**NW**
Scenario	**Standard**	**increased fresh grass**	**herb rich grassland**	**100%DVE -100OEB**	**100%DVE -500OEB**	**90%DVE -100OEB**	**90%DVE -500OEB**
Maize silage (kg DM/d)	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Grass silage (kg DM/d)	7.0	5.4	6.3	7.0	7.0	7.0	7.0
Grazed grass (kg DM/d)	3.6	5.5	3.6	3.6	3.6	3.6	3.6
Wheat straw (kg DM/d)	0.3	0.3	0.0	0.3	0.3	0.3	0.3
Herb rich grass silage (kg DM/d)	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Wet byproducts (kg DM/d)	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Low protein concentrate (kg DM/d)	4.0	4.0	4.0	4.8	4.8	5.0	5.0
High protein concentrate (kg DM/d)	1.0	1.0	1.0	0.3	0.3	0.1	0.1
Total roughage intake (kg DM/d)	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Total intake (kg DM/d)	18.9	19.3	19.0	18.9	18.9	18.9	18.9
Milk yield kg/cow/year	8372	8456	8372	8109	7973	8064	7928
Fat yield kg/cow/year	382	386	382	371	365	369	363
Protein yield kg/cow/year	297	300	297	288	283	286	282
FPCM yield kg/cow/year	9037	9127	9037	8759	8616	8711	8568

*Composition of the low protein and high protein concentrates is the same for scenario's NW standard, NW increased fresh grass and NW herb rich, but differs between the four DVE and OEB scenarios.

For the SE scenarios, the results simulated by the DCM can be found in Table 9. In the scenarios with increased fresh grass intake, the amount of grazed grass increased from 1.6 to 4.0 kg DM/d. This was compensated for by a decrease in grass silage from 5.4 to 3.4 kg DM/d. In the low protein scenarios, the share of low protein concentrates increased from 1.6 to 4.5 (100% DVE) and 4.9 kg DM/d (90% DVE). The share of high protein concentrates decreased from 3.5 to 0.6 (100% DVE) and 0.2 kg DM/d (90% DVE).

The satiety value of fresh grass is lower than the satiety value of grass silage, resulting in a higher TDMI with the same amount of concentrate. Consequently, FPCM production per year is modelled to be higher with the increased fresh grass scenario. FPCM levels are representative for an average dairy farm in the Netherlands (8843 in 2021; 8968 in 2022) (CBS, 2023).

Table 9 *Average daily feed intake per cow and milk yield of the dairy cows (including dry period) on an annual basis for different feed strategy scenarios in the South East (SE) region as simulated by the Dairy Cow Model.*

Region	**SE**	**SE**	**SE**	**SE**	**SE**	**SE**	**SE**
Scenario	**Standard**	**increased fresh grass**	**herb rich grassland**	**100%DVE -100OEB**	**100%DVE -500OEB**	**90%DVE -100OEB**	**90%DVE -500OEB**
Maize silage (kg DM/d)	5.9	5.9	5.9	5.9	5.9	5.9	5.9
Grass silage (kg DM/d)	5.4	3.4	5.0	5.4	5.4	5.4	5.4
Grazed grass (kg DM/d)	1.6	4.0	1.6	1.6	1.6	1.6	1.6
Wheat straw (kg DM/d)	0.4	0.4	0.2	0.4	0.4	0.4	0.4
Herb rich grass silage (kg DM/d)	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Wet byproducts (kg DM/d)	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Low protein concentrate (kg DM/d)	1.6	1.6	1.6	4.5	4.5	4.9	4.9
High protein concentrate (kg DM/d)	3.5	3.5	3.5	0.6	0.6	0.2	0.2
Total roughage intake (kg DM/d)	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Total intake (kg DM/d)	19.3	19.7	19.4	19.3	19.3	19.3	19.3
Milk yield kg/cow/year	8466	8641	8465	8206	8018	8106	7926
Fat yield kg/cow/year	386	395	386	375	367	370	363
Protein yield kg/cow/year	300	307	300	291	285	288	282
FPCM yield kg/cow/year	9137	9328	9136	8863	8665	8738	8567

*Composition of the low protein and high protein concentrates is the same for scenario's SE standard, SE increased fresh grass and SE herb rich, but is different for the four DVE and OEB scenarios.

3.1.2 Feeding values

The average nutrient composition of the average diets calculated in the DCM simulations are presented in Table 10 for the NW scenarios and in Table 11 for the SE scenarios. For NW, dietary CP level increased slightly in the scenario with increased fresh grass. In the low protein scenarios, a decrease in dietary CP is seen, with a maximum decrease from 178 to 148 g/kg DM (90% DVE and -500 OEB). The composition of the herb rich scenario is similar to the composition in the standard scenario, because herb rich hay was fed during the dry period, which is not included in Table 11.

Table 10 *Diet composition for lactating cows over the entire lactation period for the NW scenarios, as simulated by the DCM.*

	NW basic **g/kg DM**	**NW increased fresh grass intake** **g/kg DM**	**NW herb rich grassland** **g/kg DM**	**NW 100%DVE -100OEB** **g/kg DM**	**NW 100%DVE -500OEB** **g/kg DM**	**NW 90%DVE -100OEB** **g/kg DM**	**NW 90%DVE -500OEB** **g/kg DM**
Crude protein (incl. NH_3)	178	183	175	159	151	157	148
Ether extract	35	35	34	41	33	41	33

Starch	115	113	116	90	109	91	111
NDF	407	411	413	423	414	423	415
	NW basic	**NW increased fresh grass intake**	**NW herb rich grassland**	**NW 100%DVE -100OEB**	**NW 100%DVE -500OEB**	**NW 90%DVE -100OEB**	**NW 90%DVE -500OEB**
	g/kg DM	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**
VEM/kg	988	993	989	990	990	990	990
DVE	92	95	92	84	85	83	83
OEB	25	26	26	15	6	14	5

Table 11 *Diet composition for lactating cows over the entire lactation period for the SE scenarios, as simulated by the DCM.*

	SE basic	**SE increased fresh grass intake**	**SE herb rich grassland**	**SE 100%DVE -100OEB**	**SE 100%DVE -500OEB**	**SE 90%DVE -100OEB**	**SE 90%DVE -500OEB**
	g/kg DM	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**
Crude protein (incl. NH_3)	163	169	163	141	132	137	127
Ether extract	33	34	33	42	36	41	35
Starch	187	174	187	146	146	147	147
NDF	387	384	387	406	405	408	407
VEM/kg	992	998	992	992	992	992	992
DVE	90	93	90	78	78	75	75
OEB	13	16	13	4	-6	3	-8

3.1.3 Emission factors

For all scenarios, the EF of each ration regarding enteric CH_4 emissions was calculated based on the ration composition simulated by the DCM and Young Stock model. For fresh grass, an EF of 17.22 g CH_4/kg DM was used in the calculations based on new insights about the enteric methane emissions in relation to fresh grass by Koning et al. (2022). For the NW scenarios, the results are expressed in g/kg DM and presented in Table 12. In all NW scenarios, a decrease in the emission of GHG was seen when compared to the basic scenario due to a reduction in the use of soybean meal.

Table 12 *Emission factors for all NW rations, expressed in g CO_2-eq/kg or g CH_4/kg DM/day.*

	NW standard	**NW increased fresh grass intake**	**NW herb rich grassland**	**NW 100%DVE -100OEB**	**NW 100%DVE -500OEB**	**NW 90%DVE -100OEB**	**NW 90%DVE -500OEB**
gCO_2_EQ (g/kg)	232	201	232	156	157	154	155
EF CH_4 0% maize silage (g/kg DM)	20.8	20.6	20.8	21.1	21.5	21.1	21.6
EF CH_4 40% maize silage (g/kg DM)	20.5	20.3	20.5	20.9	21.2	21.0	21.3
EF CH_4 80% maize silage (g/kg DM)	21.3	21.0	21.3	22.0	22.2	22.0	22.2

For the SE scenarios, the results are expressed in g/kg DM and presented in table 13. Similar to the NW scenarios, a decrease in the emission of GHG was seen in all SE scenarios when compared to the basic scenario.

Table 13 *Emission factors for all SE scenarios, expressed in g/CO_2-eq/kg or g EF_CH_4/kg DM/day.*

	SE standard	**SE increased fresh grass intake**	**SE herb rich grassland**	**SE 100%DVE -100OEB**	**SE 100%DVE -500OEB**	**SE 90%DVE -100OEB**	**SE 90%DVE -500OEB**
gCO_2_EQ (g/kg)	261	220	261	174	151	173	147
EF CH_4 0% maize silage (g/kg DM)	20.5	20.4	20.5	20.4	21.2	20.8	21.3
EF CH_4 40% maize silage (g/kg DM)	20.1	20.0	20.1	20.1	20.8	20.4	20.9
EF CH_4 80% maize silage (g/kg DM)	20.3	20.0	20.3	20.6	21.5	21.0	21.6

3.1.4 Course of dry matter intake, degradable protein balance and crude protein over lactation period

For the different NW low protein scenarios, the course of DMI, dietary OEB concentration and dietary CP concentration during the entire lactation period are presented in Figure 5 to 10. Additional figures for NW and all other figures for the SE scenarios can be found in appendix 5.
Figure 5 displays the DMI (kg/day) of April calving (first, second and third parity) cows. Figure 6 displays the DMI (kg/day) of October calving (first, second and third parity) cows. Figures for April and October calving cows show two (extreme) examples; in the simulations it was assumed that the calving pattern of the herd was equally distributed over the year. The difference in feed intake pattern between April and October calving cows illustrates that calving date had an significant effect on DM intake. April calving cows may have a larger proportion of grass in their diet in early lactation, but high protein intake could only be partly counteracted by low protein concentrates (Figure 7 and 9). October calving cows, however, consumed more high protein grass in late lactation. As the level of concentrate supplementation in late lactation was lower, there was little room to counteract high protein intakes with low protein concentrate in late lactation cows (Figure 8 and 10). The drop in DMI reflects the change in diet composition (fresh grass replaced with grass silage or vice versa). The satiety value of fresh grass is lower than the satiety value of grass silage. The drop reflects replacing of fresh grass with grass silage, a jump reflects replacement of grass silage with fresh grass. The composition of fresh grass was obtained from weekly fresh grass measurement data from the feed industry collected from 2016-2021. These data were used to calculate the weekly means of the chemical composition and feeding value. The typical pattern during the grazing season reflects the weekly variation in feeding value.

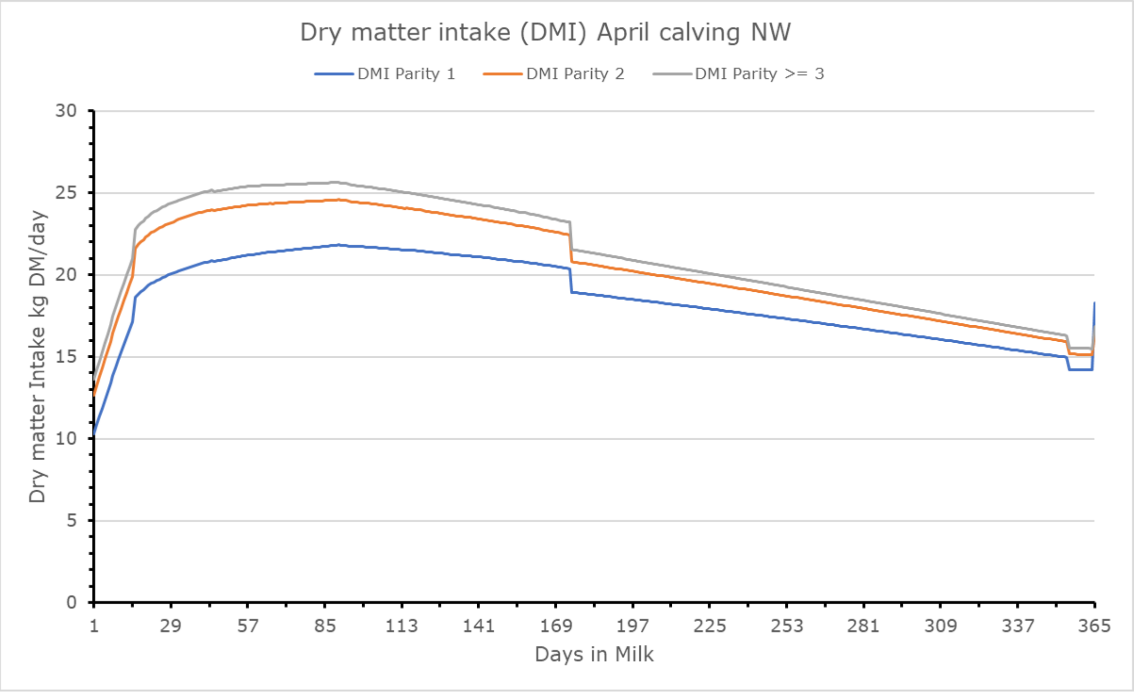

Figure 5 *Course of the DMI over the lactation period for cows (with different parities) calving in April in the NW scenarios.*

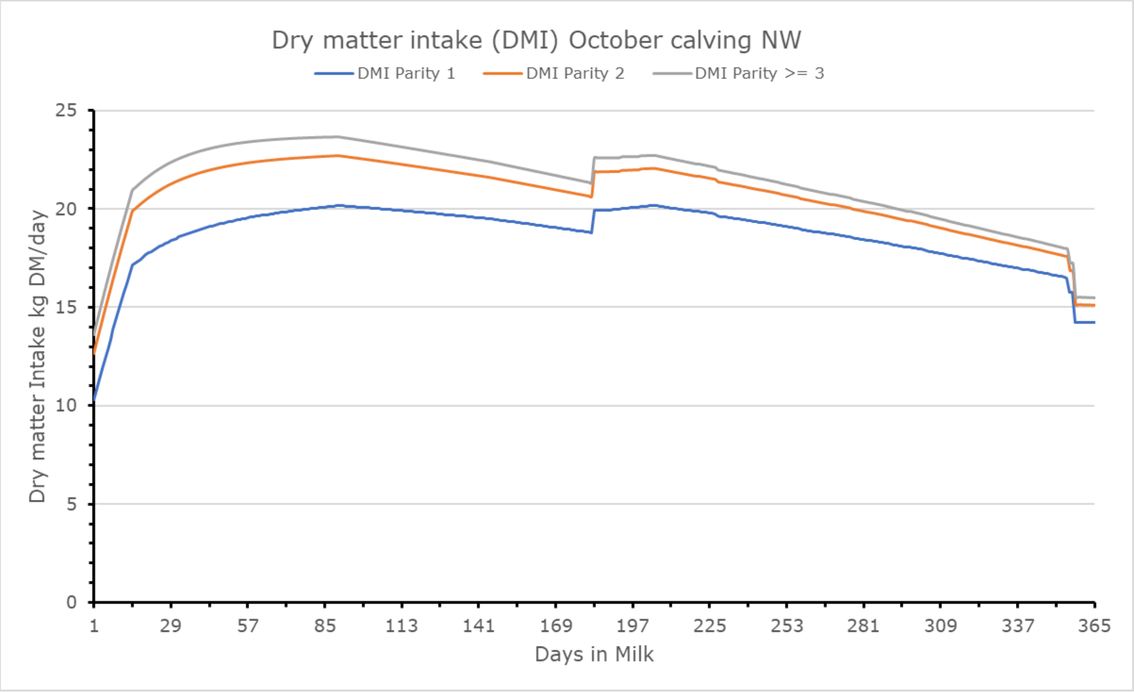

Figure 6 *Course of the DMI over the lactation period for cows (with different parities) calving in October in the NW scenarios.*

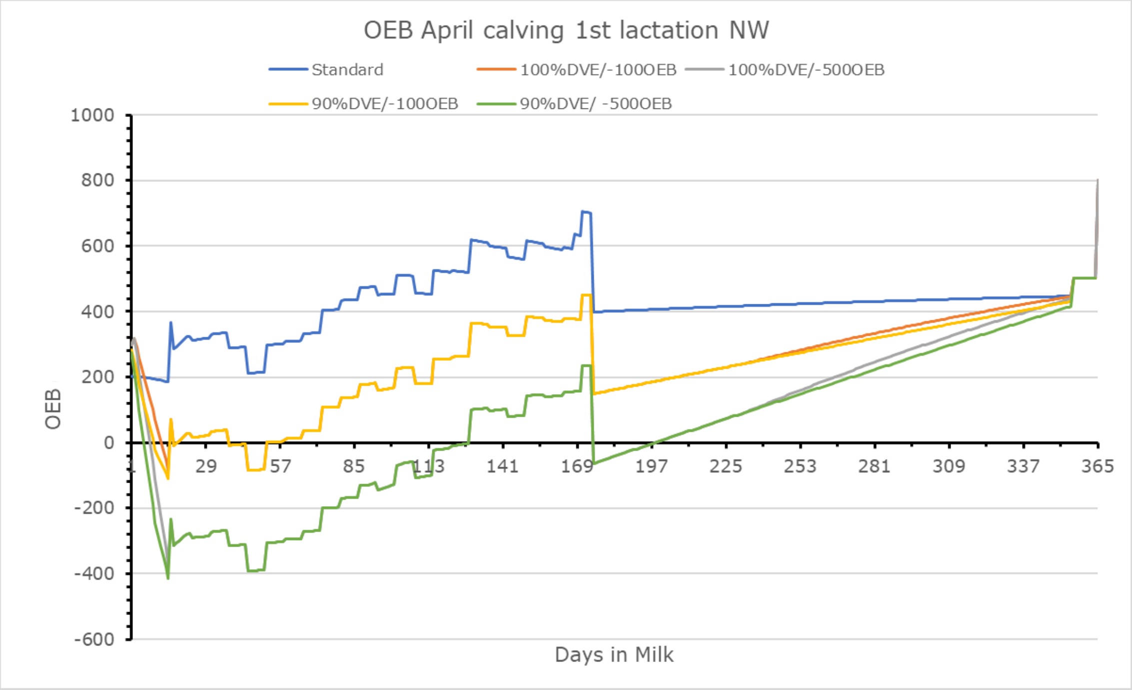

Figure 7 *Course of the OEB with 90% or 100% DVE over the first lactation period for cows calving in April in the NW scenarios.*

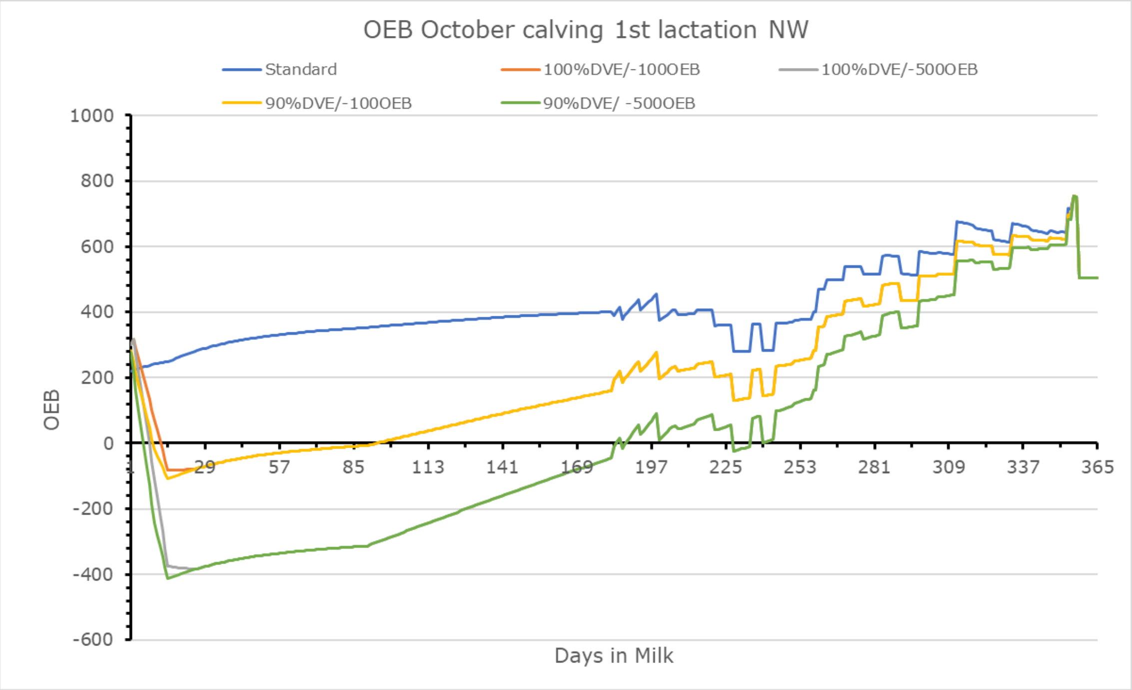

Figure 8 *Course of OEB with 90% or 100% DVE over the first lactation period for cows calving in October in the NW scenarios.*

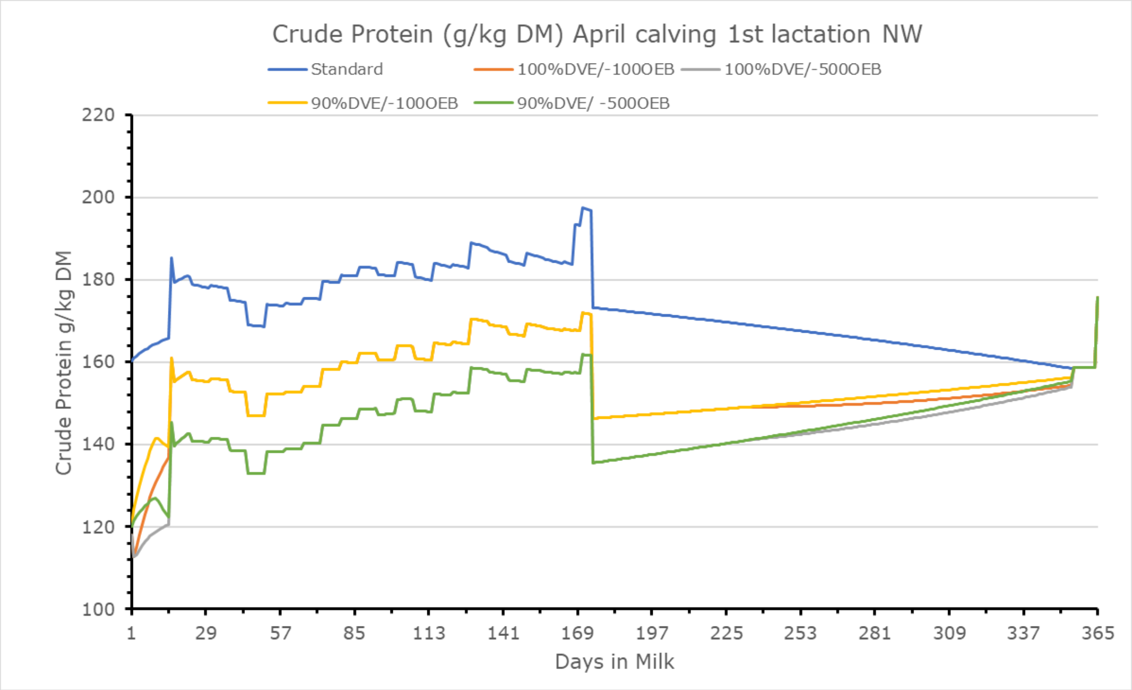

Figure 9 *Course of CP level (expressed in g/kg DM) with 90% or 100% DVE over the first lactation period for cows calving in April in the NW scenarios.*

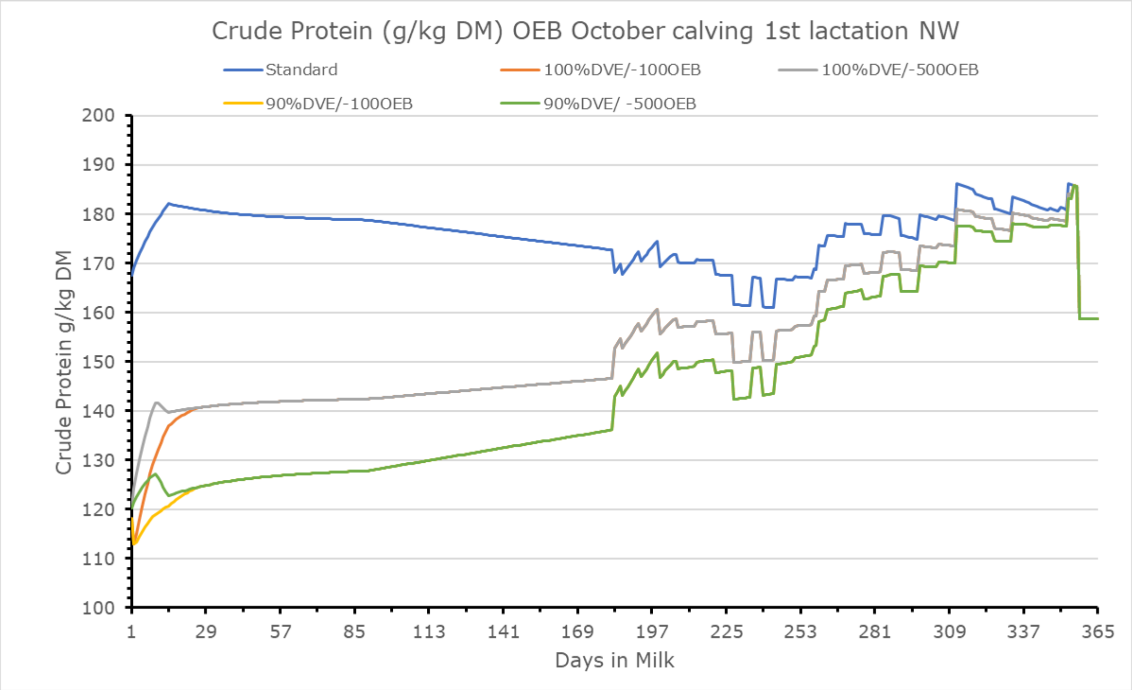

Figure 10 *Course of CP level (expressed in g/kg DM) with 90% or 100% DVE over the first lactation period for cows calving in October in the NW scenarios.*

3.1.5 Intermediate steps to connect DCM to ANCA

The results of the intermediate steps to obtain the ANCA input values from the DCM output values can be found in Appendix 6 and 7. For each scenario, Appendix 6 shows the intermediate results of the areas of grassland and maize land, total roughage production, manure production, the amount and composition of organic and artificial fertilizer and data on energy and gas usage. Appendix 7 shows the details of manure application, total volume and N and P content of manure produced.

3.2 Effects on GHG and ammonia emission

After connecting the DCM to ANCA for all NW and SE scenarios, GHG and NH_3 emissions were given as output values from ANCA. The results are presented and described below. When comparing different scenarios, it should be noted that milk production and number of hectares differed in each scenario and this affected the results.

3.2.1 Effect on carbon dioxide equivalents in NW scenarios

The emission of GHG was given in total emission per year on farm level and per kg FPCM by ANCA. In Figure 11, the emission of GHG is shown for all NW scenarios. The figures show the emission from inputs (purchased feed), usage and production of energy, on-farm feed (roughage) production, barn and manure storage and rumen fermentation.

GHG emission on farm level

On farm level, the total emission increased slightly with increased fresh grass intake and with increased grazing time compared to the basic scenario due to an increase in emission from feed production. In the scenario with herb rich grassland, rumen fermentation increased while the emission from inputs, barn and manure storage and feed production decreased, which altogether led to a lower GHG emission. All low protein scenarios showed a reduction in total GHG emission. In these scenarios, emission from rumen fermentation increased and emission from inputs decreased.

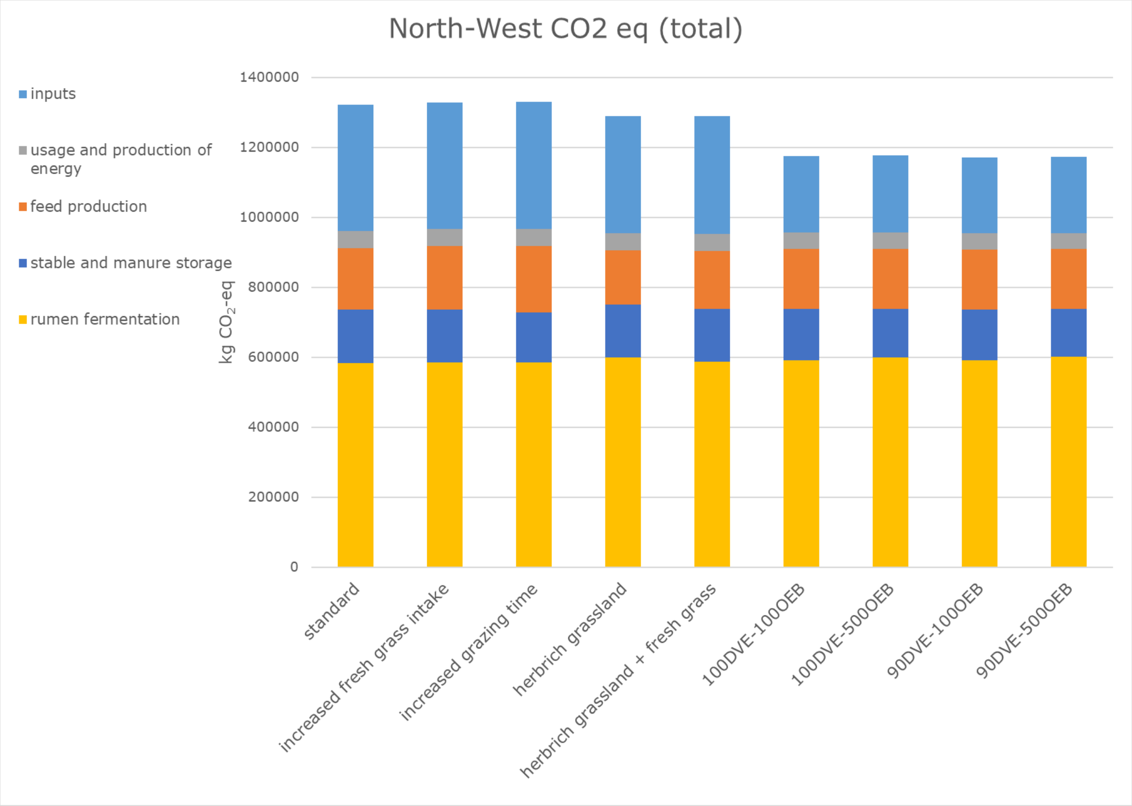

Figure 11 *Emission of GHG (in CO_2-equivalents) on farm level is shown for all scenarios (NW).*

GHG emission per kg FPCM

To account for differences in total milk production, Figure 12 shows the emission of GHG as kg CO_2-equivalents per kg FPCM for the NW scenarios. The exact emission numbers per FPCM can be found in Table 14.

Regardless of differences in milk production levels, the standard scenario, the scenario with increased fresh grass intake, the scenario with increased grazing time and the scenario with herb rich grassland have similar GHG emissions in terms of CO_2 equivalents per kg FPCM. The scenario with herb rich grassland shows a higher CH_4 emission from rumen fermentation and a lower GHG emission from inputs. All low protein scenarios had a lower emission of GHG; both on farm level and per FPCM. This effect was mostly related to lower emissions from inputs (purchased feed), reducing emissions from LUC.
In all scenarios, the effects on emission from rumen fermentation were more pronounced when expressed per kg FPCM than on farm level.

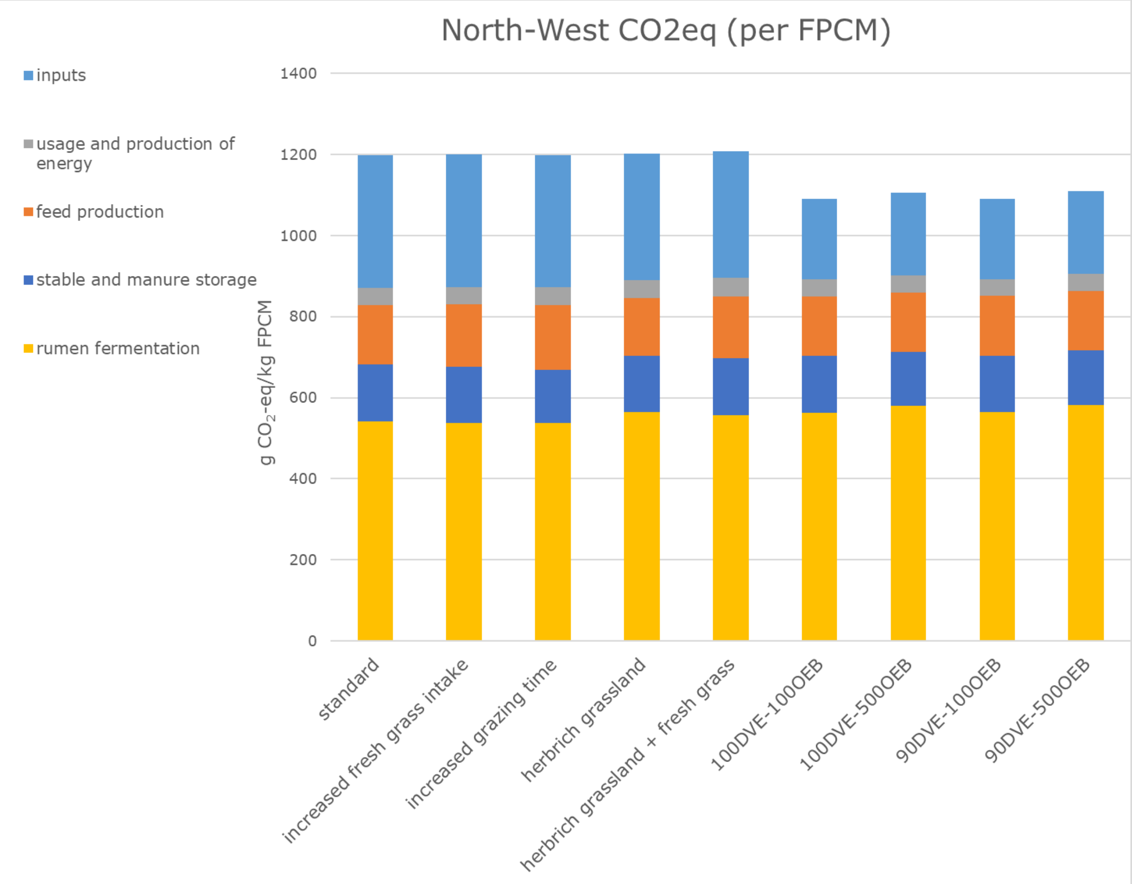

Figure 12 *Emission of GHG (in kg CO_2-equivalents) per FPCM for all scenarios (NW).*

Table 14 *Emission of GHG in the NW scenarios, expressed in g CO_2-eq/kg.*

CO_2-eq emission per FPCM	**NW standard**	**NW increased fresh grass intake**	**NW increased grazing time**	**NW herb rich grassland**	**NW herb rich grassland + increased fresh grass intake**	**NW 100%DVE -100OEB**	**NW 100%DVE -500OEB**	**NW 90%DVE -100OEB**	**NW 90%DVE -500OEB**
Inputs	327	327	327	309	313	198	204	197	203
Usage and production energy	43	43	43	45	45	42	42	42	42
Feed production	147	154	162	144	152	147	148	148	148
Barn and manure storage	141	139	131	140	140	141	134	139	134
Rumen fermentation	541	538	538	556	545	562	579	565	582
Total emission on farm level (incl. LUC)	**1199**	**1201**	**1201**	**1194**	**1196**	**1090**	**1107**	**1091**	**1108**

3.2.2 Effect on carbon dioxide equivalents in SE scenarios

In Figure 13, the GHG emission on farm level is shown for all SE scenarios. The figures show the emission from different sources.

GHG emission on farm level

On farm level, the total emission increased slightly compared to the standard scenario in the three scenarios with increased fresh grass intake. For both scenarios with increased grazing time (standard and with herb rich grassland) this was due to an increase in emission from feed production. The scenario with herb rich grassland showed an overall decrease in GHG emission, mainly caused by a decrease in emission from barn and manure storage and inputs. In all low protein scenarios, total GHG emission was reduced. Just as for the NW low protein scenarios, in the SE low protein scenarios, GHG emission from rumen fermentation increased while emission from all other sources decreased.

GHG emission per kg FPCM

Figure 14 shows the GHG emission expressed in CO_2-equivalents per FPCM for the SE scenarios. The exact emission numbers per FPCM can be found in Table 15.

When accounting for differences in milk production levels, the GHG emission in the scenario with increased fresh grass intake, increased grazing time and herb rich grassland and herb rich grassland with increased fresh grass were similar to the emission in the standard scenario while the low protein scenarios showed larger effects. The scenario with herb rich grassland shows a higher emission from rumen fermentation compared to the standard scenario, an effect which was compensated for by increased fresh grass intake. Although emission from rumen fermentation increased, all low protein scenarios have a lower GHG emission; both on farm level and per FPCM. This effect was mostly related to lower emissions from inputs, due to lower emissions from LUC.

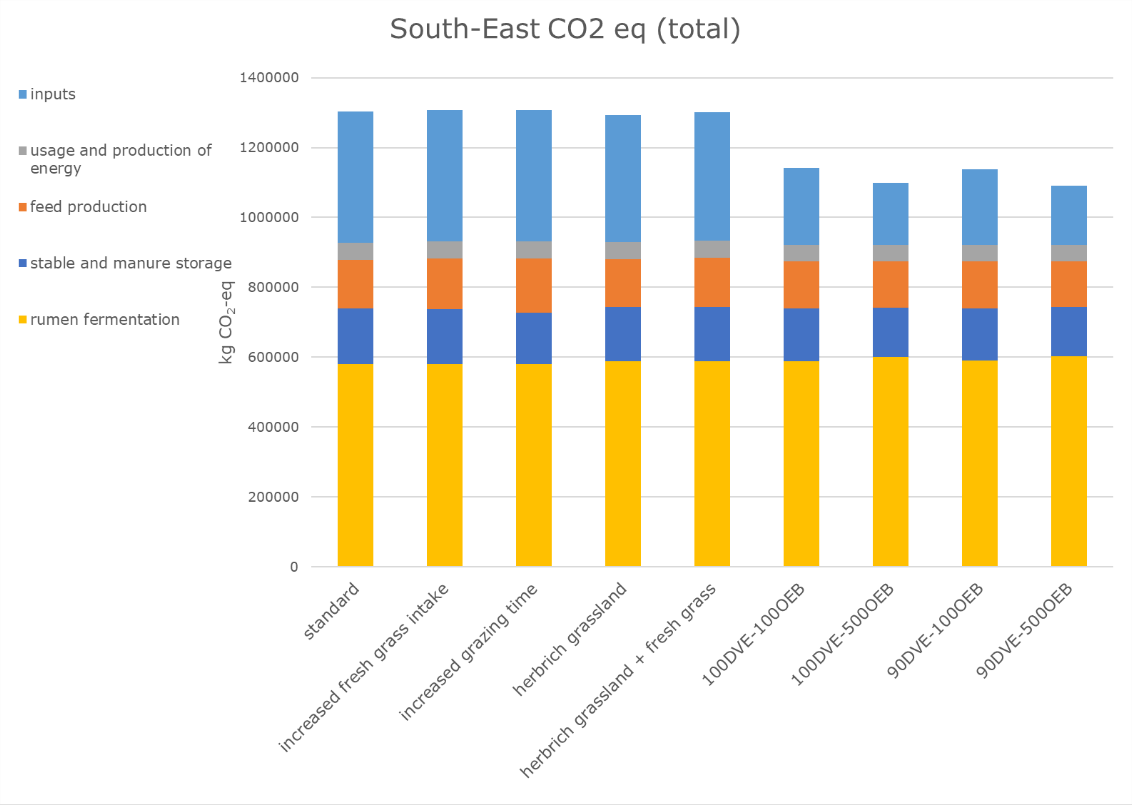

Figure 13 *Emission of GHG emission (expressed in CO_2-equivalents) on farm level is shown for all SE scenarios.*

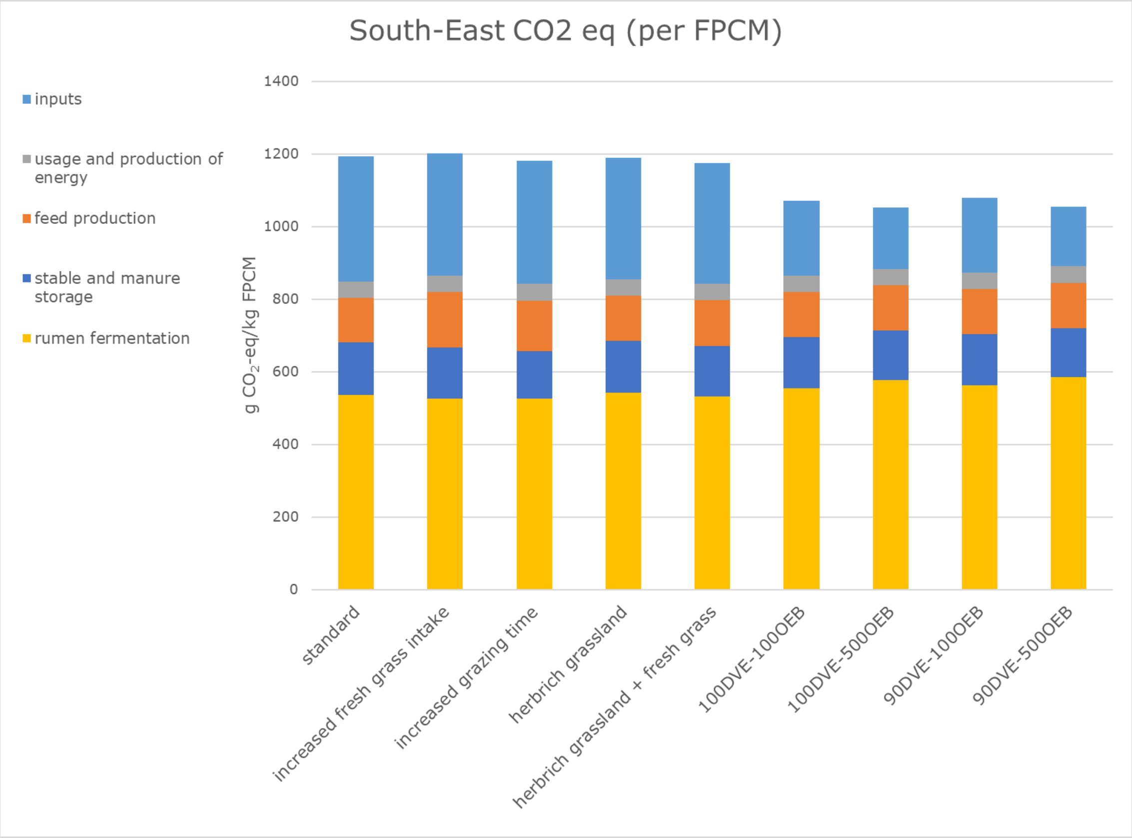

Figure 14 *Emission of GHG emission (expressed in CO_2-equivalents per kg FPCM) for all SE scenarios.*

Table 15 *Emission of GHG emission (expressed in CO_2-equivalents per kg FPCM) in the SE scenarios.*

CO_2-eq emission per FPCM	**SE standard**	**SE increased fresh grass intake**	**SE increased grazing time**	**SE herb rich grassland**	**SE herb rich grassland + increased fresh grass intake**	**SE 100%DVE -100OEB**	**SE 100%DVE -500OEB**	**SE 90%DVE -100OEB**	**SE 90%DVE -500OEB**
Inputs	345	339	339	335	332	207	170	206	164
Usage and production energy	45	45	45	45	44	45	45	45	45
Feed production	128	131	141	124	128	127	127	127	128
Barn and manure storage	145	141	132	143	139	142	137	142	136
Rumen fermentation	535	525	525	542	532	554	576	562	584
Total emission on farm level (incl. LUC)	**1197**	**1181**	**1179**	**1189**	**1175**	**1075**	**1055**	**1082**	**1057**

3.2.3 Effect on NH_3 emission in NW scenarios

In Figure 15, the NH_3 emission on farm level is shown for all NW scenarios. Figure 16 shows the NH_3 emission per hectare in the NW scenarios. The exact emission numbers per hectare can be found in Table 14.

Ammonia emission on farm level

On farm level, increasing fresh grass intake resulted in higher NH_3 emission. Since higher fresh grass intake was linked to increased grazing time only to a certain extend in our model calculations, this related to increased emission from barn and manure storage due to a higher total protein intake as caused by both a higher dry matter intake as well as higher average dietary protein levels, caused by the fresh grass. In all other scenarios, total NH_3 emission decreased. With increased grazing time, emission was reduced mostly from animal manure on grassland and transferred only partly to emissions from manure during pasturing. In the scenario with herb rich grassland the emission from animal manure on grassland increased, while emission from barn and manure storage and from artificial fertilizer on grassland decreased. When increasing fresh grass intake on herb rich grassland, emission from animal manure on grassland increased, but emission from artificial fertilizer on grassland decreased more strongly based on nutrient requirements of herb rich grassland. In the low protein scenarios, emission from barn and manure storage reduced most. For the other emission categories, no change or only a slight decrease was seen.

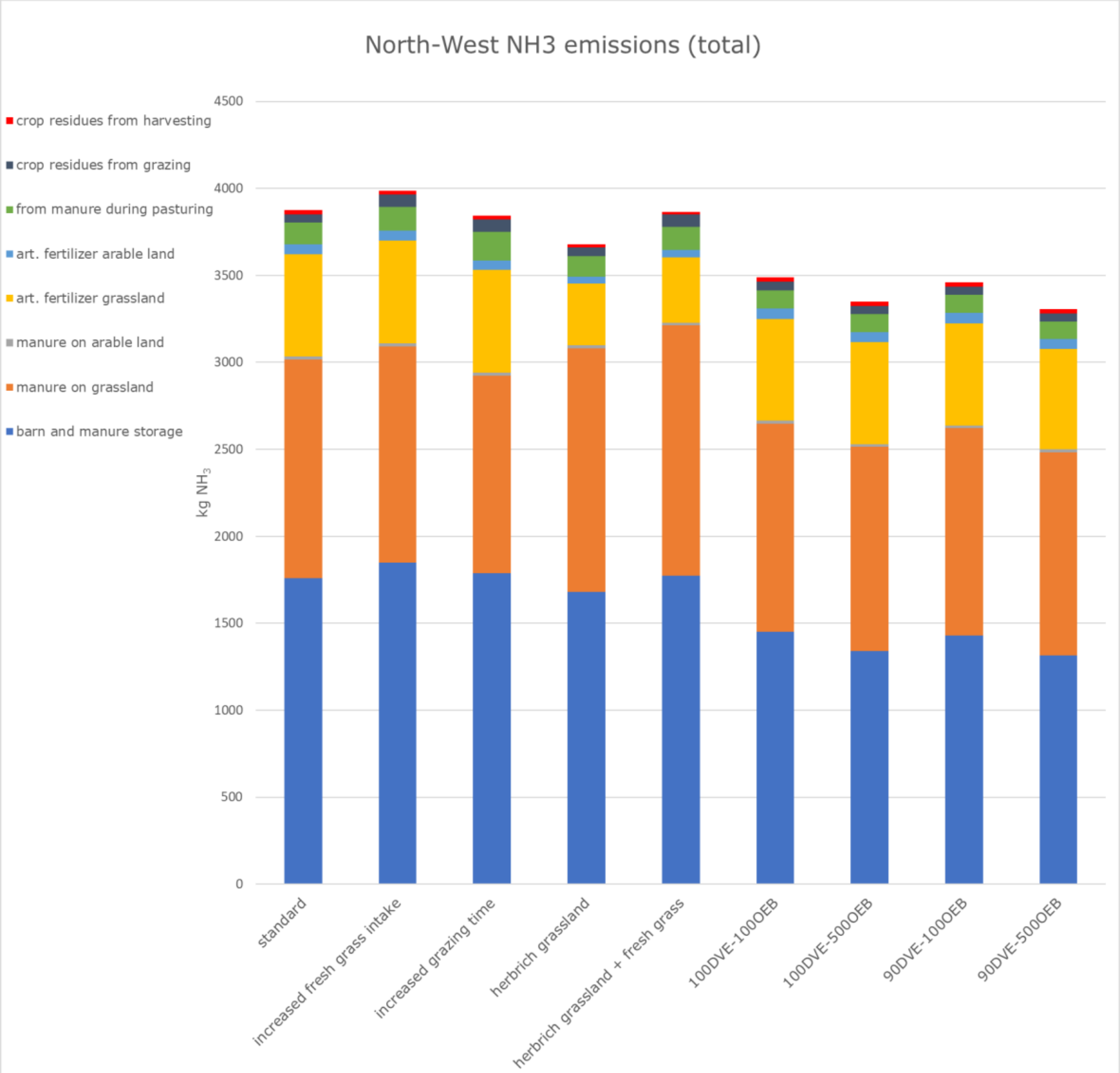

Figure 15 *Ammonia emission on farm level for all NW scenarios.*

Ammonia emission per hectare

When expressed per hectare, compared to the standard scenario the NH_3 emission was reduced in all NW scenarios except for the scenario with increased fresh grass intake, where emission from barn and manure storage increased. Increased grazing time resulted in a small reduction in NH_3 emission per hectare, but emission from barn and manure storage increased due to higher N excretion. The higher N excretion can be explained by higher protein levels in the fresh grass. In the other scenarios, emission from barn and manure storage decreased, which contributed most to the overall decrease in NH_3 emission per hectare. The results can be found in Table 16. The total N excretion and total ammonia N (TAN) production are shown in Table 17.

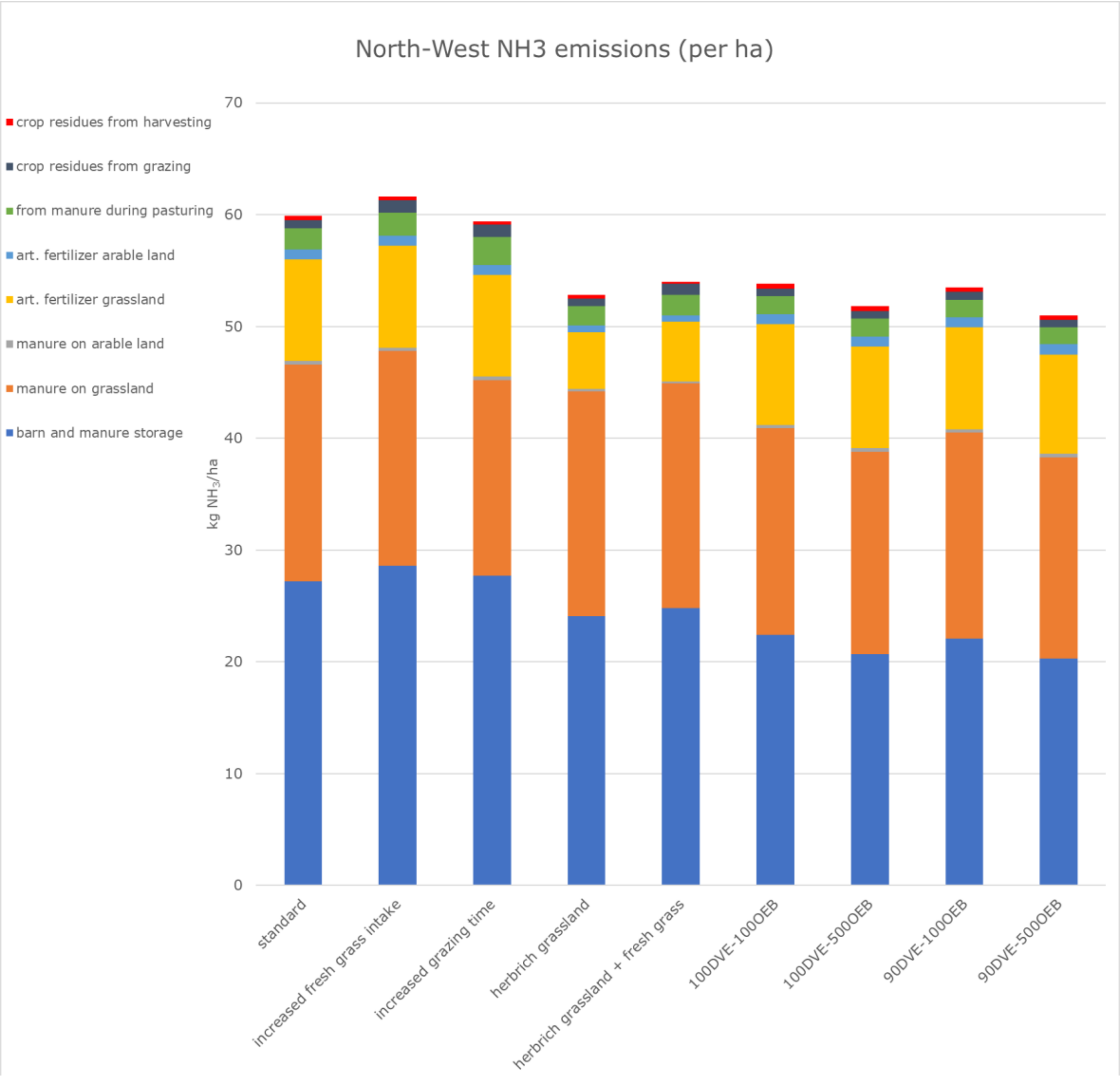

Figure 16 *Ammonia emission (kg) per hectare for all NW scenarios.*

Table 16 *Ammonia emission (kg) per hectare for all NW scenarios.*

Source of ammonia emission	**NW standard**	**NW increased fresh grass intake**	**NW increased grazing time**	**NW herb rich grassland**	**NW herb rich grassland + increased fresh grass intake**	**NW 100%DVE -100OEB**	**NW 100%DVE -500OEB**	**NW 90%DVE -100OEB**	**NW 90%DVE -500OEB**
Barn and manure storage	27.2	28.6	27.7	24.1	24.8	22.4	20.7	22.1	20.3
Manure on grassland	19.4	19.2	17.5	20.1	20.1	18.5	18.1	18.4	18
Manure on arable land	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3
Art. fertilizer grassland	9.1	9.1	9.1	5.1	5.3	9.0	9.1	9.1	8.9
Art. fertilizer arable land	0.9	0.9	0.9	0.6	0.6	0.9	0.9	0.9	0.9
From manure during pasturing	1.9	2.1	2.5	1.7	1.8	1.6	1.6	1.6	1.5
Crop residues from grazing	0.7	1.1	1.1	0.7	1	0.7	0.7	0.7	0.7
Crop residues from harvesting	0.4	0.3	0.3	0.3	0.2	0.4	0.4	0.4	0.4
Total NH_3 emission/ha	**59.9**	**61.6**	**59.4**	**52.8**	**54.2**	**53.9**	**51.7**	**53.5**	**51.1**

Table 17 *Total N excretion (kg) and total ammonia N (TAN) production (kg) for all NW scenarios.*

	NW standard	**NW increased fresh grass intake**	**NW increased grazing time**	**NW herb rich grassland**	**NW herbrich grassland + increased fresh grass intake**	**NW 100%DVE -100OEB**	**NW 100%DVE -500OEB**	**NW 90%DVE -100OEB**	**NW 90%DVE -500OEB**
N excretion on farm level (BEX) (kg)	17654	18359	18431	17155	17871	15777	15056	15647	14901
TAN production grazing animals (kg)	11866	12553	12515	11327	12024	9876	9174	9742	9015

3.2.4 Effect on NH_3 emission in SE scenarios

In Figure 17, the NH_3 emission on farm level is shown for all SE scenarios. Figure 18 shows the NH_3 emission per hectare for all SE scenarios. The emission per hectare can be found in Table 18 and 19.

Ammonia emission on farm level
On farm level in SE, increased fresh grass intake resulted in a higher total NH_3 emission, which was mainly due to higher emission from barn and manure storage based on higher nitrogen intake. When increasing the grazing time, emission from animal manure on grassland reduced most because of less manure application, but overall emission increased due to higher N excretion. On herb rich grassland (with and without increased fresh grass intake), NH_3 emission increased mainly from animal manure application on grassland and arable land. All low protein scenarios showed a reduction in NH_3 emission. The effect was mainly related to lower emission from barn and manure storage.

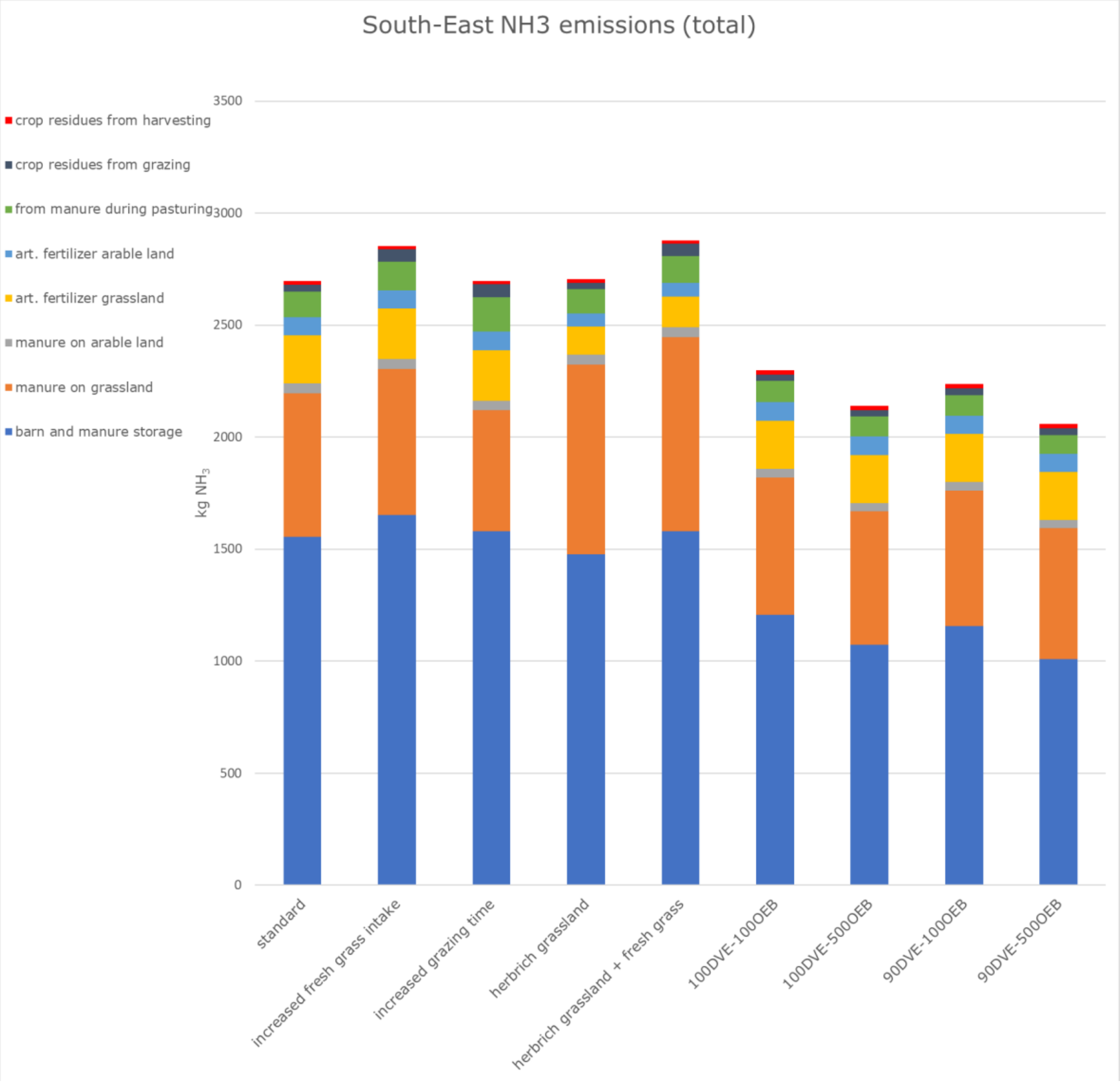

Figure 17 *Ammonia (kg/year/farm) emission on farm level for all SE scenarios.*

Ammonia emission per hectare
Figure 18 shows the NH_3 emission per hectare in the SE scenarios. A slight increase in NH_3 emission was seen when fresh grass intake was increased, due to increased emission from barn and manure storage, from manure during pasturing and from crop residues from grazing. In the other scenarios, NH_3 emission per hectare decreased. Increasing grazing time resulted in lower emission from manure on grassland. On herb rich grassland (with and without increased fresh grass intake), emission from barn and manure storage reduced. In the low protein scenarios, NH_3 emission per hectare reduced most. The effect was related to lower emissions from barn and manure storage. The results can be found in Table 18. The total N excretion and TAN production are shown in Table 19.

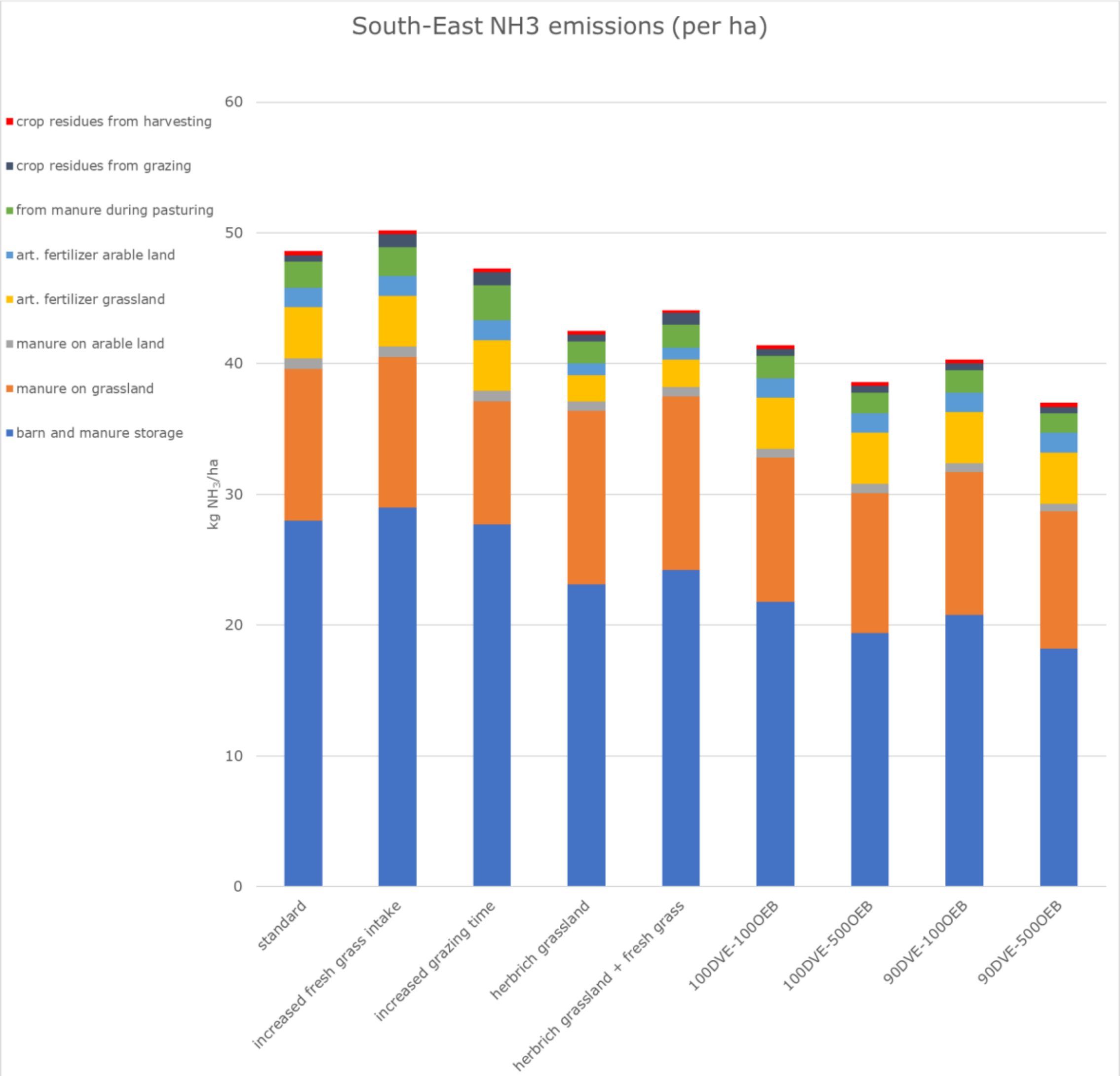

Figure 18 *Ammonia emission (kg) per hectare for all SE scenarios.*

Table 18 *Ammonia emission (kg) per hectare for all SE scenarios.*

Source of ammonia emission	**SE standard**	**SE increased fresh grass intake**	**SE increased grazing time**	**SE herb rich grassland**	**SE herb rich grassland + increased fresh grass intake**	**SE 100%DVE -100OEB**	**SE 100%DVE -500OEB**	**SE 90%DVE -100OEB**	**SE 90%DVE -500OEB**
Barn and manure storage	28	29	27.7	23.1	24.2	21.8	19.4	20.8	18.2
Manure on grassland	11.6	11.5	9.4	13.3	13.3	11	10.7	10.9	10.5
Manure on arable land	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6
Art. fertilizer grassland	3.9	3.9	3.9	2	2.1	3.9	3.9	3.9	3.9

Source of ammonia emission	SE standard	SE increased fresh grass intake	SE increased grazing time	SE herb rich grassland	SE herb rich grassland + increased fresh grass intake	SE 100%DVE -100OEB	SE 100%DVE -500OEB	SE 90%DVE -100OEB	SE 90%DVE -500OEB
Art. fertilizer arable land	1.5	1.5	1.5	0.9	0.9	1.5	1.5	1.5	1.5
From manure during pasturing	2	2.2	2.7	1.7	1.8	1.7	1.6	1.7	1.5
Crop residues from grazing	0.5	1	1	0.5	0.9	0.5	0.5	0.5	0.5
Crop residues from harvesting	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3
Total NH3 emission/ha	**48.6**	**50.2**	**47.3**	**42.4**	**44**	**41.4**	**38.6**	**40.3**	**37.1**

Table 19 *Total N excretion (kg) and total ammonia N (TAN) production (kg) for all SE scenarios.*

	SE standard	SE increased fresh grass intake	SE increased grazing time	SE herb rich grassland	SE herb rich grassland + increased fresh grass intake	SE 100%DVE -100OEB	SE 100%DVE -500OEB	SE 90%DVE-100OEB	SE 90%DVE -500OEB
N excretion on farm level (BEX) (kg)	16364	17068	17151	15825	16551	14280	13443	13965	13041
TAN production grazing animals (kg)	10574	11291	11244	10051	10790	8349	7507	8024	7092

4 Discussion

This is the first study that combined the DCM with ANCA. Combining the DCM with ANCA showed several advantages over using a single model such as the Farm Budget Program Cattle (BBPR). For this study, it was essential to simulate a variety of feeding strategies. With BBPR, it would not have been possible to simulate predefined dairy cow rations, as the DVE and OEB level cannot be adapted manually. Therefore, this model was not suited to simulate the low protein scenarios in this study. Combining DCM and ANCA, the two models enabled us to simulate our desired scenarios. The DCM can model the impact of different feeding strategies on production on herd level, while ANCA estimates the impact on GHG and NH_3 emissions on farm level. Thereby, it was used to predict the effects of different feeding strategies on farm level.

4.1 Dairy Cow Model

Calving effect
In the current study, total feed intake, milk yield and emissions were calculated for a herd with an evenly distributed calving pattern throughout the year. However, in situations with a seasonal calving the outcomes can be different. In an autumn calving herd, a larger proportion of the diet would have consisted of the barn ration, resulting in a lower N intake. In a spring calving herd the intake of N would have been higher due to a larger proportion of (protein rich) fresh grass as displayed in the figures of April and October calving cows.

Parity effect
In the simulations, the amount of concentrates per lactation was equal for all parities. Because the feed intake capacity increased with lactation number, the proportion of roughage in the TDMI also increased (higher forage to concentrate ratio). Therefore, with the same basal roughage rations the composition of concentrate had smaller impact on the composition of the total diet in older cows.

Dietary crude protein levels
The average dietary CP level for the standard scenario was 178 and 163g CP/kg DM for the NW and SE regions, respectively. This difference is the result of a higher use of grass products (silage and fresh grass) in the NW region. For the NW scenarios, protein levels were 148 g/kg DM at the lowest in the most extreme low protein scenarios with 90 % DVE and -500 OEB. It should be noted that this protein level may impact milk yield. In SE, lower dietary CP levels were seen: 163 g/kg DM for the standard scenario on average. In the SE scenarios with 90% DVE and -500 OEB, CP levels decreased to 127 g/kg DM. This is extremely low, and these modelled scenarios also did have a substantial drop in calculated milk yield.

Milk production
In reality, milk production is affected by CP levels (e.g. DVE and OEB) levels. The DCM estimates milk production based only on energy value. In this study, we also included the effect of CP level of the diet. However, it has to be mentioned that we made an experimental, maybe even pragmatic adjustment of FPCM curves in this study by adjusting for DVE balance based on Daniel et al. (2016, 2017, 2020) and adjusting for OEB based on the meta-analysis as shown in Appendix 1. The OEB adjustments were exploratory and more research is needed to quantify the actual effect of OEB level on milk production level. Therefore actual milk production may be different (lower or higher) as estimated in this study. The authors would like to address the importance of properly correcting for differences in CP (DVE and OEB) instead of only focusing on energy intake.

Results showed a decrease in milk production based on lower protein levels in the diet. When expressed in FPCM, this effect was larger in the SE scenarios. This is because of two reasons: firstly, the drop in DVE levels with the low protein scenarios was larger in SE than in NW and secondly, the OEB levels dropped equally for NW versus SE, however, in SE the effects of a lower overall OEB level were stronger because of the quadratic nature of the response in milk production with a decrease in OEB.

The difference in the drop in DVE levels happened despite similar formulation goals and was caused by the amount of maize silage in the diet. In low protein diets protein efficiency may increase due to less overfeeding or as a result of enhanced N recycling (Russell et al., 1992). This means decreasing protein levels could be a promising strategy for NH_3 emission mitigation.

4.2 ANCA

In this study, several scenarios were analysed. In every scenario, several assumptions were made and, consequently, several input parameters changed. For example, feed composition, feed intake, N intake, but also the amount of hectares on the farm, and milk production differed for each scenario. In every scenario we applied, the total N that is legally allowed. However, due to different rations in every scenario, the total TAN per kg N was different in every scenario, which affected total NH_3 emissions. This should be considered when comparing the different scenarios.

Basic scenario
The SE basic scenario showed higher levels of GHG emissions compared to the NW basic scenario, which can be explained by the higher levels of high protein concentrates (and their off farm emissions) that were fed in the SE region.

Increased fresh grass intake
In this scenario, fresh grass intake was increased with only a small increase in actual grazing time. The TAN excretion from manure increased due to higher N intake from feed. It was assumed that increased fresh grass intake was mainly achieved by grazing management. A limited impact on GHG emission could be observed. In this scenario there was a shift from grass silage to fresh grass, with no change in the absolute amounts of maize silage and concentrates. The TDMI was increased with 0.5 kg. Enteric CH_4 emission from fresh grass was lower than from silage and therefore total enteric CH_4 emissions decreased per kg DM intake. However, with the increase in TDMI of approximately 0.5 kg DM, total CH_4 emission increased. Greenhouse gas emissions from barn and manure storage had a minor decrease. Methane emissions from storage decreased, but N_2O emissions increased due to a higher amount of TAN excreted in housing (results not shown in this report). In this model calculation the CP amount of the feed in combination with extra grazing was not adapted, which in practice would be common to do. But this indeed shows that it is important to manage total ration CP level when increasing intake from fresh grass.
More TAN was emitted on grassland from grazing. This resulted in a higher N_2O emissions. In total, there was a small decrease of GHG emissions for NW and SE. Ammonia emission in NW and SE increased in this scenario, because N intake was higher and therefore a higher N and TAN excretion. This resulted in higher NH_3 emissions from barn and storage. Emissions from roughage production were reduced because of lower emissions from application of animal manure. However, because more animal manure was excreted during grazing, NH_3 emission from grazing increased. In this scenario, where more fresh grass was consumed, but grazing time not substantially increased, total NH_3 emissions actually increased.
Based on new insights about the enteric CH_4 emissions in relation to fresh grass by Koning et al. (2022) an EF of 17.22 g CH_4/kg DM was used in the calculations. This EF is based on two years of grazing experiments with fulltime grazing. In the ANCA, the EF used in practice is 19.2 g CH_4/kg DM. Therefore, the increased use of fresh grass in our calculations reduced the enteric CH_4 emissions stronger than in the current ANCA. In the coming years, follow-up research will be done to analyse whether the EF in the ANCA needs adjustment.
It is important to realize that in this scenario the main change in the diet was caused by a different share of grass silage and fresh grass. Other components of the diet did not change. With the higher CP content in fresh grass, this led to a higher total CP intake. This led to almost equal carbon footprint and higher NH_3 emissions. In practice, when increasing fresh grass intake it is important to manage the CP content of the diet, preferably to the same level as without grazing. The CP content can be managed by changing the diet or the CP concentration of the other components such as concentrates, grass silage and maize silage. In that case, the benefits of fresh grass, such as a lower CH_4 emission, can be better utilized.

Increased grazing time
In this scenario, fresh grass intake was increased with a substantial increase in grazing time. Total GHG emissions were similar to the emissions in the increased fresh grass intake scenario.

Feed intake was the same but only grazing time was different. This resulted in a decrease of emissions from barn and manure storage but an increase in emissions from feed production. The increase from feed production is caused by an increase in N_2O emissions (results not shown in this report) from the increased N excretion in the form of manure applied on the field.

Ammonia emissions had a small reduction (NW) or similar impact (SE) compared to the basic scenario, and a reduction (>4%) compared to the increased fresh grass intake scenario. Ammonia emissions from barn and manure storage had a small increase compared to the basic scenario but decreased compared to the increased fresh grass intake scenario. Although TAN excretion in the storage was a bit lower compared to the basic scenario, emissions from the storage were higher. The NH_3 emissions from the manure storage in ANCA, however, are calculated with total TAN and NH_3 emissions factor. The ANCA tool is based on NEMA, meaning the emission factor for NH_3/kg TAN from barn and storage depends on the amount of days and hours spent grazing outside. With increased grazing time, TAN excretion in the barn was lower but the emission factor for NH_3/kg TAN increased because the surface in the barn from which N can volatize remained the same resulting in higher volatilization per kg TAN. Therefore, with only a minor decrease of TAN excretion in the barn and storage due to increased grazing time, the impact on NH_3 emission from barn and manure storage was also minor. Extra management factors can further reduce NH_3 emissions from storage and barn, such as reduction of floor space, or floor cleaning. On farm level, a minor decrease in NH_3 emission could be seen due to lower emissions from manure on grassland.

An important assumption in this scenario was the amount of grazing hours and the difference in hours between the NW and SE scenarios (NW: 2021 kg DM fresh grass intake in 2455 hours; SE: 1466 kg DM fresh grass in 2620 hours). As the difference in hours between the NW and SE scenarios was quite big, this was one of the weaker assumptions of this scenario.

A fair comparison could be made between the scenarios with increased fresh grass intake and the scenario with increased grazing time, since the N excretion was the same. Also, for this scenario, as for the increased fresh grass intake scenario, the diet composition did not change relative to the standard scenario. So also in this case greater benefits from grazing should be possible when the total ration is managed in such a way that the CP level of the diet does not increase.

Herb rich grassland

In this scenario, herb rich forages were fed to youngstock and dry cows. In this study, 20% of herb rich grass from nature conservation areas was included, corresponding with key performance indicators from Friesland Campina (Van Doorn et al., 2019). At this moment, the relation between feeding of herb rich grass and CH_4 emission is still being researched. In our simulations, the EF for herb rich grass was therefore similar to the EF of fresh grass. Total GHG emissions of NW and SE had a small change (<1%), with especially an increase in NW for enteric CH_4 emissions. Emissions from barn and manure storage and external input decreased, the latter mainly due to lower use of artificial fertilizer.

The results of the inventory of the composition of herb rich grasses is shown in Appendix 2. As one would expect the CP level decreased and the NDF level increased with more biodiverse grass silage from land with low fertilization levels.

For NH_3 emissions, total emissions in NW decreased, and in SE remained similar. For both scenarios NH_3 emissions from barn and manure storage decreased. TAN excretion was lower, mainly due to lower N excretion of youngstock older than one year. However, total NH_3 emissions from application of animal manure for maize and grass production were higher. In this scenario, more animal manure was applied per hectare of grass and maize, because no animal manure was applied on herb rich grassland. This resulted in higher NH_3 emissions from animal manure. However, due to higher application of N from animal manure on grass and maize land, a lower amount of artificial fertilizer was applied on grass and maize land and no artificial fertilizer was applied on herb rich grassland. This resulted in a high reduction of NH_3 emissions from artificial fertilizer. Moreover, in the herb rich grassland scenario, farm size was much bigger than in the basic scenario to fulfil the roughage production. Thus, farmers need more land, less cows, or lower milk production in order to produce sufficient roughage.

Therefore, expressing NH_3 emissions per hectare, including hectares of herb rich grassland, showed a high reduction in NH_3 emissions for NW and SE.

Herb rich grassland with increased fresh grass intake
This scenario showed similar results as the scenario increased fresh grass intake. Therefore, expressing NH_3 emission per hectare showed an increase compared to the herb rich grassland scenario but a decrease compared to the reference scenario.

Low protein scenarios
The low protein rations were achieved by changing the compound feed portion of the diet. For each low protein scenario a new low protein compound feed was formulated. One new high protein compound feed was formulated which was used for all scenarios. For both NW and SE the low protein scenarios reduced the CP level of the total diet.
For NW the reduction in CP level of the diet was from 178 g CP/kg DM in the basic scenario to 159-148 g CP/kg DM in the low protein scenarios. The average OEB was still above 0 g OEB/day, however, from the Figure 7 and 8 (and 19 to 22), it was clear that for the -500 OEB scenarios the OEB level during early lactation was substantially below 0 g OEB/day. This may have consequences for milk production by a lower organic matter digestion in the rumen giving the cow less energy, and by of a lower microbial protein synthesis giving the cow less DVE. Intestine-degradable protein values were not corrected for the lower OEB in the diets.
For the SE scenarios the reduction in CP level of the diet was from 150 g CP/kg DM to 141-127 g CP/kg DM. In the -500 OEB scenarios the average OEB did not remain above 0 g OEB/d anymore and from the OEB figures in the appendix it is clear that also the -100 OEB scenarios did not always remain above 0 g OEB/d in early lactation (Figure 29 to 34).
The CP levels of the rations have clearly been reduced. Using only one low protein concentrate and one high protein diet per scenario, as done in these simulations, is not ideal to optimize the CP level and OEB level during lactation. An approach where more than two concentrates are used per scenario might give more flexibility in lowering total CP of the diet, while remaining around or slightly above 0 g OEB/d in a diet. This would mean that during lactation one would switch between scenarios as given in the figures (Figure 7 and 8, 19 to 22 and 29 to 34).
Although scenarios might be further optimized, these scenario calculations showed that average CP levels in the rations can be reduced relative to the basic scenarios.

Regardless of differences in milk production levels, all low protein scenarios had a lower GHG emission; both on farm level and per FPCM. This effect was mostly related to lower emissions from inputs. These lower emissions from input were caused by lower levels of especially soybean meal. The GHG emission of soybean meal was substantially higher and more variable (2990-4469 g CO_2-equivalents per kg) than most other concentrate ingredients (e.g. beet pulp at 477 g and corn at 567 g CO_2-equivalents per kg). A large part of this high footprint was caused by land use and land use change, depending on the land of origin. In this model we corrected for land use change based on the carbon footprint values from Nevedi, however recently these EF have been reduced in the latest ANCA version (2023). These recent changes will reduce the difference in CO_2-footprint between basic and low protein scenarios compared to what we found in the current study.

In the low protein scenarios, a trade-off was seen: although the overall GHG emission decreased, emission from rumen fermentation increased. The emission from rumen fermentation increased by 9.2% in the most extreme low protein scenario (90% DVE -500 OEB), assuming the EF of the feed ingredients remained the same at lower OEB levels. The increase in rumen fermentation was mainly caused by the composition of the concentrates. The low protein concentrates in the low protein scenarios contained higher levels of beet pulp than the low protein concentrate in the basic scenario. Beet pulp is a fermentable fibre source with a relatively high EF for enteric CH_4 production (Table 2; EF beet pulp varying from 25.8-28.3 g CH_4/kg). An alternative ingredient with a low EF for CH_4 would have been maize (EF 21.2-17.8 g CH_4/kg), however including high levels of corn in the diet may not be desirable as starch levels in the feed may increase to levels causing ruminal or large intestinal overfermentation. Additionally, corn is potentially a human consumable ingredient, whereas beet pulp is a co-product from sugar production and is not human consumable.

In all scenarios with low protein levels, the NH_3 emission decreased. A decrease in dietary protein leads to a decrease in TAN, resulting in an overall decrease in NH_3 emission.

According to the ANCA output, this effect was mostly related to lower emission from barn and manure storage. Moreover, in NW not enough N was excreted to fulfil the allowed N from animal manure. With the expected loss of derogation, reduced excretion of N can also result in reduced removal of manure from the farm and reduced related costs of removal of animal manure.

The different scenarios also showed that there will be trade-offs. One important trade-off is that while the NH_3 emission decreased in the low-protein scenarios, milk production is affected. Also, there was a decrease in GHG emissions for the low protein scenarios, mainly achieved by lower land use emissions. However, CH_4 emission increased. This study focused on GHG and NH_3 emissions, while the impact of different feeding strategies on other environmental issues such as land use, biodiversity or on economic and animal welfare should also be considered to prevent trade-offs.

5 Conclusion

In this study, scenarios for integral sustainable diet formulation and feeding concepts were identified and evaluated in relation to animal nutrition practices. The DCM was connected to the ANCA model. Combining these two models showed several advantages. The DCM model can model the impact of different feeding strategies on production on animal level, while ANCA estimates the impact on GHG and NH_3 emissions on farm level. Three relevant areas of interest, when it comes to future developments in the dairy sector, were evaluated by using this method. Low protein rations, increased grazing and biodiverse grassland formed the basis for our scenarios to calculate the potential mitigating effect on GHG and NH_3 emission. Regional differences were accounted for by defining specific scenarios for the NW and SE regions.

This study analysed different feeding strategies by using two models. Some strategies may be easier to apply in practice than others. Results showed that each different feeding strategy can reduce NH_3 emissions while having a minimal effect on GHG emissions. Regardless of differences in milk production levels, the standard scenario, scenario with increased fresh grass intake, increased grazing time and herb rich grassland had similar GHG emissions in terms of CO_2 equivalents per kg FPCM for both NW and SE. Regardless of differences in milk production levels, all low protein scenarios showed a lower GHG; both on farm level and per kg of FPCM. This effect was mostly related to lower emissions from inputs. These lower emissions from input can be related to lower levels of especially protein rich soybean meal with a high carbon footprint. A large part of this high footprint is caused by land use and land use change in the production of soybean meal; depending on its origin. The NW basic scenario showed lower GHG emission compared to the SE basic scenario, which can also be explained by the lower levels of high protein concentrates in the NW region.

Low protein scenarios showed there is a high potential to reduce NH_3 emissions. Total GHG emissions decreased as well, mainly due to a reduction in emissions from LUC. However, enteric CH_4 emissions increased due to different ingredients in concentrates. The emission from rumen fermentation increased by 9.2% in the most extreme low protein scenario (90% DVE -500 OEB). The low protein concentrates in the low protein scenarios contained higher levels of beet pulp than the low protein concentrate in the basic scenario. Beet pulp is a fermentable fibre source with a relatively high EF for enteric CH_4 production. An alternative ingredient with a low EF for CH_4 would be corn, however, corn is potentially a human consumable ingredient, whereas beet pulp is a co-product from sugar production and is not human consumable.

When expressed per hectare, the NH_3 emission reduced in all scenarios except for the scenario with increased fresh grass intake, where mainly emission from barn and manure storage was increased. Increased grazing time resulted in a small reduction in NH_3 emission per hectare, but in the NW region, emission from barn and manure storage increased. In the other scenarios, emission from barn and manure storage decreased, which contributed most to the overall decrease in NH_3 emission per hectare. In the low protein scenarios, NH_3 emission per hectare reduced most. This means decreasing protein levels could be a promising strategy for NH_3 emission mitigation. In all scenarios with low protein levels, the NH_3 emission decreased. A decrease in dietary protein leads to a decrease in TAN, resulting in an overall decrease in NH_3 emission. According to the ANCA output, this effect was mostly related to lower emission from barn and manure storage.

The SE region showed lower protein levels in the basal rations compared to the NW region based on the CBS data used. On average, OEB levels were positive, even in the scenarios with the lowest protein levels. This was due to higher protein intake from roughages. The CP levels of the rations have clearly been reduced, however ideally one would keep the OEB level around 0 OEB g/day during the whole lactation period. The current way of using only one low protein concentrate and one high protein diet per scenario is not ideal to optimize the CP level and OEB level during lactation. An approach where more than two concentrates are used per scenario might give more flexibility in lowering total CP of the diet, while remaining around or slightly above 0 g OEB/day in a diet. Although scenarios might be further optimized, these scenario calculations do show that average CP levels in the rations can be reduced relative to the basic scenarios.

Increased fresh grass intake and increased grazing time had a limited impact on NH_3 emissions and GHG emissions compared to the basic scenario. With increased grazing time, TAN excretion in the barn is lower but the EF for NH_3/kg TAN increases because the surface from which N can volatize does not change. Therefore, the impact on total emission from barn and manure storage is minor. In practice extra management factors would need to be taken, such as reduction of floor space, or floor cleaning, to reduce emissions for the barn. In addition, it is very important to manage the CP content of the diet when increasing fresh grass intake in the diet. The CP content of the diet should preferably be at the same level as without grazing. The CP can be managed by changing the ratio in the diet or the CP concentration of the other components such as concentrates, grass silage and maize silage. In that case the benefits of fresh grass, such as a lower CH_4 emission, can be utilized.

Herb rich grassland resulted in a minor reduction of GHG emissions. Total NH_3 emissions decreased (NW) or increased (SE). However, in this scenario more land was required and therefore expressing NH_3 emissions per hectare showed a high reduction.

Although different scenarios showed the potential to reduce NH_3 emissions, this study also showed that there will be trade-offs. One important trade-off is that the NH_3 emission decreased in the low-protein scenarios, at the cost of milk production. Also, there was a decrease in GHG emissions for the lower protein scenarios, mainly achieved by lower land use emissions. However, CH_4 emission increased. In this study the focus was on GHG and NH_3 emissions. However, the impact of different feeding strategies on other environmental issues such as land use, biodiversity or on economic and animal welfare should also be considered to prevent trade-offs.

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Appendix 1 Quantitative meta-analysis on the effects of manipulating OEB by changing protein degradability on fat and protein corrected milk in Holstein dairy cows

Introduction

In dairy cows, inefficiency of N utilization is largely due to the losses of N in urine and faeces (Van Soest, 1994, Castillo et al., 2001). Losses of N in urine are mainly caused by an oversupply of crude protein and/or an (im)balance in the supply of amino acids. When energy from fermentable carbohydrate is supplied in sufficient quantities in the rumen, enteric microorganisms can capture nitrogen (N) sources such as amino acids, peptides, or ammonia and convert them to microbial protein (MP) (Nocek and Russell, 1988). If, however, the available carbohydrate sources are insufficient, ammonia may accumulate in the rumen and be absorbed into the blood and excreted in urine, resulting in inefficient utilization of nitrogen. Improving the balance between microbial protein synthesis potentially possible from rumen degradable and fermentable organic matter has been proposed to maximize the capture of rumen degradable protein and to optimize microbial growth rate and efficiency (Nocek and Russell, 1988, Hoover and Stokes, 1991, Chanjula et al., 2004). In the Dutch protein evaluation system, the OEB value shows the (im)balance between microbial protein synthesis potentially possible from available rumen degradable CP and that potentially possible from the energy extracted during anaerobic fermentation in the rumen. When positive, the OEB-value gives the loss of N from the rumen and when OEB is negative, microbial protein synthesis may be impaired, because of a shortage of N in the rumen. The optimum OEB-value in a ration is therefore zero or slightly above. While the balance (OEB) may be a theoretical sound principle, animal performance is the critical standard to justify the use of OEB in composing rations for cattle. In theory, synchronization of rumen energy and protein is required for optimal microbial protein synthesis (MPS), but experimental results have been conflicting regarding the effect of synchronization on milk production and N-efficiency (Casper and Schingoethe, 1986, Casper and Schingoethe, 1989, Casper et al., 1990, Cameron et al., 1991, Kolver et al., 1998, Chanjula et al., 2004, Cabrita et al., 2006, Charbonneau et al., 2007, Qiao et al., 2018, Mirzaei-Alamouti et al., 2020, Rauch et al., 2021). In essence, changing the OEB is possible by changing the ratio of rumen fermentable organic matter (FOM) to rumen fermentable dietary protein (Tamminga et al., 1994, Van Duinkerken et al., 2011). Reducing dietary crude protein (CP) intake is the main strategy for NH_3 losses (Sajeev et al., 2018) and changing OEB by changing the rumen degradability of dietary CP is of interest because in low protein rations the amount of available nitrogen in the rumen can be limiting (Batista et al., 2017). However, it is not clear how the milk production is affected by a changing OEB in the ration.

To our knowledge, no previous comprehensive meta-analysis investigated the effect of changing OEB on milk production in dairy cows and this prompted us to carry out a meta-analysis on experimental data with respect to the effect of OEB on milk production.

Material and Methods

Database

A literature study was carried out on available peer-reviewed published studies in scientific journals using search terms “protein degradability”, “RDP”, “rumen” “cattle or cows” and in combination with names of common protein-rich feedstuff (soybean meal, canola meal, etc.). Our literature search used PubMed (http://www.ncbi.nlm.nih.gov/pubmed), Google Scholar (http://scholar.google.com), ScienceDirect, ISI Web of Science, (http://apps.webofknowledge.com), and CABI (http://www.cabi.org) databases. only peer-reviewed papers on dairy cows written in English and published in scientific literature were considered. Only studies that have been designed to investigate the protein degradability and studies that had variation in enteric protein degradability caused by changing protein-rich feedstuff were included in the dataset. Thus regarding nutrients, the OEB (or actually the rumen degradable protein) was variable whereas DVE (The rumen undegradable part) was kept constant as much as possible.

The papers to be included in the dataset must have a clear description of materials and methods and animals, including milk production, milk composition, dry matter intake (DMI), body weight (BW), and details of diet composition. If a study had an unusual feed ingredient (i.e., commercial products with no nutritional details), the treatment or study was not included in the dataset. The final dataset had 206 observations from 56 studies. While more data exists in the literature than the database generated here, we included as many as possible in the limited time available for this exercise. When a description of the diet was available, but a comprehensive chemical composition was missing, missing values were replaced with values from (CVB, 2011). In order to standardize the milk yield for the composition, milk production (kg/d) was corrected for fat and protein content (FPCM) using the formula from CVB (2022):

$$\text{FPCM (kg)} = \text{milk (kg)} \times [0.337 + 0.116 \times \text{fat content (\%)} + 0.06 \times \text{protein content (\%)}]$$

In Table 1 a summary of the dataset is given for the different parameters.

***Table 1** Average values of the different parameter in the dataset.*

Animal characteristics per cow.	Average	Std	Min	Max
Body Weight (kg)	638	48.4	543	772
DMI (kg/d)	23.2	3.52	9.8	31.8
Milk (kg/d)	35.7	6.83	12.1	58.7
Milk Fat (%)	3.56	0.470	2.65	5.24
Milk Protein (%)	3.10	0.243	2.38	4.40
Milk Lactose (%)	4.79	0.430	3.01	8.87
FPCM (kg/d)	33.3	6.03	11.5	53.5
Dietary characteristics of total ration				
	Average	Std	Min	Max
Concentrate (% in DM)	48.7	8.21	31.9	70.0
OM (g/kg DM)	920.4	18.07	766.2	948.9
FOM (g/kg DM)	508.5	33.92	352.0	607.3
CP (g/kg DM)	169.7	20.11	124.1	292.9
RDP$_{2007}$ (g/kg DM)	87.5	19.26	36.0	147.3
OEB$_{2007}$ (g/kg DM)	8.7	17.86	-29.5	68.8
DVE$_{2007}$ (g/kg DM)	90.7	15.51	56.6	137.0
NDF (g/kg DM)	317.0	51.87	166.9	480.2
VEM$_{CVB}$ (g/kg DM)	949.0	53.35	727.6	1144.0

DMI: Dry Matter Intake; FPCM: Fat and Protein Corrected Milk; OM: Organic Matter; FOM : Fermentable Organic Matter; CP: Crude protein; RDP: Rumen Degradable Protein; OEB: Rumen Protein Balance (Onbestendig Eiwit Balans); DVE: Metabolisable protein / small intestinal digestible protein (Darm Verteerbaar Eiwit); NDF: Neutral Detergent Fibre; VEM: Net energy for Lactation (Voeder Eenheid Melk).

Statistical analysis

Predictors (OEB (g/kg DM) and OEB intake (OEBI; kg/d)) were inspected for multicollinearity for the response analysed (FPCM) using collinearity analysis (Collin) in the REG procedure of SAS (SAS/STAT, SAS Institute Inc.) and inspecting condition index, tolerance, and variance inflation factor (VIF). There was no indication of multicollinearity based on condition index less than 20 and VIF smaller than 2.0 in all final multivariable models as previously described. The relationship between FPCM and each of predictors (OEB and OEBI) was investigated by an exponential FPCM=a+b×(1-exp(-c×OEB(I)) using procs GLIMMIX and NLMIX of SAS. In this report only the results of exponential function will be discussed. For evaluating the models, the goodness of fit of the predicted FPCM, was compared to observed values using two methods as described by Ellis et al. (2010). The first method was calculating the mean square prediction error (MSPE) as follows:

$$\sum_{i=1}^{n}(O_i - P_i)^2 \,/\, n$$

Where n is the total number of observations, O_i is the observed FPCM, and P_i is the predicted FPCM. The square root of the MSPE (RMSPE), expressed as a percentage of the observed mean, gives an estimate of the overall relative prediction error. The second method consisted of calculating the concordance correlation coefficients (CCC) according to Lawrence and Lin (1989)**.** The evaluation was done while accounting for a random study effect. If the study involved a secondary level treatment the random effect was set at the level of the secondary treatment.

Results

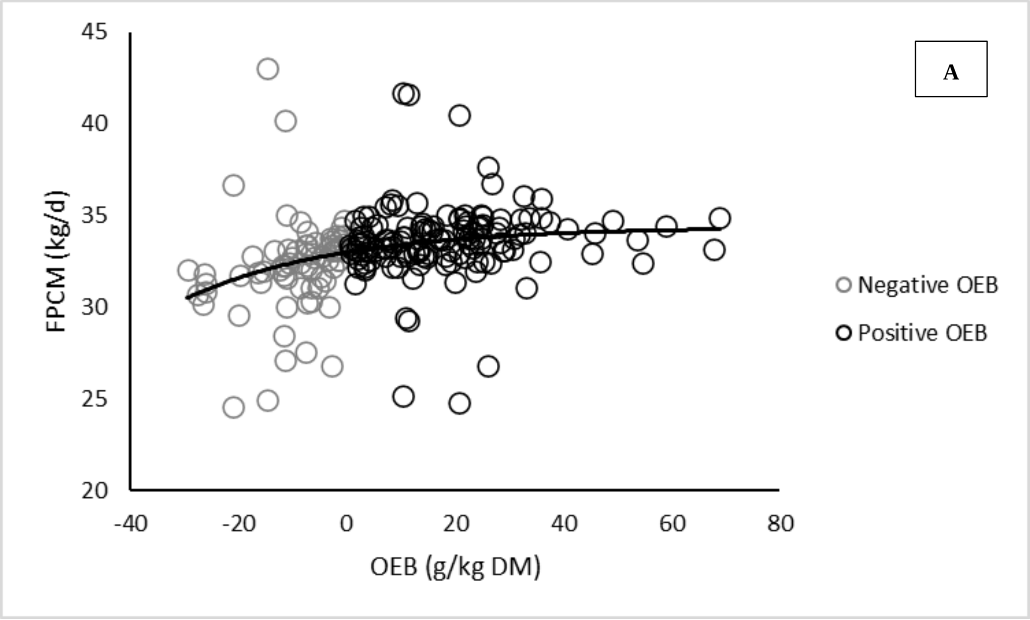
A description of the dietary and animal factors collected and used in the current meta-analysis such as feed intake, BW, milk production, and chemical composition of rations are shown in Table 1. The number of observations per treatment was on average 3.7. Generally, both the animal and feed data covered ranges encompassing the most typical dairy cattle rations.

Table 2 *Parameter estimates (+/- se) and overall model performance for models predicting FPCM (kg/d) using OEB (g/kg DM) or OEB intake (kg/d) as predictors.*

Model	Parameter	Estimate	SE	AIC	RMSPE	R^2	CCC
OEB (g/kg DM)	a	33.01	0.900	1164.9	6.82	0.88	0.93
	b	1.376	1.4581				
	c	0.0350	0.03115				
OEBI (kg/d)	a	32.84	0.894	1162.4	6.81	0.88	0.93
	b	4.156	6.3648				
	c	0.0005	0.00082				

Parameter estimates (+/- se) and overall model performance for models predicting FPCM (kg/d) using OEB (g/kg DM) or OEB intake (kg/d) as predictors are presented in table 2. Predicting FPCM based on both OEB and OEBI resulted in almost the same intercepts and dynamics with similar performance parameters. Both models predicted that FPCM will increase with an increase in OEB with a higher effect for low (negative) OEB values and a lower effect for higher OEB values. This is graphically represented in Figure 1.

In the DVE system, the OEB value is recommended not to become negative to avoid the risk of a shortage of N for the microbes in the rumen. When wanting to keep the OEB positive then the exact level of OEB at which minimal losses of N from the rumen emerge has theoretically been established at zero. Of course going lower than 0 in OEB will reduce N losses further. However it is not known till what level rumen functioning decreases to the point where (relative) N losses increase again. Our results show that negative OEB values result in a noticeable reduction in FPCM, and that the benefit of increasing OEB to avoid potential shortage of Nitrogen in rumen and support milk yield seems to be marginal (Fig 1).



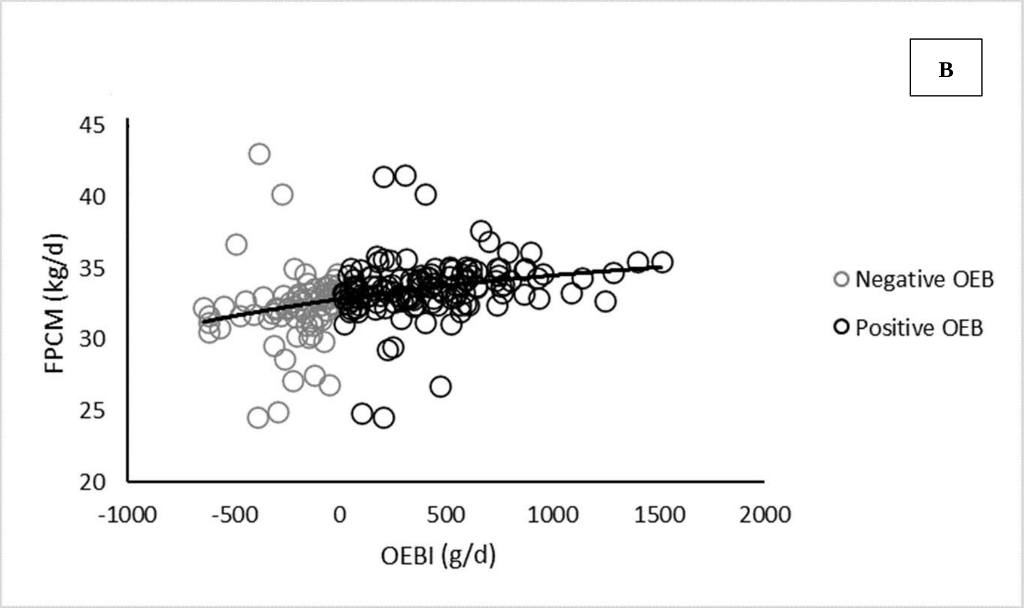


Fig 1- *Predicted FPCM (kg/d) in response to changing OEB (a) or OEBI (b).*

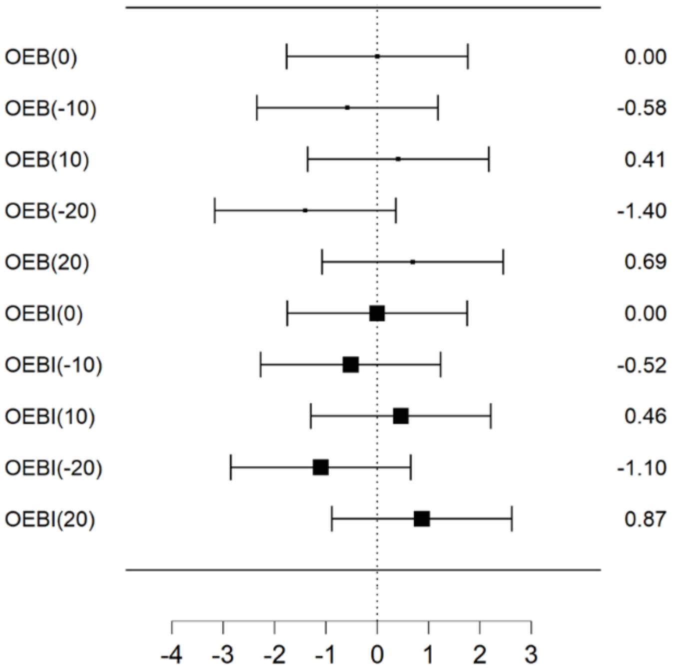


Fig 2- predicted effect of changing OEB concentration (in g/kg DM total ration basis, top 5 bars) and OEB intake (g/day, bottom 5 bars) between -20 and +20 (either g/kg DM, or g/day) on FPCM (kg/d) based on the models as described in table 2.

The nature of the response of FPCM to OEB level is curvilinear. Based on the OEB model, increasing the OEB from -10 to 0 (g/kg DM) would increase FPCM with 0.58 kg/d while increasing OEB from 0 to +10 will result in a further, but lower increase of 0.41 kg/d FPCM. Increasing OEB further than that does not lead to large increases in FPCM. The response in FPCM flattens out at about 25 g OEB/kg DM. The curvilinear response is very visible if we use the steps -20 to 0 and 0 to +20 g OEB /kg DM. In that case the response below 0 OEB is almost twice as big then when OEB is increase from 0 to +20 g/kg DM (1.4 kg increase in FPCM vs. 0.69 kg/d increase). The predicted shift in FPCM by changing OEBI follows the same trend but the difference between outcomes with negative and positive OEBI are smaller. Reports from experiments that studied the effect of changing OEB on milk production are scarce. In agreement with our results, (Geerts et al., 2004) reported that increasing the OEBI from 143 g/d to 398 g/d did not improve FPCM but increased rumen NH_3 from around 20 to 24 mmol/l, and milk urea concentration from 25 to 33 (mg/dl) in rations with the same DVE and VEM. In a recent study, (Kand and Dickhoefer, 2021) reported that negative OEBI of ~ - 406 g/d (OEB of −20 g/kg DM) as recalculated from the German feed evaluation system reduced performance of high-yielding dairy cows by 1.2 tot 2.2 kg/d compared to OEB of zero. They suggested that these effects may be more pronounced in rations containing rapidly degradable protein sources. In contrast (Aschemann et al., 2012) reported that increasing OEBI from ~-450 g/d to zero had no impact on milk yield. Similarly, (Agle et al., 2010) reported that cows that received rations with OEBI of 162, −326, and −636 g/d did not differ in milk yield and composition which is in contrast with our results. Latter results are surprising as milk production is expected to be lower below 0 OEB.

Conclusion

The small scale meta-analysis shows that OEB levels in the diet influence milk yield via a curvilinear relationship. Increasing OEB generally increases milk yield up to a level of around 20-25 g OEB/kg dry matter intake. These results have been used in the calculations for milk yield in this report. This has been done by using the equations as presented based on OEB as g/kg DM total ration to calculate a potential change in milk yield for the diets formulated.

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Appendix 2 Dutch data on nutritional value of biodiverse forages

Background

Biodiversity is becoming increasingly important and is gaining interest from cattle farmers. Grasslands with pluriform cultivars, herb rich grasslands, and flowery field borders are becoming a more common basis for cattle rations. In this study, scenarios for integral sustainable diet formulation and feeding concepts were identified and evaluated. In one of the scenarios, the effect of decreased protein levels (100% DVE, 0 OEB) for the NW and SE scenarios is calculated by using low fertilized biodiverse forages for the youngstock and dry cows.

Biodiverse grasslands can be divided in agro-biodiverse grasslands and semi-natural grasslands. Agro-biodiverse grasslands are agricultural grasslands consisting of a mixture of grass and herb species. This type of grassland is primarily intended for agricultural production. Semi-natural grasslands play an important role in nature conservation. It concerns lowly fertilized or non-fertilized grassland with a relatively low yield (<5 000 kg DM/ha/year), which is not primarily intended for livestock farming or agricultural production. These grasslands are managed by mowing, by disposing biomass and by grazing.

Biodiverse grasslands do not only provide primary production, but also serve other ecosystem services such as biodiversity, carbon sequestration, climate adaptation, underground nitrogen fixation, cow health and reduction of emissions. The level of primary production and of other secondary functions depends on the land use intensity (Kleijn et al. 2009).

Scenarios for biodiverse forages include a range in different land use intensities. The main impact on the dairy cow diet will include a different nutrient composition of herb rich grasses. In addition, grass yield may be reduced which has implications for the on-farm land use and feed purchases.

The current model that is used to calculate the scenarios at cow level (Koemodel) needs input on the nutritional value of biodiverse grassland so that the consequences for the calculations at cow and farm level can be estimated. This appendix focuses on collecting the available information regarding the chemical and nutritional properties of biodiverse forages for determining the nutritional value (e.g. Energy (VEM), intestinal digestible protein (DVE) and rumen protein balance (OEB) of these forages for use in the cow model.

Method

To calculate the scenarios using biodiverse forages, Data from three Dutch studies ((Bruinenberg 2003, Duinkerken 2005, Remmelink 2000) were used. These studies were selected because they contained results from fields that resemble semi-natural grasslands with low fertilization levels. From these studies the data of biodiverse grass silage were selected and averaged.

Results

Table 1 *Nutritional value of herb rich grass silage that was used in the scenario biodiverse forages.*

Feed	Herb rich grass Silage g/kg DM
CO2eq g/kg	241
EF_CH4 0% maize sil.	24.3
EF_CH4 40% maize sil.	24.3
EF_CH4 80% maize sil.	25.8
Dry matter (g/kg)	488
Crude protein (ex. NH3)	103
Crude protein total	115
Crude fiber	288
Ash	88
Ether extract	27
Sugar	64
Starch	0
By pass starch	0
NDF	562
ADF	349
ADL	43
OMD (%)	62.4
DOM	569
GE (MJ)	17862
ME (MJ)	5823
VEM (g/kg)	697
DVE	39
OEB	8
OEB 2u	29
FOSp	472
FOSp 2u	191
DVE91	44
OEB91	2
FOS91	484
Digestible CP	60
Phosphorus	3.3

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Appendix 3 Composition and feeding values of roughages and concentrates

Table 20 *Nutrients, feeding values, GHG emissions and emission factors of the roughage (g/kg DM) and low (LP) and high (HP) protein concentrates (g/kg) in the basic scenarios.*

Feed	**Grass Silage**	**Fresh grass**	**Maize Silage**	**Straw**	**Wet by-products**	**LP**	**HP**
	g/kg DM	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg DM**	**g/kg**	**g/kg**
CO2eq g/kg	241	76	52	245	6.43	766	1640
EF_CH4 0% maize sil.	20.1	18.3	18.5	17	21.6	21.8	20.6
EF_CH4 40% maize sil.	20.1	18.3	17.6	17	21.6	21.5	20.3
EF_CH4 80% maize sil.	21.6	19.2	16.3	17	22.7	22.3	21.1
Dry matter (g/kg)	460	161	370	902	224	891	876
Crude protein (ex. NH3)	161	227	67	44	137	155	217
Crude protein total	176	227	72	44	138	155	218
Crude fiber	248	228	175	419	191	103	101
Ash	105	106	36	100	57	63	84
Ether extract	41	44	32	12	40	25	35
Sugar	84	97	15	0	32	50	110
Starch	0	0	362	0	58	267	66
By pass starch	0	0	99	0	29	72	19
NDF	477	445	364	745	453	250	220
ADF	267	264	203	489	140	144	127
ADL	20	34	16	74.5	16	26	19
OMD (%)	77.1	83.8	76.3	42	79.5	83.3	83.3
DOM	690	750	736	337	748	688	685
GE (MJ)	18188	18536	18759	17487	18518	16138	16044
ME (MJ)	10735	11608	11400	5488	11678	10757	10839
VEM (/kg)	909	1006	982	418	1019	951	962
DVE	64	100	50	-4	110	103	155
OEB	49	69	-35	-17	-27	-2	12
OEB 2u	57	18	3	8	-8	-1	1
FOSp	546	550	531	259	521	492	484
FOSp 2u	252	179	264	26	173	236	223
DVE91	75	106	49	15.4	113	92	155
OEB91	31	52	-33	4.4	-32	2	13
FOS91	570	633	514	24.2	585	502	515
Digestible CP	121	184	23	10.12	96	118	181
Phosphorus	3.8	4.3	1.9	1.1	2.6	4.4	3.9

Table 21 *Ingredients of concentrates (in %) used to simulate protein scenarios.*

Region	**NW**	**NW**	**SE**	**SE**	**High Protein NW, SE**
OEB scenario	**OEB-100**	**OEB-500**	**OEB-100**	**OEB-500**	
Sugar beet pulp	44.6	58.6	40.5	67.9	0.0
Peas	0.0	0.0	0.0	0.0	0.0
Corn DDGS	8.8	0.0	6.5	1.7	30.0

Region **OEB scenario**	**NW** **OEB-100**	**NW** **OEB-500**	**SE** **OEB-100**	**SE** **OEB-500**	**High Protein NW, SE**
Linseed expeller	0.0	0.0	0.0	0.0	18.3
Alfalfameal	0.0	0.0	0.0	0.0	0.0
Corn	18.1	34.2	5.2	13.4	0.0
Cornglutenfeed	0.0	0.0	18.3	0.0	0.0
Molasses	5.0	5.0	5.0	5.0	5.0
Vegetable fat	1.5	0.0	2.2	1.7	0.9
Rapeseedmeal Formaldehyde treated	0.0	0.0	0.0	0.0	35.0
Wheat midlings	19.8	0.0	20.0	8.1	0.0
Sunflower meal	0.0	0.0	0.0	0.0	0.0
Horse beans	0.0	0.0	0.0	0.0	8.7
Chalk	0.3	0.3	0.3	0.3	0.3
Magnesiumoxide	0.3	0.3	0.3	0.3	0.3
Salt	0.8	0.8	0.8	0.8	0.8
Premix	1.0	1.0	1.0	1.0	0.8

Table 22 *Nutrients, feeding values, GHG emission and emission factors of concentrates used to simulate protein scenarios.*

Region **OEB scenario**	**NW** **OEB-100**	**NW** **OEB-500**	**SE** **OEB-100**	**SE** **OEB-500**	**High Protein NW, SE**
	g/kg	**g/kg**	**g/kg**	**g/kg**	**g/kg**
gCO2_EQ	421	431	644	431	802
EF_CH4_0_SM (g/kg DM)	22	24	22	24	19
EF_CH4_40SM (g/kg DM)	22	23	22	23	19
EF_CH4_80SM (g/kg DM)	24	24	23	25	21
Dry matter	880	880	882	885	879
Crude protein	112	85	127	93	275
Crude protein (total)	112	85	127	93	275
Crude fiber	106	112	108	132	87
Crude ash	68	66	74	74	72
Fat	42	15	47	28	59
Sugar	70	68	70	78	71
Starch	149	210	99	99	49
By pass starch	43	74	21	30	8
NDF	289	261	314	310	241
ADF	129	130	130	154	135
ADL	14	8	14	11	47
OMD (%)	84.3	87.5	83.3	85.9	80.0
DOM	684	713	673	696	646
GE (MJ/kg)	15746	15200	15948	15529	17219
ME (MJ/kg)	10789	10729	10813	10762	10943
VEM (/kg)	960	960	960	960	955
DVE	93	93	89	89	190

Region	**NW**	**NW**	**SE**	**SE**	**High Protein NW, SE**
OEB scenario	**OEB-100**	**OEB-500**	**OEB-100**	**OEB-500**	
OEB	-30	-59	-12	-48	33
OEB 2u	-6	-20	7	-14	7
FOSp	506	528	508	529	388
FOSp 2u	222	211	232	212	185
VW (/kg)	0.27	0.28	0.27	0.28	0.26
SW (/kg)	0.25	0.26	0.25	0.29	0.25
VRE	79	51	91	59	229
P	3.4	1.3	5	1.8	8
DVE91	87	86	85	86	185
OEB91	-22	-48	-7	-42	38
FOS91	545	576	554	589	386

Appendix 4 Total ration compositions

NW basic

Table 4.1 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the **Standard** scenario in North-West region

North-West												
Stage of lactation$^{1)}$	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)$^{2)}$	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		7,8		0,0		0,0	
Grass silage (kg DM)	7,0		9,1		11,2		3,8		9,0		9,0	
Maize silage (kg DM)	2,3		1,7		2,8		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		3,0		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	5,2		6,2		2,5		6,4		0,0		0,0	
High protein concentrate (kg/d)	1,3		3,9		1,8		0,1		0,0		1,0	
Roughage (kg DM/d)	14,6		11,9		15,0		15,3		12,1		12,2	
Concentrates (kg DM/d)	5,8		8,9		3,8		6,5		0,0		0,9	
Emission factors$^{3)}$												
gCO2_EQ (g/kg)	12867	232	17150	435	11476	290	11972	174	5744	242	7110	246
EF CH4 0% maize silage (g/kg DM)	422	20,8	451,7	21,7	382	20,3	430	20,5	449	18,6	244	19,9
EF CH4 40% maize silage (g/kg DM)	417	20,5	445,6	21,4	378	20,1	425	20,2	449	18,6	244	19,9
EF CH4 80% maize silage (g/kg DM)	432	21,3	462,6	22,2	394	21,0	438	20,8	476	19,8	262	21,4
Nutrient intake and diet composition$^{4)}$												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3524	173	3717	178	2960	157	3690	176	1703	141	2992	124
Crude protein (incl NH3)	3641	178	3862	185	3138	167	3293	157	1857	154	3232	134
Crude fiber	3855	189	3669	176	3760	200	3643	173	3386	281	5196	216
Ash	1715	84	1740	83	1604	85	1482	71	1447	120	1814	75
Ether extract	710	35	702	34	670	36	968	46	414	34	897	37
Water soluble carbohydrates	1601	78	1465	70	1280	68	2884	137	591	49	1290	54
Starch	2347	115	2800	134	1808	96	1298	62	0	0	3353	139
Rumen by-pass starch	562	27	647	31	453	24	1883	90	0	0	950	39
NDF	8322	407	7821	375	7659	407	7983	380	6389	530	10438	433
ADF	4402	216	4260	204	4167	221	3737	178	3794	315	5578	231
ADL	442	22	478	23	389	21	848	40	416	35	444	18
Digestible OM	15023	735	15359	737	13204	702	115961	5521	7025	583	17163	712
Gross energy (MJ/kg DM)	375	18345,6	382	18,3	337	17,9	351	16,7	214839	17,8	444	18,4
Metabolisable energy (MJ/kg)	233	11422,1	240	11,5	206	10,9	178	8,5	110427	9,2	267	11,1
kVEM (1kVEM = 6.9 MJ NEL)	20,2	988	20,7	995	17,7	938	15,5	740	9203,6	764	22,8	946
DVE	1883	92	2090	100	1506	80	1216	58	548	46	1513	63
OEB	510	25	504	24	509	27	460	22	542	45	269	11
OEB-2h	460	23	509	24	633	34	3702	176	642	53	743	31
FOMr	11397	558	11560	554	10065	535	10207	486	5644	468	12961	538
FOMr-2h	5173	253	5516	265	4716	251	3523	168	2341	194	6008	249
DVE91	1954	96	2144	103	1608	85	1319	63	688	57	1653	69
OEB91	378	19	414	20	339	18	328	16	415	34	39	2
FOM91	12028	589	12091	580	10476	557	9094	433	4896	406	13267	550
	0	0										
Digestible crude protein	2658	130	2847	137	2199	117	1952	93	2491	103	1984	82
Phosphorus	79	3,9	88	4	70	3,7	773	36,8	78	3	72	3,0
Milk production												
Milk (kg/d)	26,6		32,2		21,7		27,4					
Fat (g/d)	1216		1451		1008		1247					
Protein (g/d)	945		1089		805		971					
Fat%	4,57		4,51		4,65		4,55					
Protein %	3,55		3,38		3,71		3,54					
FPCM (kg/d)	28,8		34,2		23,8		29,5					
kVEM requirement (/d)	19,2		22,4		17,4		20,1					
DVE requirement (g/d)	1615		1873		1371		1661					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopwijzer)

Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen

NW increased grazing

Table 4.2 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario ***with increased grazing*** in the North-West region

North-West												
Stage of lactation1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104;	285-365			105-284		1-104; 285-365			
Indoor/Outdoor (grazing)2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	6,4		0,0		0,0		7,8		0,0		0,0	
Grass silage (kg DM)	5,2		9,1		11,2		3,8		9,0		9,0	
Maize silage (kg DM)	2,3		1,7		2,8		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		3,0		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	5,2		6,2		2,5		6,4		0,0		0,0	
High protein concentrate (kg/d)	1,3		3,9		1,8		0,1		0,0		1,0	
	0											
Roughage (kg DM/d)	15,0		11,9		15,0		15,3		24,1		12,2	
Concentrates (kg DM/d)	5,8		8,9		3,8		1,6		0,0		0,9	
Emission factors3)												
gCO2_EQ (g/kg)	12798	201	17047	432	11692	290	11856	139	5744	242	6437	204
EF CH4 0% maize silage (g/kg DM)	427	20,6	452,3	21,7	389	20,8	439	20,1	225	18,6	246	20,1
EF CH4 40% maize silage (g/kg DM)	422	20,3	446,2	21,4	385	20,6	434	19,8	225	18,6	245	20,0
EF CH4 80% maize silage (g/kg DM)	436	21,0	463,3	22,2	403	21,5	445	20,3	238	19,8	258	21,1
Nutrient intake and diet composition4)												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3708	179	3709	178	3033	162	4085	187	3407	141	2992	124
Crude protein (incl NH3)	3798	183	3862	185	3219	172	4101	188	3714	154	3232	134
Crude fiber	3875	187	3669	176	3867	206	3952	181	6772	281	5196	216
Ash	1744	84	1740	83	1648	88	1805	83	2895	120	1814	75
Ether extract	718	35	702	34	685	37	744	34	828	34	897	37
Water soluble carbohydrates	1685	81	1465	70	1326	71	1966	90	1182	49	1290	54
Starch	2346	113	2800	134	1731	92	2525	115	0	0	3353	139
Rumen by-pass starch	561	27	647	31	432	23	603	28	0	0	950	39
NDF	8542	411	7821	375	7856	419	9185	420	12778	530	10438	433
ADF	4450	214	4260	204	4271	228	4623	211	7588	315	5578	231
ADL	449	22	478	23	395	21	471	22	832	35	444	18
Digestible OM	15347	739	15359	737	13444	718	16400	750	14050	583	17163	712
Gross energy (MJ/kg DM)	381	18,4	382	18,3	343	18,3	402	18,4	430	17,8	444	18,4
Metabolisable energy (MJ/kg)	238	11,5	240	11,5	209	11,2	253	11,6	221	9,2	267	11,1
kVEM (1VEM = 6.9 kJ NEL)	20,6	993	21	995	18	959	22	1008	18	764	23	946
DVE	1969	95	2090	100	1530	82	2171	99	1097	46	1513	63
OEB	550	26	504	24	539	29	577	26	1083	45	269	11
OEB-2h	405	20	509	24	659	35	229	10	1285	53	743	31
FOMr	11654	561	11560	554	10273	548	12450	569	11289	468	12961	538
FOMr-2h	5154	248	5516	265	4809	257	5209	238	4683	194	6008	249
DVE91	1918	92	2144	103	1563	83	2099	96	1376	57	1653	69
OEB91	345	17	414	20	306	16	392	18	829	34	39	2
FOM91	11792	568	12091	580	10342	552	12790	585	9791	406	13267	550
Digestible crude protein	2817	136	2847	137	2262	121	3115	142	2491	103	1984	82
Phosphorus	80	3,8	88	4,2	71	3,8	82	3,7	78	3,2	72	3,0
Milk production												
Milk (kg/d)	26,9		32,2		21,7		27,9					
Fat (g/d)	1228		1451		1010		1269					
Protein (g/d)	954		1089		806		988					
Fat%	4,57		4,51		4,65		4,55					
Protein %	3,55		3,38		3,71		3,54					
FPCM (kg/d)	29,0		34,2		23,9		30,0					
kVEM requirement (/d)	19,4		22,4		17,4		20,4					
DVE requirement (g/d)	1632		1873		1373		1691					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopwijze

DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91 Intestinal digestible protein, FOM91= rumen rumen fermentable organic

NW herb rich grass silage

Table 4.3 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario **with *herb rich grass silage*** in the North-West region

North-West												
Stage of lactation1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	6,4		0,0		0,0		7,8		0,0		0,0	
Grass silage (kg DM)	5,2		9,2		11,8		3,8		1,0		9,0	
Maize silage (kg DM)	2,3		1,7		2,1		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		0,0		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		11,9		0,0	
Low protein concentrate (kg/d)	5,2		6,2		2,5		6,4		0,0		0,0	
High protein concentrate (kg/d)	1,3		3,9		1,8		0,1		0,0		1,0	
Roughage (kg DM/d)	15,0		11,9		14,9		15,3		13,0		12,2	
Concentrates (kg DM/d)	5,8		8,9		3,8		6,5		0,0		0,9	
Emission factors3)												
gCO2_EQ (g/kg)	12190	201	15553	394	10693	265	11856	139	5744	242	7110	246
EF CH4 0% maize silage (g/kg DM)	428	20,6	454,6	21,8	391	20,9	439	20,1	449	18,6	244	19,9
EF CH4 40% maize silage (g/kg DM)	423	20,3	448,7	21,5	387	20,7	434	19,8	449	18,6	244	19,9
EF CH4 80% maize silage (g/kg DM)	437	21,0	466,0	22,3	405	21,6	445	20,3	476	19,8	262	21,4
Nutrient intake and diet composition4)												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3629	175	3516	169	2903	155	3690	176	1611	124	2992	124
Crude protein (incl NH3)	3719	179	3862	185	3138	167	3293	157	1770	137	3232	134
Crude fiber	3897	188	3669	176	3760	200	3643	173	3659	283	5196	216
Ash	1734	83	1740	83	1604	85	1482	71	1363	105	1814	75
Ether extract	713	34	702	34	670	36	968	46	403	31	897	37
Water soluble carbohydrates	1676	81	1465	70	1280	68	2884	137	738	57	1290	54
Starch	2401	116	2800	134	1808	96	1298	62	0	0	3353	139
Rumen by-pass starch	568	27	647	31	453	24	1883	90	0	0	950	39
NDF	8582	413	7821	375	7659	407	7983	380	7023	542	10438	433
ADF	4472	215	4260	204	4167	221	3737	178	4258	329	5578	231
ADL	448	22	478	23	389	21	848	40	493	38	444	18
Digestible OM	15349	739	15359	737	13204	702	115961	5521	7505	580	17163	712
Gross energy (MJ/kg DM)	381	18,4	382	18,3	337	17,9	351	16,7	231	17848,7	444	18,4
Metabolisable energy (MJ/kg)	238	11,5	240	11,5	206	10,9	178	8,5	115	8906,9	267	11,1
kVEM (1kVEM = 6.9 MJ NEL)	20,6	993	21	995	18	938	16	740	9,5	736	23	946
DVE	1932	93	2090	100	1506	80	1216	58	557	43	1513	63
OEB	506	24	504	24	509	27	460	22	364	28	269	11
OEB-2h	391	19	509	24	633	34	3702	176	546	42	743	31
FOMr	11677	562	11560	554	10065	535	10207	486	6125	473	12961	538
FOMr-2h	5168	249	5516	265	4716	251	3523	168	2522	195	6008	249
DVE91	1878	90	2144	103	1608	85	1319	63	666	51	1653	69
OEB91	305	15	414	20	339	18	328	16	248	19	39	2
FOM91	11823	569	12091	580	10476	557	9094	433	5806	448	13267	550
Digestible crude protein	2647	130	2847	137	2199	117	1952	93	1086	84	1984	82
Phosphorus	78	3,9	88	4,2	70	3,7	773	36,8	41	3,2	72	3,0
Milk production												
Milk (kg/d)	26,9		32,2		21,7		27,4					
Fat (g/d)	1228		1451		1010		1247					
Protein (g/d)	954		1089		806		971					
Fat%	4,57		4,51		4,65		4,55					
Protein %	3,55		3,38		3,71		3,54					
FPCM (kg/d)	29,0		34,2		23,9		29,5					
kVEM requirement (/d)	19,4		22,4		17,4		20,1					
DVE requirement (g/d)	1632		1873		1373		1661					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen

NW 100% DVE -100 OEB

Table 4.4 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with **a DVE supply at 100% of the requirement and OEB aimed at a level of -100 g OEB/day** in the North-West region

North-West												
Stage of lactation[1]	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)[2]	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		7,9		0,0		0,0	
Grass silage (kg DM)	7,0		9,1		11,3		3,8		9,0		9,0	
Maize silage (kg DM)	2,3		1,7		0,0		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		3,0		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	6,1		8,5		4,6		6,4		0,0		0,0	
High protein concentrate (kg/d)	0,4		1,5		0,1		0,0		0,0		1,0	
Roughage (kg DM/d)	14,6		11,9		14,6		15,3		12,1		12,2	
Concentrates (kg DM/d)	5,8		8,9		4,1		5,7		0,0		0,9	
Emission factors[3]												
gCO2_EQ (g/kg)	8674	156	9658	249	8262	207	8529	121	5744	242	5591	191
EF CH4 0% maize silage (g/kg DM)	430	21,1	444,2	21,9	396	21,2	444	20,7	449	18,6	242	19,7
EF CH4 40% maize silage (g/kg DM)	427	20,9	441,1	21,8	392	21,0	440	20,6	449	18,6	238	19,3
EF CH4 80% maize silage (g/kg DM)	449	22,0	467,4	23,1	414	22,2	460	21,5	476	19,8	243	19,8
Nutrient intake and diet composition[4]												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3129	153	3070	152	2653	142	3412	159	1703	141	1496	124
Crude protein (incl NH3)	3246	159	3214	159	2831	152	3485	163	1857	154	1616	134
Crude fiber	3938	193	3729	184	3880	208	4040	189	3386	281	2598	216
Ash	1760	86	1732	86	1650	88	1828	85	1447	120	907	75
Ether extract	842	41	890	44	766	41	866	40	414	34	448	37
Water soluble carbohydrates	1655	81	1479	73	1339	72	1894	88	591	49	645	54
Starch	1842	90	1951	96	1560	84	1957	91	0	0	1677	139
Rumen by-pass starch	531	26	557	28	451	24	565	26	0	0	475	39
NDF	8632	423	8105	400	8018	429	9154	428	6389	530	5219	433
ADF	4365	214	4152	205	4212	225	4523	211	3794	315	2789	231
ADL	389	19	422	21	353	19	397	19	416	35	222	18
Digestible OM	14952	733	14771	730	13408	718	15858	741	7025	583	8582	712
Gross energy (MJ/kg DM)	372	18,2	370	18,3	340	18,2	391	18,2	215	17,8	222	18,4
Metabolisable energy (MJ/kg)	233	11,4	233	11,5	209	11,2	246	11,5	110	9,2	133	11,1
VEM (1VEM = 6.9 kJ NEL)	20,2	990	20,2	996	18,0	964	21,4	1000	9,2	764	11,4	946
DVE	1724	84	1834	91	1390	74	1869	87	548	46	757	63
OEB	297	15	176	9	315	17	331	15	542	45	135	11
OEB-2h	446	22	470	23	609	33	346	16	642	53	372	31
FOMr	11332	555	11031	545	10244	548	12032	562	5644	468	6480	538
FOMr-2h	4928	241	4977	246	4652	249	5057	236	2341	194	3004	249
DVE91	1789	88	1877	93	1484	79	1924	90	688	57	826	69
OEB91	168	8	87	4	151	8	207	10	415	34	20	2
FOM91	12011	589	11584	572	10722	574	12870	601	4896	406	6634	550
Digestible crude protein	2278	112	1275	63	1896	101	2501	117	1245	103	992	82
Phosphorus	74	3,6	1034	51	66	3,5	75	3,5	39	3	36	3,0
Milk production												
Milk (kg/d)	26,2		31,2		21,2		27,1					
Fat (g/d)	1196		1410		987		1232					
Protein (g/d)	929		1059		788		959					
Fat%	4,57		4,52		4,65		4,55					
Protein %	3,55		3,40		3,72		3,54					
FPCM (kg/d)	28,3		33,2		23,3		29,2					
kVEM requirement (/d)	19,0		21,9		17,1		19,9					
DVE requirement (g/d)	1587		1818		1343		1639					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen

NW 100% DVE -500 OEB

Table 4.5 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a **DVE supply at 100% of the requirement and OEB aimed at a level of -500 g OEB/day** in the North-West region

North-West												
Stage of lactation[1]	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)[2]	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		0,0		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		7,8		0,0		0,0	
Grass silage (kg DM)	7,0		9,1		11,2		3,8		9,0		9,0	
Maize silage (kg DM)	2,3		1,7		2,8		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		3,0		0,0	
Herb rich grass silage	6,1		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	0,4		6,2		2,5		6,4		0,0		0,0	
High protein concentrate (kg/d)	0,0		3,9		1,8		0,1		0,0		1,0	
Roughage (kg DM/d)	14,6		11,9		15,0		15,3		12,1		12,2	
Concentrates (kg DM/d)	5,8		8,9		3,8		5,7		0,0		0,9	
Emission factors[3]												
gCO2_EQ (g/kg)	8694	157	9966	253	8138	205	8438	123	5744	242	5710	197
EF CH4 0% maize silage (g/kg DM)	437	21,5	470,5	22,7	394	20,9	445	21,2	225	18,6	241	19,7
EF CH4 40% maize silage (g/kg DM)	432	21,2	464,5	22,4	389	20,7	439	20,9	225	18,6	237	19,3
EF CH4 80% maize silage (g/kg DM)	451	22,2	487,8	23,5	408	21,7	456	21,7	238	19,8	242	19,8
Nutrient intake and diet composition[4]												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	2947	145	2880	139	2496	133	3173	151	1703	141	1496	124
Crude protein (incl NH3)	3063	151	3025	146	2674	142	3244	154	1857	154	1616	134
Crude fiber	3950	194	3851	185	3864	205	3982	190	3386	281	2598	216
Ash	1734	85	1758	85	1610	86	1771	84	1447	120	907	75
Ether extract	676	33	686	33	641	34	683	33	414	34	448	37
Water soluble carbohydrates	1640	81	1519	73	1304	69	1842	88	591	49	645	54
Starch	2216	109	2534	122	1793	95	2336	111	0	0	1677	139
Rumen by-pass starch	719	35	838	40	573	30	756	36	0	0	475	39
NDF	8416	414	8056	388	7796	414	8776	418	6389	530	5219	433
ADF	4347	214	4240	204	4170	221	4426	211	3794	315	2789	231
ADL	351	17	373	18	323	17	353	17	416	35	222	18
Digestible OM	15071	741	15423	743	13304	707	15748	750	7025	583	8582	712
Gross energy (MJ/kg DM)	367	18,1	374	18,0	333	17,7	380	18,1	215	17,8	222	18,4
Metabolisable energy (MJ/kg)	232	11,4	238	11,5	206	10,9	241	11,5	110	9,2	133	11,1
VEM (1VEM = 6.9 kJ NEL)	20,1	990	20,7	998	17,7	940	21,0	1001	9,2	764	21,0	1001
DVE	1721	85	1872	90	1359	72	1844	88	548	46	757	63
OEB	116	6	-90	-4	200	11	133	6	542	45	135	11
OEB-2h	357	18	353	17	550	29	246	12	642	53	372	31
FOMr	11420	562	11544	556	10164	540	11935	568	5644	468	6480	538
FOMr-2h	4836	238	5016	242	4530	241	4888	233	2341	194	3004	249
DVE91	1780	88	1907	92	1453	77	1892	90	688	57	826	69
OEB91	3	0	-156	-7	43	2	29	1	415	34	20	2
FOM91	12153	598	12210	588	10662	566	12809	610	4896	406	6634	550
Digestible crude protein	2103	103	2039	98	1752	93	2283	109	1245	103	992	82
Phosphorus	61	3,0	65	3	56	3,0	61	2,9	39	3	36	3,0
Milk production												
Milk (kg/d)	25,4		30,8		20,9		25,9					
Fat (g/d)	1161		1394		974		1180					
Protein (g/d)	902		1048		777		919					
Fat%	4,57		4,52		4,66		4,56					
Protein %	3,55		3,40		3,72		3,55					
FPCM (kg/d)	27,4		32,8		23,0		27,9					
kVEM requirement (/d)	18,6		21,7		17,0		19,3					
DVE requirement (g/d)	1540		1798		1325		1569					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopwi

DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen

NW 90% DVE -100 OEB

Table 4.6 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a **DVE supply at 90% of the requirement and OEB aimed at a level of -100 g OEB/day** in the North-West region

North-West												
Stage of lactation[1)]	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365	days PP	0-120	days AP	121-365	days PP	1-365	days PP	55 to 11	days AP	10 to 0	days AP
Day of the year	1-365		1-104;	285-365			105-284		1-104;	285-365		
Indoor/Outdoor (grazing)[2)]	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		8,1		8,1		0,0		0,0	
Grass silage (kg DM)	7,0		9,0		4,0		4,0		9,0		9,0	
Maize silage (kg DM)	2,3		1,8		2,6		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		3,0		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	6,4		8,7		6,5		6,5		0,0		0,0	
High protein concentrate (kg/d)	0,1		0,8		0,0		0,0		0,0		1,0	
Roughage (kg DM/d)	14,7		11,9		15,7		15,7		12,1		12,2	
Concentrates (kg DM/d)	5,8		8,3		5,7		5,7		0,0		0,9	
Emission factors[3)]												
gCO2_EQ (g/kg)	8583	154	9277	239	8241	206	8518	121	5744	242	5710	197
EF CH4 0% maize silage (g/kg DM)	431	21,1	447,1	22,1	397	21,2	445	20,8	225	18,6	245	20,0
EF CH4 40% maize silage (g/kg DM)	428	21,0	443,7	22,0	394	21,0	441	20,6	225	18,6	243	19,9
EF CH4 80% maize silage (g/kg DM)	449	22,0	469,7	23,2	416	22,2	461	21,5	238	19,8	258	21,1
Nutrient intake and diet composition[4)]												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3088	151	2906	144	2641	141	3405	159	1703	141	1496	124
Crude protein (incl NH3)	3206	157	3049	151	2820	151	3478	162	1857	154	1616	134
Crude fiber	3940	193	3739	185	3889	208	4043	189	3386	281	2598	216
Ash	1756	86	1723	85	1651	88	1828	85	1447	120	907	75
Ether extract	841	41	876	43	768	41	869	41	414	34	448	37
Water soluble carbohydrates	1658	81	1480	73	1343	72	1899	89	591	49	645	54
Starch	1866	91	2045	101	1574	84	1964	92	0	0	1677	139
Rumen by-pass starch	539	26	590	29	456	24	567	26	0	0	475	39
NDF	8644	423	8141	403	8041	429	9167	428	6389	530	5219	433
ADF	4365	214	4141	205	4221	225	4527	211	3794	315	2789	231
ADL	381	19	389	19	350	19	395	18	416	35	222	18
Digestible OM	14965	733	14790	732	13442	718	15879	741	7025	583	8582	712
Gross energy (MJ/kg DM)	372	18,2	368	18,2	341	18,2	391	18,2	215	17,8	222	18,4
Metabolisable energy (MJ/kg)	233	11,4	232	11,5	210	11,2	247	11,5	110	9,2	133	11,1
kVEM (1kVEM = 6.9 MJ NEL)	20,2	990	20,1	996	18,0	964	21,4	1000	9,2	764	11,4	946
DVE	1701	83	1738	86	1383	74	1866	87	548	46	757	63
OEB	282	14	115	6	309	17	329	15	542	45	135	11
OEB-2h	446	22	460	23	611	33	348	16	642	53	372	31
FOMr	11360	557	11129	551	10277	549	12049	562	5644	468	6480	538
FOMr-2h	4936	242	5004	248	4665	249	5062	236	2341	194	3004	249
DVE91	1767	87	1781	88	1479	79	1922	90	688	57	826	69
OEB91	151	7	26	1	143	8	201	9	415	34	20	2
FOM91	12053	590	11724	580	10763	575	12894	602	4896	406	6634	550
Digestible crude protein	2245	110	2097	104	1888	101	2499	117	1245	103	992	82
Phosphorus	72	3,5	76	3,8	66	3,5	75	3,5	39	3,2	36	3,0
Milk production												
Milk (kg/d)	26,1		30,6		21,2		27,1					
Fat (g/d)	1190		1383		987		1232					
Protein (g/d)	925		1040		788		959					
Fat%	4,57		4,52		4,65		4,55					
Protein %	3,55		3,40		3,72		3,54					
FPCM (kg/d)	28,1		32,6		23,3		29,2					
kVEM requirement (/d)	18,9		21,6		17,1		19,9					
DVE requirement (g/d)	1579		1784		1343		1640					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen

NW 90% DVE -500 OEB

Table 4.7 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a D**VE supply at 90% of the requirement and OEB aimed at a level of -500 g OEB/day** in the North-West region

North-West												
Stage of lactation[1]	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104;	285-365			105-284		1-104; 285-365			
Indoor/Outdoor (grazing)[2]	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		8,1		0,0		0,0	
Grass silage (kg DM)	7,0		9,0		11,3		4,0		9,0		9,0	
Maize silage (kg DM)	2,3		1,8		2,2		2,6		0,0		1,3	
Wheat straw	0,0		0,0		0,0		0,0		3,0		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	6,4		8,7		4,7		6,5		0,0		0,0	
High protein concentrate (kg/d)	0,1		0,8		0,0		0,0		0,0		1,0	
Roughage (kg DM/d)	14,7		11,9		14,6		15,7		12,1		12,2	
Concentrates (kg DM/d)	5,8		8,3		4,1		5,7		0,0		0,9	
Emission factors[3]												
gCO2_EQ (g/kg)	8645	155	9362	241	8287	207	8581	122	5744	242	6378	220
EF CH4 0% maize silage (g/kg DM)	440	21,6	459,5	22,7	403	21,5	454	21,2	225	18,6	245	20,1
EF CH4 40% maize silage (g/kg DM)	435	21,3	453,2	22,4	399	21,3	448	20,9	225	18,6	246	20,1
EF CH4 80% maize silage (g/kg DM)	453	22,2	475,0	23,5	418	22,3	465	21,7	238	19,8	264	21,5
Nutrient intake and diet composition[4]												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	2913	143	2668	132	2512	134	3227	151	1703	141	1496	124
Crude protein (incl NH3)	3030	148	2811	139	2691	144	3300	154	1857	154	1616	134
Crude fiber	3977	195	3790	187	3916	209	4081	190	3386	281	2598	216
Ash	1742	85	1703	84	1640	88	1813	85	1447	120	907	75
Ether extract	669	33	642	32	642	34	694	32	414	34	448	37
Water soluble carbohydrates	1647	81	1465	72	1336	71	1888	88	591	49	645	54
Starch	2258	111	2577	127	1861	99	2361	110	0	0	1677	139
Rumen by-pass starch	735	36	857	42	600	32	766	36	0	0	475	39
NDF	8462	415	7893	390	7907	422	8982	419	6389	530	5219	433
ADF	4369	214	4147	205	4224	226	4531	211	3794	315	2789	231
ADL	342	17	337	17	322	17	356	17	416	35	222	18
Digestible OM	15148	742	15039	744	13577	725	16065	750	7025	583	8582	712
Gross energy (MJ/kg DM)	368	18,1	363	18,0	338	18,1	387	18,1	215	17,8	222	18,4
Metabolisable energy (MJ/kg)	233	11,4	232	11,5	210	11,2	246	11,5	110	9,2	133	11,1
kVEM (1kVEM = 6.9 MJ NEL)	20,2	990	20,1	996	18,0	964	21,4	1000	9,2	764	11,4	946
DVE	1702	83	1738	86	1383	74	1866	87	548	46	757	63
OEB	97	5	-136	-7	174	9	141	7	542	45	135	11
OEB-2h	355	17	337	17	544	29	256	12	642	53	372	31
FOMr	11503	563	11323	560	10382	554	12194	569	5644	468	6480	538
FOMr-2h	4864	238	4907	243	4612	246	4990	233	2341	194	3004	249
DVE91	1761	86	1774	88	1475	79	1917	89	688	57	826	69
OEB91	-16	-1	-201	-10	20	1	32	1	415	34	20	2
FOM91	12193	597	11695	579	10908	583	13095	611	4896	406	6634	550
Digestible crude protein	2068	101	1856	92	1758	94	2320	108	1245	103	992	82
Phosphorus	59	2,9	58	2,9	56	3,0	61	2,9	39	3,2	36	3,0
Milk production												
Milk (kg/d)	25,8		30,1		21,0		26,8					
Fat (g/d)	1177		1361		979		1219					
Protein (g/d)	915		1023		782		949					
Fat%	4,57		4,52		4,66		4,55					
Protein %	3,55		3,40		3,72		3,54					
FPCM (kg/d)	27,8		32,1		23,1		28,9					
kVEM requirement (/d)	18,8		21,3		17,1		19,8					
DVE requirement (g/d)	1561		1753		1332		1622					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen

SE basic

Table 4.8 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the Standard scenario in South-East region

South-East												
Stage of lactation[1)]	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)[2)]	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		7,8		0,0		0,0	
Grass silage (kg DM)	7,0		9,1		11,2		3,8		4,0		5,8	
Maize silage (kg DM)	2,3		1,7		2,8		2,6		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		4,2		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	5,2		6,2		2,5		6,4		0,0		0,0	
High protein concentrate (kg/d)	1,3		3,9		1,8		0,1		0,0		1,0	
Roughage (kg DM/d)	14,6		11,9		15,0		15,3		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,9		3,8		6,5		0,0		0,9	
Emission factors[3)]												
gCO2_EQ (g/kg)	12867	232	17150	435	11476	290	11972	174	3866	282	5348	162
EF CH4 0% maize silage (g/kg DM)	422	20,8	451,7	21,7	382	20,3	430	20,5	220	18,2	254	19,3
EF CH4 40% maize silage (g/kg DM)	417	20,5	445,6	21,4	378	20,1	425	20,2	216	17,9	246	18,7
EF CH4 80% maize silage (g/kg DM)	432	21,3	462,6	22,2	394	21,0	438	20,8	217	18,0	243	18,5
Nutrient intake and diet composition[4)]												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3328	158	3845	179	2876	147	3347	158	1140	95	1517	126
Crude protein (incl NH3)	3448	163	3964	185	3027	155	3447	163	1229	102	1622	135
Crude fiber	3741	177	3450	161	3666	187	3775	178	3369	280	2433	202
Ash	1522	72	1572	73	1413	72	1540	73	1065	88	850	71
Ether extract	716	34	716	33	686	35	712	34	340	28	432	36
Water soluble carbohydrates	1274	60	1302	61	1074	55	1366	64	319	26	606	50
Starch	3759	178	3903	182	3393	173	3673	173	1397	116	1984	165
Rumen by-pass starch	971	46	990	46	906	46	935	44	383	32	550	46
NDF	8024	380	7493	349	7599	389	8218	388	6356	527	4954	411
ADF	4301	204	4062	189	4126	211	4355	205	3856	320	2653	220
ADL	439	21	476	22	393	20	441	21	458	38	224	19
Digestible OM	15561	737	15956	743	14228	727	15678	740	6915	574	8597	713
Gross energy (MJ/kg DM)	391	18,5	398	18,5	362	18,5	391	18,5	217	18,0	221	18,3
Metabolisable energy (MJ/kg)	242	11,5	250	11,6	222	11,3	244	11,5	109	9,0	134	11,1
kVEM (1kVEM = 6.9 MJ NEL)	20,9	992	21,6	1007	19,1	976	21,1	995	9,1	752	11,5	951
DVE	20947	992	21637	1007	19087	976	21090	995	424	35	814	68
OEB	285	13	425	20	263	13	269	13	58	5	94	8
OEB-2h	386	18	401	19	472	24	331	16	319	26	313	26
FOMr	11573	548	11745	547	10593	542	11710	553	5290	439	6435	534
FOMr-2h	5435	257	5658	263	5043	258	5399	255	2133	177	3015	250
DVE91	1826	86	2111	98	1585	81	1824	86	538	45	748	62
OEB91	126	6	256	12	102	5	113	5	68	6	-168	-14
FOM91	11387	539	11255	524	10463	535	11616	548	4226	351	6468	537
	0	0	0	0	0	0	0	0				
Digestible crude protein	2427	115	2933	137	2049	105	2438	115	670	56	1013	84
Phosphorus	77	3,6	89	4	68	3,5	76	3,6	28	2	36	3,0
Milk production												
Milk (kg/d)	26,9		33,2		22,7		27,0					
Fat (g/d)	1230		1496		1056		1229					
Protein (g/d)	955		1123		843		956					
Fat%	4,56		4,51		4,65		4,55					
Protein %	3,55		3,38		3,72		3,54					
FPCM (kg/d)	29,1		35,3		25,0		29,1					
VEM requirement (/d)	19,4		22,9		17,9		19,9					
DVE requirement (g/d)	1633		1935		1437		1635					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopwijzer)

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91 Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991 DVE/OEB system (Tamminga et al.1994);

SE increased grazing

Table 4.9 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with **increased grazing** in the South-East region

South-East												
Stage of lactation1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104;	285-365			105-284		1-104; 285-365			
Indoor/Outdoor (grazing)2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,7		0,0		0,0		9,0		0,0		0,0	
Grass silage (kg DM)	3,4		6,0		7,7		0,0		4,0		5,8	
Maize silage (kg DM)	6,7		5,5		7,1		6,2		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		4,2		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		0,0		0,0	
Low protein concentrate (kg/d)	2,1		0,5		4,3		3,8		0,0		0,0	
High protein concentrate (kg/d)	4,4		9,5		0,0		2,7		0,0		1,0	
				0								
Roughage (kg DM/d)	15,8		12,6		15,8		16,3		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,9		3,8		5,8		0,0		0,9	
Emission factors3)												
gCO2_EQ (g/kg)	4642	84	13599	220	3950	120	19247	449	3866	282	5348	162
EF CH4 0% maize silage (g/kg DM)	304	19,3	440,2	20,4	247	19,6	454	21,1	220	18,2	254	19,3
EF CH4 40% maize silage (g/kg DM)	298	18,9	431,1	20,0	242	19,2	444	20,6	216	17,9	246	18,7
EF CH4 80% maize silage (g/kg DM)	295	18,7	431,2	20,0	245	19,4	451	20,9	217	18,0	243	18,5
Nutrient intake and diet composition4)												
	Intake	Diet	Intake	Diet	Intake	Diet	Intake	Diet	Intake	Diet	Intake	Diet
	g/day	g/kg DM	g/day	g/kg DM	g/day	g/kg DM	g/day	g/kg DM	g/day	g/kg DM	g/day	g/kg DM
Crude protein	3567	165	3878	180	2891	148	3787	172	1016	81	1517	126
Crude protein (incl NH3)	3653	169	3997	185	3042	155	3821	173	1109	88	1622	135
Crude fiber	3748	174	3449	160	3666	187	3790	172	3519	279	2433	202
Ash	1582	73	1626	75	1437	73	1624	74	941	75	850	71
Ether extract	732	34	722	33	688	35	739	34	321	25	432	36
Water soluble carbohydrates	1411	65	1303	60	1074	55	1629	74	461	37	606	50
Starch	3759	174	3903	181	3393	173	3674	167	1397	111	1984	165
Rumen by-pass starch	972	45	991	46	906	46	936	42	383	30	550	46
NDF	8275	384	7500	348	7603	388	8696	395	6769	537	4954	411
ADF	4364	202	4081	189	4134	211	4464	203	4181	332	2653	220
ADL	453	21	482	22	395	20	464	21	515	41	224	19
Digestible OM	15992	741	15974	741	14237	727	16497	749	7249	575	8597	713
Gross energy (MJ/kg DM)	399	18,5	398	18,5	362	18,5	407	18,5	228	18,1	221	18,3
Metabolisable energy (MJ/kg)	249	11,5	250	11,6	222	11,3	256	11,6	111	8,8	134	11,1
kVEM (1VEM = 6.9 kJ NEL)	21,5	998	22	1004	19	974	22	1008	9	730	11	951
DVE	21530	998	21645	1004	19092	974	22207	1008	9201	730	814	68
OEB	347	16	456	21	277	14	370	17	-126	-10	94	8
OEB-2h	331	15	432	20	486	25	206	9	211	17	313	26
FOMr	11885	551	11744	545	10593	541	12311	559	5657	449	6435	534
FOMr-2h	5427	252	5653	262	5041	257	5387	245	2284	181	3015	250
DVE91	2048	95	2291	106	1662	85	2143	97	504	40	748	62
OEB91	275	13	413	19	170	9	305	14	-108	-9	-168	-14
FOM91	12324	571	12063	560	10808	552	12931	587	5089	403	6468	537
	0	0	0	0	0	0	0	0	0	0		
Digestible crude protein	2620	121	2938	136	2051	105	2806	127	491	39	1013	84
Phosphorus	78	3,6	89	4,1	68	3,5	79	3,6	30	2,3	36	3,0
Milk production												
Milk (kg/d)	27,5		33,2		22,7		28,1					
Fat (g/d)	1255		1497		1057		1278					
Protein (g/d)	976		1124		844		995					
Fat%	4,57		4,51		4,65		4,55					
Protein %	3,55		3,38		3,72		3,54					
FPCM (kg/d)	29,7		35,3		25,0		30,2					
kVEM requirement (/d)	19,7		22,9		17,9		20,5					
DVE requirement (g/d)	1669		1937		1438		1703					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopwij

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91 Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991 DVE/OEB system (Tamminga et al.1994);

SE herb rich grass silage

Table 4.10 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with **herb rich grass silage** in the South-East region

South-East												
Stage of lactation 1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365	days PP	0-120	days AP	121-365	days PP	1-365	days PP	55 to 11	days AP	10 to 0	days AP
Day of the year	1-365		1-104;	285-365			105-284		1-104; 285-365			
Indoor/Outdoor (grazing) 2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	1,9		0,0		0,0		3,7		0,0		0,0	
Grass silage (kg DM)	5,7		6,0		7,7		4,5		0,0		5,8	
Maize silage (kg DM)	6,7		5,5		7,1		6,2		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		2,7		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		6,0		0,0	
Low protein concentrate (kg/d)	2,1		0,5		4,3		3,8		0,0		0,0	
High protein concentrate (kg/d)	4,4		9,5		0,0		2,7		0,0		1,0	
Roughage (kg DM/d)	15,3		12,6		15,8		15,4		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,9		3,8		5,7		0,0		0,9	
Emission factors 3)												
gCO2_EQ (g/kg)	13549	261	18955	442	11577	259	12574	218	4215	165	5348	162
EF CH4 0% maize silage (g/kg DM)	433	20,5	453,6	21,1	396	20,2	433	20,4	262	21,0	254	19,3
EF CH4 40% maize silage (g/kg DM)	423	20,1	443,5	20,7	387	19,8	425	20,0	259	20,7	246	18,7
EF CH4 80% maize silage (g/kg DM)	429	20,3	450,3	21,0	392	20,1	430	20,3	263	21,0	243	18,5
Nutrient intake and diet composition 4)												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	3328	158	3845	179	2876	147	3347	158	992	79	1517	126
Crude protein (incl NH3)	3448	163	3964	185	3027	155	3447	163	1080	86	1622	135
Crude fiber	3741	177	3450	161	3666	187	3775	178	3515	281	2433	202
Ash	1522	72	1572	73	1413	72	1540	73	933	75	850	71
Ether extract	716	34	716	33	686	35	712	34	315	25	432	36
Water soluble carbohydrates	1274	60	1302	61	1074	55	1366	64	440	35	606	50
Starch	3759	178	3903	182	3393	173	3673	173	1397	112	1984	165
Rumen by-pass starch	971	46	990	46	906	46	935	44	383	31	550	46
NDF	8024	380	7493	349	7599	389	8218	388	6746	540	4954	411
ADF	4301	204	4062	189	4126	211	4355	205	4173	334	2653	220
ADL	439	21	476	22	393	20	441	21	518	41	224	19
Digestible OM	15561	737	15956	743	14228	727	15678	740	7134	571	8597	713
Gross energy (MJ/kg DM)	391	18,5	398	18,5	362	18,5	391	18,5	226	18,1	221	18,3
Metabolisable energy (MJ/kg)	242	11,5	250	11,6	222	11,3	244	11,5	110	8,8	134	11,1
kVEM (1kVEM = 6.9 MJ NEL)	20,9	992	22	1007	19	976	21	995	9,1	725	11	951
DVE	20947	992	21637	1007	19087	976	21090	995	414	33	814	68
OEB	285	13	425	20	263	13	269	13	-132	-11	94	8
OEB-2h	386	18	401	19	472	24	331	16	203	16	313	26
FOMr	11573	548	11745	547	10593	542	11710	553	5558	445	6435	534
FOMr-2h	5435	257	5658	263	5043	258	5399	255	2227	178	3015	250
DVE91	1826	86	2111	98	1585	81	1824	86	229	18	748	62
OEB91	126	6	256	12	102	5	113	5	-117	-9	-168	-14
FOM91	11387	539	11255	524	10463	535	11616	548	2046	164	6468	537
	0	0	0	0	0	0	0	0				
Digestible crude protein	2427	115	2933	137	2049	105	2438	115	473	38	1013	84
Phosphorus	77	3,6	89	4,1	68	3,5	76	3,6	29	2,3	36	3,0
Milk production												
Milk (kg/d)	26,9		33,2		22,7		27,0					
Fat (g/d)	1230		1496		1056		1229					
Protein (g/d)	955		1123		843		956					
Fat%	4,56		4,51		4,65		4,55					
Protein %	3,55		3,38		3,72		3,54					
FPCM (kg/d)	29,1		35,3		25,0		29,1					
kVEM requirement (/d)	19,4		22,9		17,9		19,9					
DVE requirement (g/d)	1633		1935		1437		1635					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91 Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991DVE/OEB system (Tamminga et al.1994);

SE 100% DVE -100 OEB

Table 4.11 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a **DVE supply at 100% of the requirement and OEB aimed at a level of -100 g OEB/day** in the South-East region

South-East												
Stage of lactation1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365	days PP	0-120	days AP	121-365	days PP	1-365	days PP	55 to 11	days AP	10 to 0	days AP
Day of the year	1-365		1-104;	285-365			105-284		1-104;	285-365		
Indoor/Outdoor (grazing)2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		7,9		0,0		0,0	
Grass silage (kg DM)	7,0		9,1		11,3		3,8		0,0		5,8	
Maize silage (kg DM)	2,3		1,7		0,0		2,6		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		2,7		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		6,0		0,0	
Low protein concentrate (kg/d)	6,1		8,5		4,6		6,4		0,0		0,0	
High protein concentrate (kg/d)	0,4		1,5		0,1		0,0		0,0		1,0	
Roughage (kg DM/d)	14,6		11,9		14,6		15,3		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,9		4,1		5,7		0,0		0,9	
Emission factors3)												
gCO2_EQ (g/kg)	8674	156	9658	249	8262	207	8529	121	3866	160	4633	140
EF CH4 0% maize silage (g/kg DM)	430	21,1	444,2	21,9	396	21,2	444	20,7	220	18,2	257	19,5
EF CH4 40% maize silage (g/kg DM)	427	20,9	441,1	21,8	392	21,0	440	20,6	216	17,9	252	19,1
EF CH4 80% maize silage (g/kg DM)	449	22,0	467,4	23,1	414	22,2	460	21,5	217	18,0	256	19,5
Nutrient intake and diet composition4)												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	2858	135	3070	143	2502	128	2934	138	1140	95	1546	128
Crude protein (incl NH3)	2978	141	3189	149	2653	136	3034	143	1229	102	1652	137
Crude fiber	3885	184	3704	173	3782	193	3894	184	3369	280	2441	203
Ash	1579	75	1634	76	1438	74	1614	76	1065	88	853	71
Ether extract	877	42	962	45	788	40	875	41	340	28	459	38
Water soluble carbohydrates	1300	62	1319	61	1079	55	1407	66	319	26	608	50
Starch	3082	146	2951	137	3007	154	2935	139	1397	116	1878	156
Rumen by-pass starch	821	39	765	36	814	42	781	37	383	32	524	44
NDF	8575	406	8368	390	7994	409	8736	412	6356	527	4979	413
ADF	4348	206	4191	195	4184	214	4363	206	3856	320	2667	221
ADL	395	19	435	20	369	19	384	18	458	38	242	20
Digestible OM	15422	731	15722	732	14134	723	15548	734	6915	574	8561	710
Gross energy (MJ/kg DM)	389	18,4	396	18,4	361	18,4	390	18,4	217	18,0	0	0,0
Metabolisable energy (MJ/kg)	242	11,5	249	11,6	221	11,3	243	11,5	109	9,0	0	0,0
VEM (1VEM = 6.9 kJ NEL)	20,9	992	21,6	1007	19,1	976	21,1	996	9,1	752	0,0	951
DVE	1648	78	1882	88	1409	72	1664	79	424	35	847	70
OEB	80	4	47	2	84	4	113	5	58	5	90	7
OEB-2h	420	20	419	19	476	24	387	18	319	26	314	26
FOMr	11530	546	11622	541	10566	540	11686	551	5290	439	6349	527
FOMr-2h	5269	250	5394	251	4941	253	5233	247	2133	177	2965	246
DVE91	1694	80	1905	89	1472	75	1709	81	538	45	899	75
OEB91	-11	-1	-9	0	-27	-1	20	1	68	6	2	0
FOM91	11992	568	12102	564	10861	555	12247	578	4226	351	6458	536
	0	0	0	0	0	0	0	0				
Digestible crude protein	1959	93	2158	101	1677	86	2029	96	670	56	1036	86
Phosphorus	77	3,7	90	4	68	3,5	76	3,6	28	2	39	3,2
Milk production												
Milk (kg/d)	26,1		31,9		21,9		26,3					
Fat (g/d)	1193		1440		1023		1198					
Protein (g/d)	927		1081		816		932					
Fat%	4,57		4,52		4,66		4,55					
Protein %	3,55		3,39		3,72		3,54					
FPCM (kg/d)	28,2		33,9		24,2		28,4					
kVEM requirement (/d)	19,0		22,3		17,5		19,6					
DVE requirement (g/d)	1583		1859		1391		1593					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91 Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991 DVE/OEB system (Tamminga et al.1994);

SE 100% DVE -500 OEB

Table 4.12 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a **DVE supply at 100% of the requirement and OEB aimed at a level of -500 g OEB/day** in the South-East region

South-East												
Stage of lactation[1)]	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)[2)]	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		0,0		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		7,8		0,0		0,0	
Grass silage (kg DM)	7,0		9,1		11,2		3,8		0,0		5,8	
Maize silage (kg DM)	2,3		1,7		2,8		2,6		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		2,7		0,0	
Herb rich grass silage	6,1		0,0		0,0		0,0		6,0		0,0	
Low protein concentrate (kg/d)	0,4		6,2		2,5		6,4		0,0		0,0	
High protein concentrate (kg/d)	0,0		3,9		1,8		0,1		0,0		1,0	
Roughage (kg DM/d)	14,6		11,9		15,0		15,3		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,9		3,8		5,7		0,0		0,9	
Emission factors[3)]												
gCO2_EQ (g/kg)	7833	151	9054	211	7152	160	7674	133	3866	160	4633	140
EF CH4 0% maize silage (g/kg DM)	447	21,2	473,5	22,0	405	20,7	448	21,1	220	18,2	257	19,5
EF CH4 40% maize silage (g/kg DM)	440	20,8	467,1	21,7	398	20,4	442	20,8	216	17,9	252	19,1
EF CH4 80% maize silage (g/kg DM)	454	21,5	487,4	22,7	409	20,9	456	21,5	217	18,0	256	19,5
Nutrient intake and diet composition[4)]												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	2660	126	2799	130	2380	122	2722	128	1140	95	1546	128
Crude protein (incl NH3)	2780	132	2917	136	2531	129	2822	133	1229	102	1652	137
Crude fiber	4023	190	3893	181	3867	198	4042	191	3369	280	2441	203
Ash	1579	75	1634	76	1438	73	1614	76	1065	88	853	71
Ether extract	763	36	806	38	718	37	753	35	340	28	459	38
Water soluble carbohydrates	1348	64	1385	64	1108	57	1458	69	319	26	608	50
Starch	3082	146	2951	137	3007	154	2935	138	1397	116	1878	156
Rumen by-pass starch	875	41	839	39	847	43	838	40	383	32	524	44
NDF	8554	405	8339	388	7982	408	8714	411	6356	527	4979	413
ADF	4484	212	4378	204	4269	218	4510	213	3856	320	2667	221
ADL	381	18	417	19	361	18	369	17	458	38	242	20
Digestible OM	15551	736	15900	740	14214	727	15688	740	6915	574	8561	710
Gross energy (MJ/kg DM)	386	18,3	392	18,3	359	18,4	387	18,2	217	18,0	222	18,4
Metabolisable energy (MJ/kg)	242	11,4	249	11,6	221	11,3	243	11,5	109	9,0	134	11,1
VEM (1VEM = 6.9 kJ NEL)	20,9	992	21,6	1006	19,1	975	21,1	995	9,1	752	11,5	951
DVE	1648	78	1882	88	1409	72	1664	78	424	35	847	70
OEB	-128	-6	-239	-11	-45	-2	-111	-5	58	5	90	7
OEB-2h	301	14	255	12	403	21	259	12	319	26	314	26
FOMr	11650	552	11787	549	10641	544	11815	557	5290	439	6349	527
FOMr-2h	5150	244	5230	243	4867	249	5105	241	2133	177	2965	246
DVE91	1697	80	1909	89	1473	75	1712	81	538	45	899	75
OEB91	-215	-10	-289	-13	-153	-8	-199	-9	68	6	2	0
FOM91	12196	577	12382	576	10987	562	12465	588	4226	351	6458	536
	0	0	0	0	0	0	0	0	0	0	0	0
Digestible crude protein	1775	84	1905	89	1563	80	1831	86	670	56	1036	86
Phosphorus	61	2,9	68	3	58	2,9	59	2,8	28	2	39	3,2
Milk production												
Milk (kg/d)	25,4		30,8		20,9		25,9					
Fat (g/d)	1161		1394		974		1180					
Protein (g/d)	902		1048		777		919					
Fat%	4,57		4,52		4,66		4,56					
Protein %	3,55		3,40		3,72		3,55					
FPCM (kg/d)	27,4		32,8		23,0		27,9					
kVEM requirement (/d)	18,6		21,7		17,0		19,3					
DVE requirement (g/d)	1540		1798		1325		1569					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91 Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991 DVE/OEB system (Tamminga et al.1994);

SE 90% DVE -100 OEB

Table 4.13 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a DVE supply **of 90% the requirement aimed at a OEB level of -100 g OEB/day** in the South-East region

South-East												
Stage of lactation 1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365	days PP	0-120	days AP	121-365	days PP	1-365	days PP	55 to 11	days AP	10 to 0	days AP
Day of the year	1-365		1-104;	285-365			105-284		1-104;	285-365		
Indoor/Outdoor (grazing) 2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		8,1		8,1		0,0		0,0	
Grass silage (kg DM)	7,0		9,0		4,0		4,0		0,0		5,8	
Maize silage (kg DM)	2,3		1,8		2,6		2,6		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		2,7		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		6,0		0,0	
Low protein concentrate (kg/d)	6,4		8,7		6,5		6,5		0,0		0,0	
High protein concentrate (kg/d)	0,1		0,8		0,0		0,0		0,0		1,0	
Roughage (kg DM/d)	14,7		11,9		15,7		15,7		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,3		5,7		5,7		0,0		0,9	
Emission factors 3)												
gCO2_EQ (g/kg)	8976	173	10564	246	7799	174	8959	156	3866	160	3704	104
EF CH4 0% maize silage (g/kg DM)	439	20,8	463,0	21,6	401	20,5	438	20,7	220	18,2	254	19,3
EF CH4 40% maize silage (g/kg DM)	432	20,4	456,8	21,3	394	20,2	432	20,4	216	17,9	246	18,7
EF CH4 80% maize silage (g/kg DM)	444	21,0	474,4	22,1	404	20,7	444	20,9	217	18,0	243	18,5
Nutrient intake and diet composition 4)												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	2774	131	2898	135	2395	122	2895	137	1140	95	1219	101
Crude protein (incl NH3)	2894	137	3017	140	2546	130	2996	141	1229	102	1312	109
Crude fiber	3897	185	3728	174	3797	194	3900	184	3369	280	2386	198
Ash	1580	75	1636	76	1439	74	1614	76	1065	88	704	58
Ether extract	870	41	948	44	779	40	872	41	340	28	422	35
Water soluble carbohydrates	1299	62	1318	61	1078	55	1407	66	319	26	443	37
Starch	3111	147	3009	140	3043	156	2948	139	1397	116	2742	228
Rumen by-pass starch	828	39	780	36	823	42	784	37	383	32	767	64
NDF	8616	408	8452	394	8047	411	8755	413	6356	527	4885	405
ADF	4345	206	4186	195	4181	214	4362	206	3856	320	2606	216
ADL	376	18	397	18	345	18	375	18	458	38	209	17
Digestible OM	15437	731	15754	734	14153	724	15555	734	6915	574	8714	723
Gross energy (MJ/kg DM)	388	18,4	394	18,4	360	18,4	389	18,4	217	18,0	224	18,6
Metabolisable energy (MJ/kg)	242	11,5	249	11,6	221	11,3	243	11,5	109	9,0	135	11,2
kVEM (1kVEM = 6.9 MJ NEL)	20,9	992	21,6	1007	19,1	976	21,1	996	9,1	752	11,6	963
DVE	1591	75	1765	82	1336	68	1637	77	424	35	713	59
OEB	55	3	-5	0	52	3	102	5	58	5	-110	-9
OEB-2h	420	20	418	19	476	24	387	18	319	26	216	18
FOMr	11598	549	11762	548	10653	545	11717	553	5290	439	6438	534
FOMr-2h	5296	251	5448	254	4975	254	5245	248	2133	177	3044	253
DVE91	1638	78	1789	83	1400	72	1683	79	538	45	748	62
OEB91	-36	-2	-61	-3	-60	-3	8	0	68	6	-168	-14
FOM91	12087	573	12297	573	10982	562	12290	580	4226	351	6468	537
	0	0	0	0	0	0	0	0	0	0	0	0
Digestible crude protein	1881	89	1998	93	1577	81	1993	94	670	56	705	58
Phosphorus	75	3,6	86	4,0	65	3,3	75	3,6	28	2,3	31	2,5
Milk production												
Milk (kg/d)	25,8		31,2		21,5		26,1					
Fat (g/d)	1179		1412		1002		1188					
Protein (g/d)	916		1061		799		925					
Fat%	4,57		4,52		4,66		4,55					
Protein %	3,55		3,40		3,72		3,54					
FPCM (kg/d)	27,9		33,3		23,7		28,1					
kVEM requirement (/d)	18,8		21,9		17,3		19,4					
DVE requirement (g/d)	1564		1822		1362		1579					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991DVE/OEB system (Tamminga et al.1994);

SE 90% DVE -500 OEB

Table 4.14 Appendix. Simulated feed intake, emission factors, nutrient intake, diet composition and milk production specified for different stages of lactation during indoor and outdoor season for the scenario with a **DVE supply at 90% of the requirement and OEB aimed at a level of -500 g OEB/day** in the South-East region

South-East												
Stage of lactation1)	N.S.		Early		Mid-Late		N.S.		Dry, Far-off		Dry, Close-up	
Days in milk	1-365 days PP		0-120 days AP		121-365 days PP		1-365 days PP		55 to 11 days AP		10 to 0 days AP	
Day of the year	1-365		1-104; 285-365				105-284		1-104; 285-365			
Indoor/Outdoor (grazing)2)	N.S.		Indoors		Indoors		Outdoor		Indoors		Indoors	
Wet by-products (kg DM)	1,1		1,1		1,1		1,1		0,0		1,1	
Grazed grass	4,2		0,0		0,0		8,1		0,0		0,0	
Grass silage (kg DM)	7,0		9,0		11,3		4,0		0,0		5,8	
Maize silage (kg DM)	2,3		1,8		2,2		2,6		3,9		5,4	
Wheat straw	0,0		0,0		0,0		0,0		2,7		0,0	
Herb rich grass silage	0,0		0,0		0,0		0,0		6,0		0,0	
Low protein concentrate (kg/d)	6,4		8,7		4,7		6,5		0,0		0,0	
High protein concentrate (kg/d)	0,1		0,8		0,0		0,0		0,0		1,0	
Roughage (kg DM/d)	14,7		11,9		14,6		15,7		12,1		12,3	
Concentrates (kg DM/d)	5,8		8,3		4,1		5,7		0,0		0,9	
Emission factors3)												
gCO2_EQ (g/kg)	7624	147	8625	201	6885	154	7577	132	3866	160	3704	104
EF CH4 0% maize silage (g/kg DM)	450	21,3	479,2	22,3	409	20,9	450	21,2	220	18,2	254	19,3
EF CH4 40% maize silage (g/kg DM)	443	20,9	472,5	22,0	402	20,5	443	20,9	216	17,9	246	18,7
EF CH4 80% maize silage (g/kg DM)	456	21,6	492,7	22,9	413	21,1	457	21,5	217	18,0	243	18,5
Nutrient intake and diet composition4)												
	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM	Intake g/day	Diet g/kg DM
Crude protein	2557	121	2587	120	2248	115	2674	126	1140	95	1219	101
Crude protein (incl NH3)	2677	127	2706	126	2399	123	2774	131	1229	102	1312	109
Crude fiber	4048	192	3944	184	3899	199	4054	191	3369	280	2386	198
Ash	1580	75	1636	76	1439	74	1614	76	1065	88	704	58
Ether extract	746	35	770	36	695	36	744	35	340	28	422	35
Water soluble carbohydrates	1352	64	1394	65	1114	57	1460	69	319	26	443	37
Starch	3111	147	3009	140	3043	156	2948	139	1397	116	2742	228
Rumen by-pass starch	887	42	865	40	863	44	844	40	383	32	767	64
NDF	8593	407	8420	392	8031	410	8732	412	6356	527	4885	405
ADF	4495	213	4401	205	4283	219	4515	213	3856	320	2606	216
ADL	361	17	375	17	335	17	360	17	458	38	209	17
Digestible OM	15580	737	15958	743	14250	728	15701	740	6915	574	8714	723
Gross energy (MJ/kg DM)	385	18,2	390	18,2	358	18,3	386	18,2	217	18,0	224	18,6
Metabolisable energy (MJ/kg)	242	11,4	248	11,6	221	11,3	243	11,5	109	9,0	135	11,2
kVEM (1kVEM = 6.9 MJ NEL)	20,9	992	21,6	1006	19,1	975	21,1	995	9,1	752	11,6	963
DVE	1591	75	1765	82	1336	68	1637	77	424	35	713	59
OEB	-173	-8	-332	-15	-103	-5	-132	-6	58	5	-110	-9
OEB-2h	289	14	231	11	388	20	253	12	319	26	216	18
FOMr	11730	555	11951	556	10742	549	11852	559	5290	439	6438	534
FOMr-2h	5165	244	5261	245	4886	250	5112	241	2133	177	3044	253
DVE91	1641	78	1794	83	1402	72	1686	80	538	45	748	62
OEB91	-260	-12	-382	-18	-211	-11	-220	-10	68	6	-168	-14
FOM91	12310	583	12617	587	11133	569	12518	590	4226	351	6468	537
	0	0	0	0	0	0	0	0	0	0	0	0
Digestible crude protein	1679	79	1708	79	1441	74	1786	84	670	56	705	58
Phosphorus	57	2,7	60	2,8	53	2,7	57	2,7	28	2,3	31	2,5
Milk production												
Milk (kg/d)	25,2		30,4		21,2		25,5					
Fat (g/d)	1154		1375		990		1163					
Protein (g/d)	897		1034		791		906					
Fat%	4,57		4,52		4,66		4,55					
Protein %	3,55		3,40		3,72		3,55					
FPCM (kg/d)	27,3		32,4		23,4		27,5					
kVEM requirement (/d)	18,5		21,5		17,2		19,2					
DVE requirement (g/d)	1530		1773		1347		1546					

1) N.S. not specified includes all lactating cows regardless stage of lactation

2) N.S. not specified includes all lactating cows regardless indoor or door season (grazing)

3) gCO2_EQ CO2 equivalents calculated from the intake of each feed (kg) and CO2 carbonfoot print from NEVEDI 2022 (concentrate ingredients) and roughages (ANCA kringloopw

4) All values in g (intake) or g/kg DM (diet composition), except for Gross energy (MJ and MJ/kg DM), Metabolisable energy (MJ and MJ/kg DM),VEM (no dimensions and VEM/kg DM); Ether extract, exctration withe petroleum ether.(ISO 6492, 1999), Starch analyzed using amyloglucosidase (ISO/DIS 15914, 2004); DVE = Intestinal digestible protein, OEB = rumen degradable protein balance, OEB-2h = rumen degradable protein balance within 2 h after intake, FOMr = rumen rumen fermentable organic matter, FOMr-2 = rumen rumen fermentable organic matter within 2 h after intake (van Duinkerken et al. 2010;Centraal Veevoeder Bureau, 2022), DVE91Intestinal digestible protein, FOM91= rumen rumen fermentable organic matter OEB91= rumen degradable protein balance according to the 1991DVE/OEB system (Tamminga et al.1994);

Appendix 5 Course of TDMI, CP and OEB over lactation period

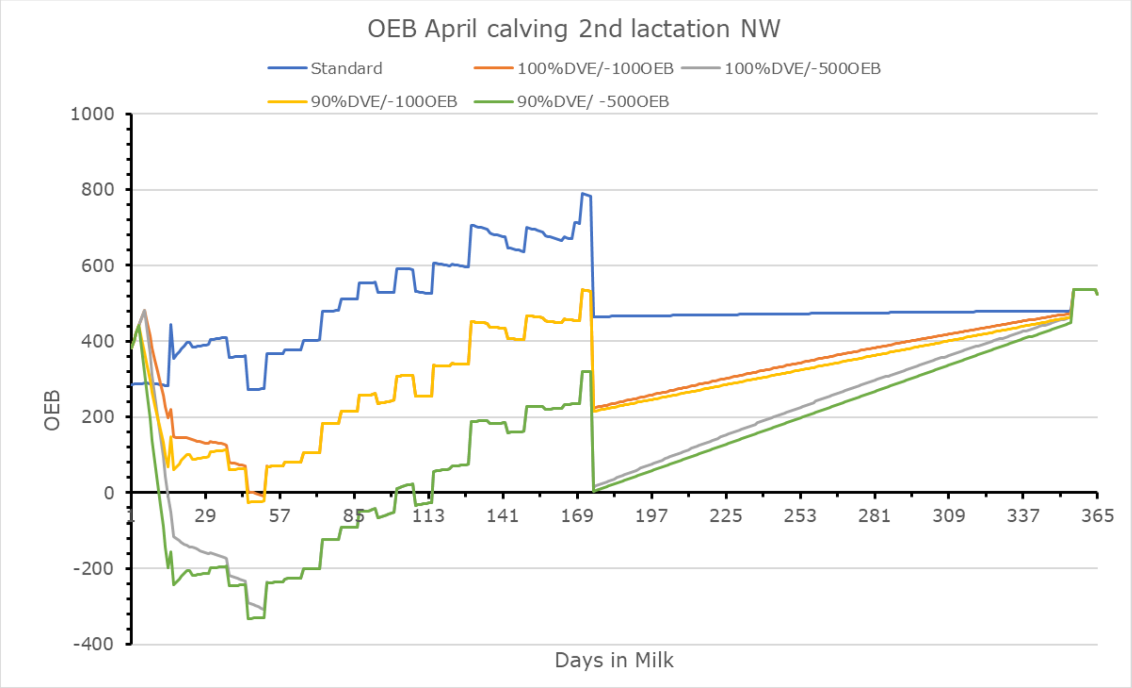

Figure 19 *Course of the degradable protein balance over the second lactation period for cows calving in April in the NW scenarios.*

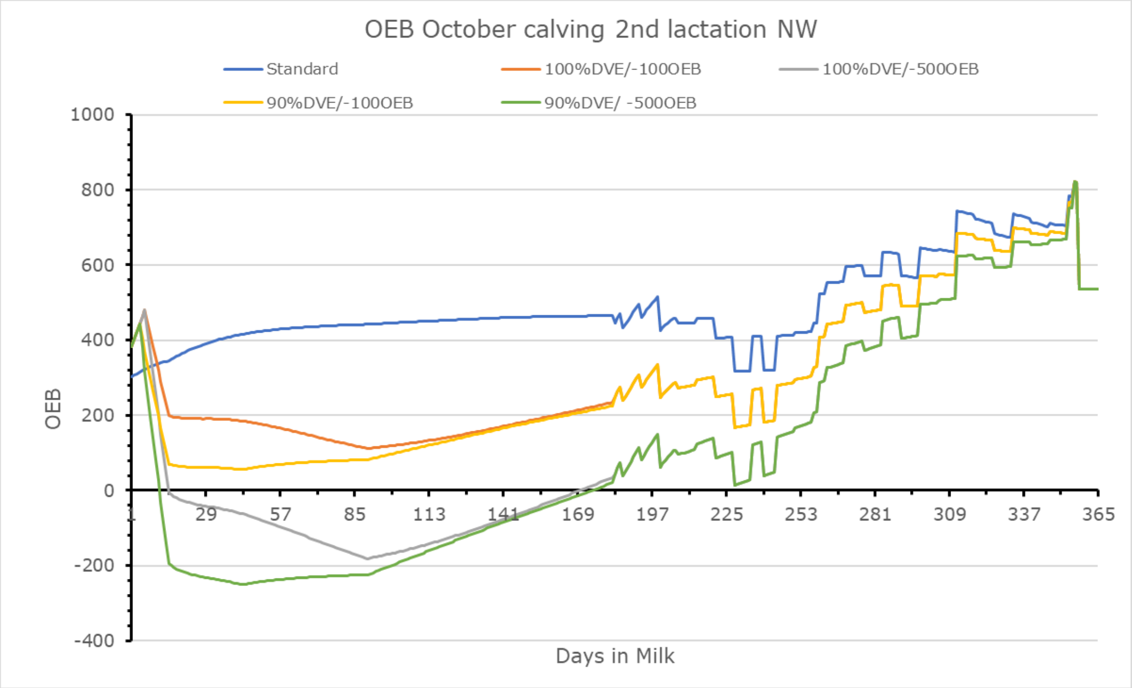

Figure 20 *Course of the degradable protein balance over the second lactation period for cows calving in October in the NW scenarios.*

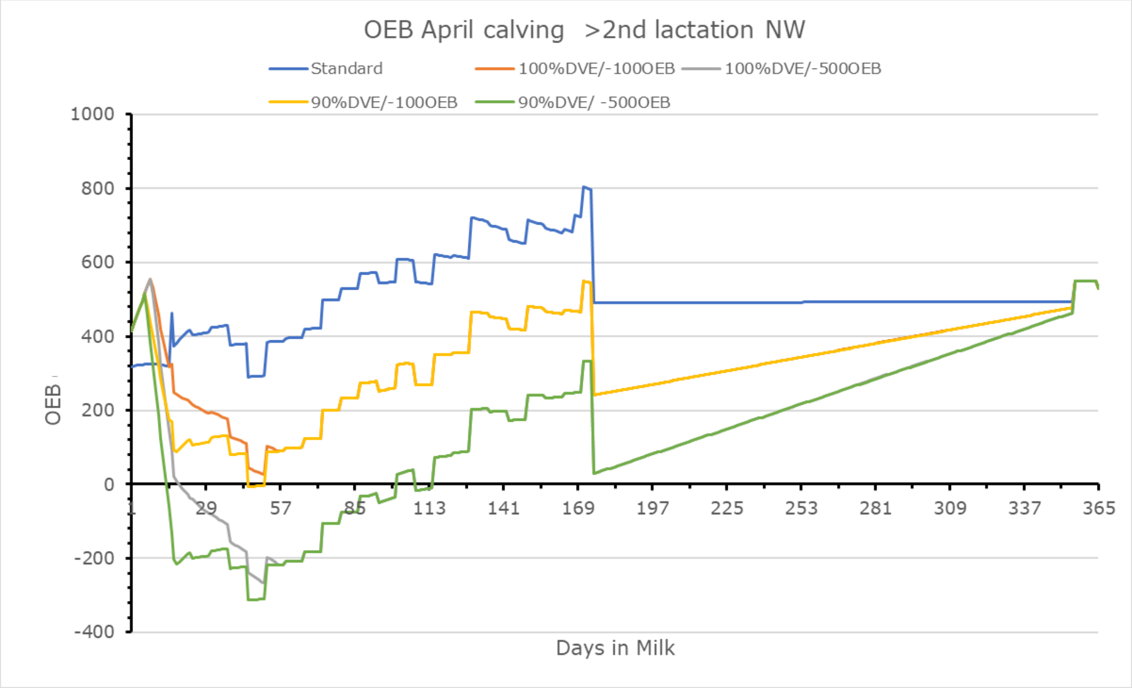

Figure 21 *Course of the degradable protein balance over the >second lactation period for cows calving in April in the NW scenarios.*

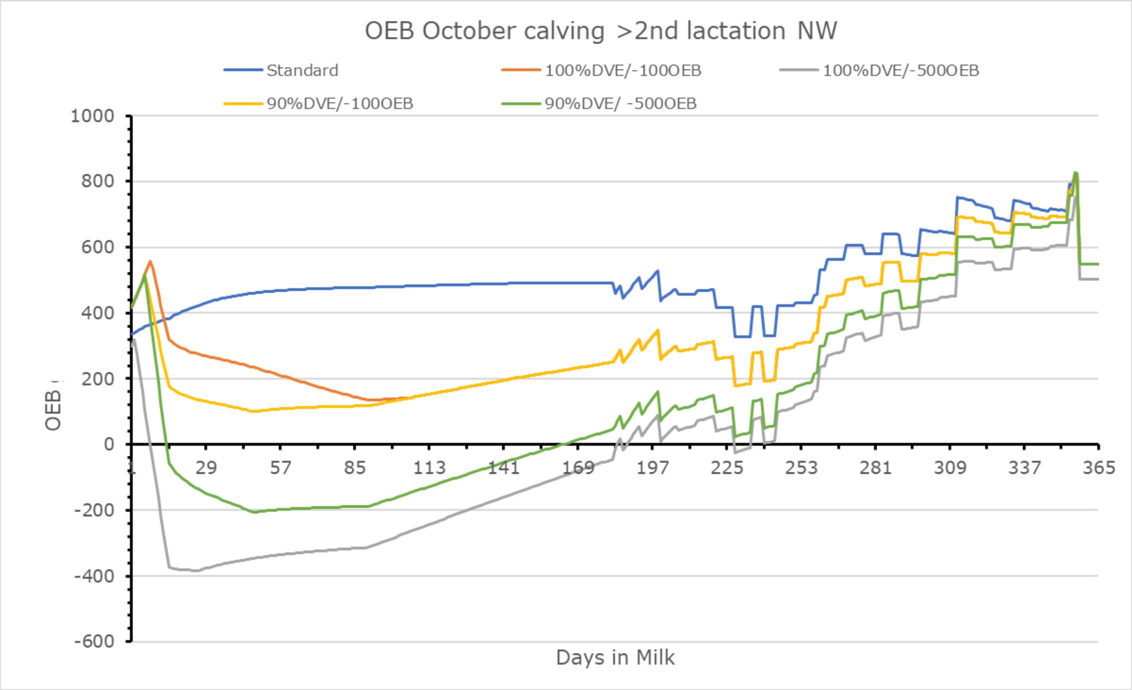

Figure 22 *Course of the degradable protein balance over the >second lactation period for cows calving in October in the NW scenarios.*

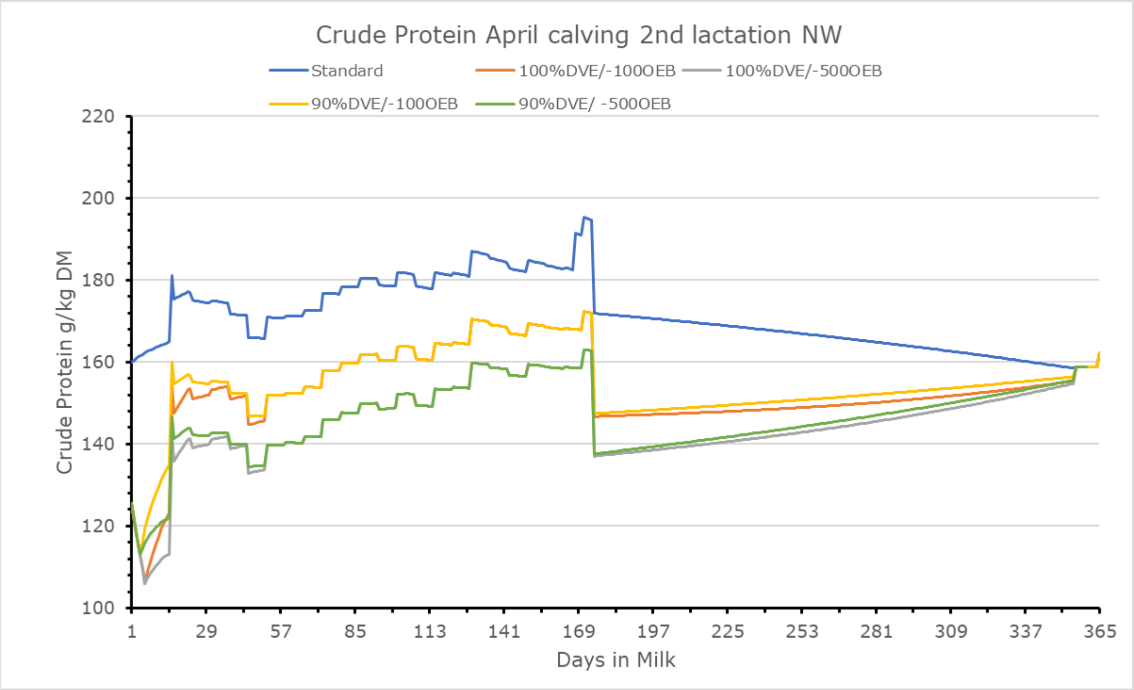

Figure 23 *Course of crude protein level (expressed in g/kg DM) over the second lactation period for cows calving in April in the NW scenarios.*

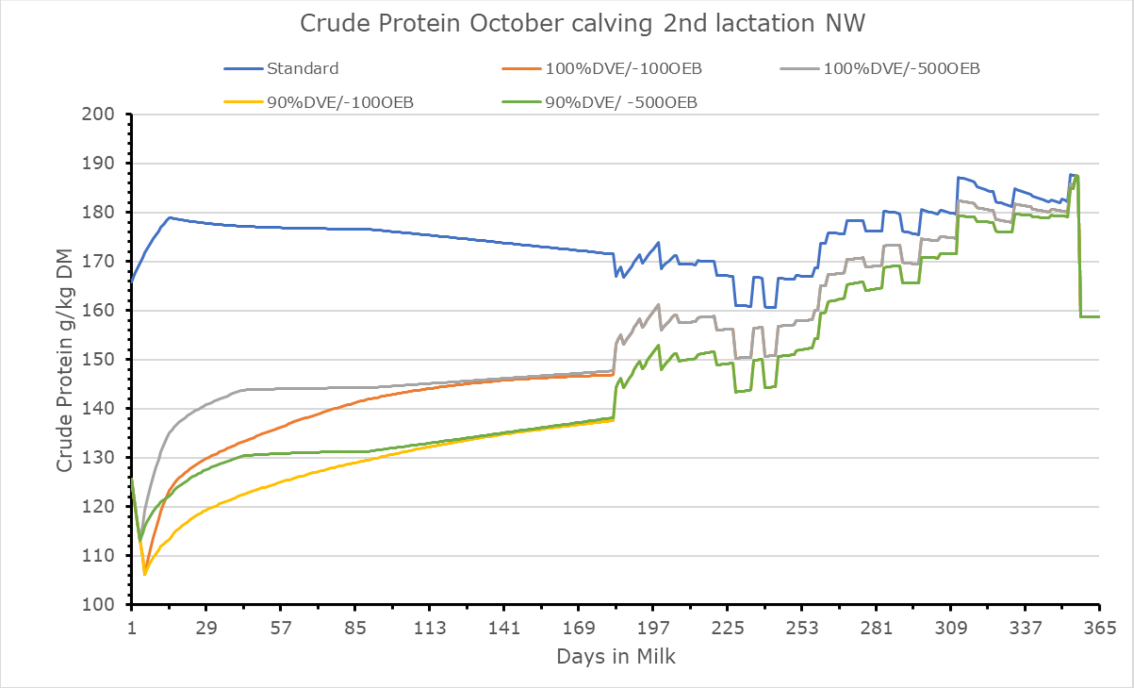

Figure 24 *Course of crude protein level (expressed in g/kg DM) over the second lactation period for cows calving in October in the NW scenarios.*

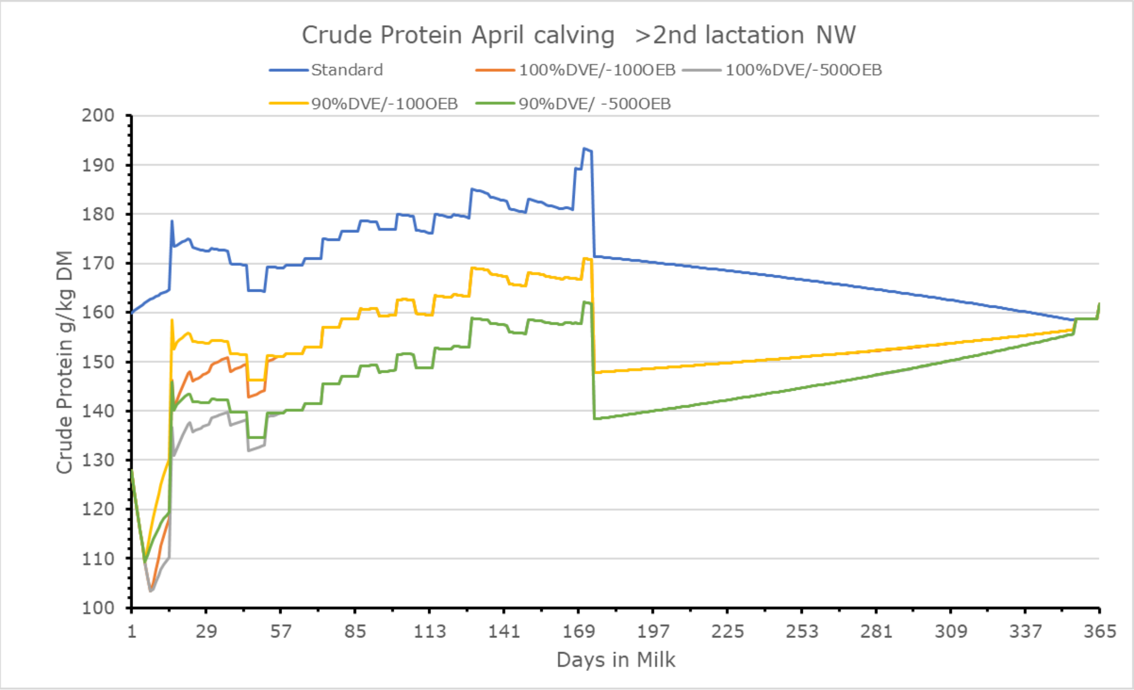

Figure 25 *Course of crude protein level (expressed in g/kg DM) over the >second lactation period for cows calving in April in the NW scenarios.*

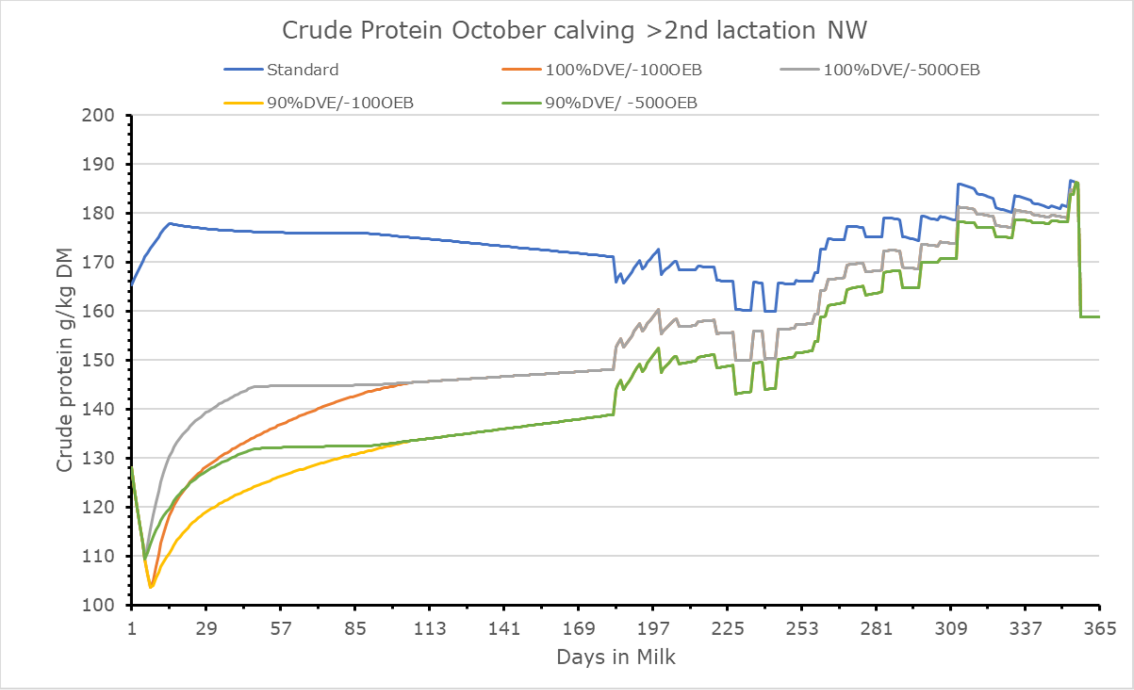

Figure 26 *Course of crude protein level (expressed in g/kg DM) over the >second lactation period for cows calving in October in the NW scenarios.*

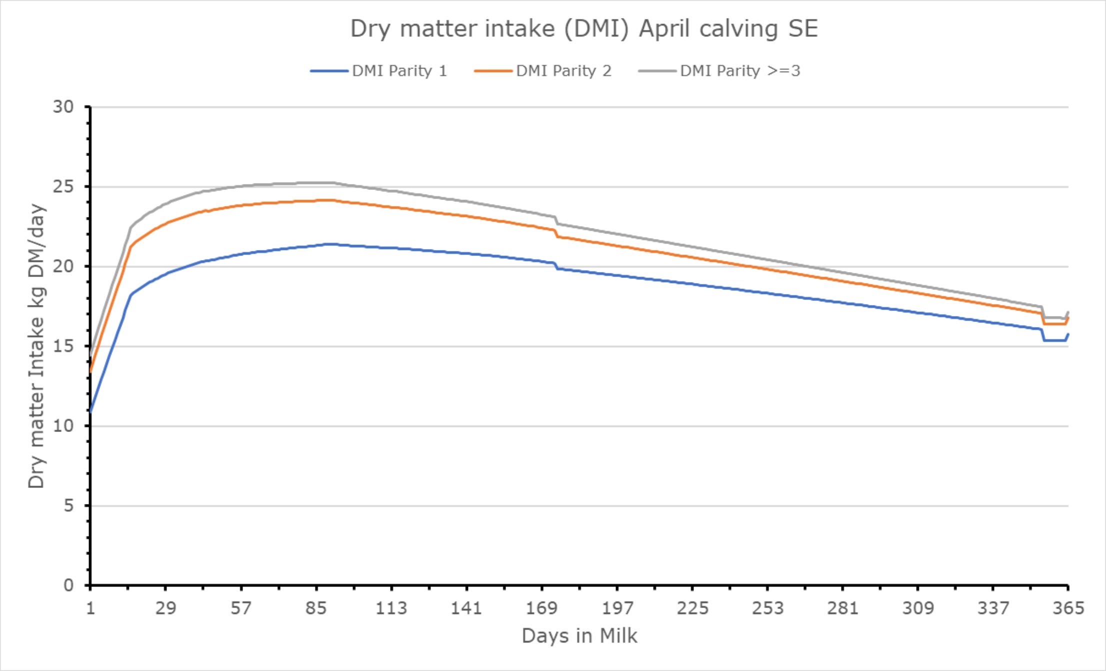

Figure 27 *Course of dry matter intake(expressed in kg DM/day) over the first lactation period for cows calving in April in the SE scenarios.*

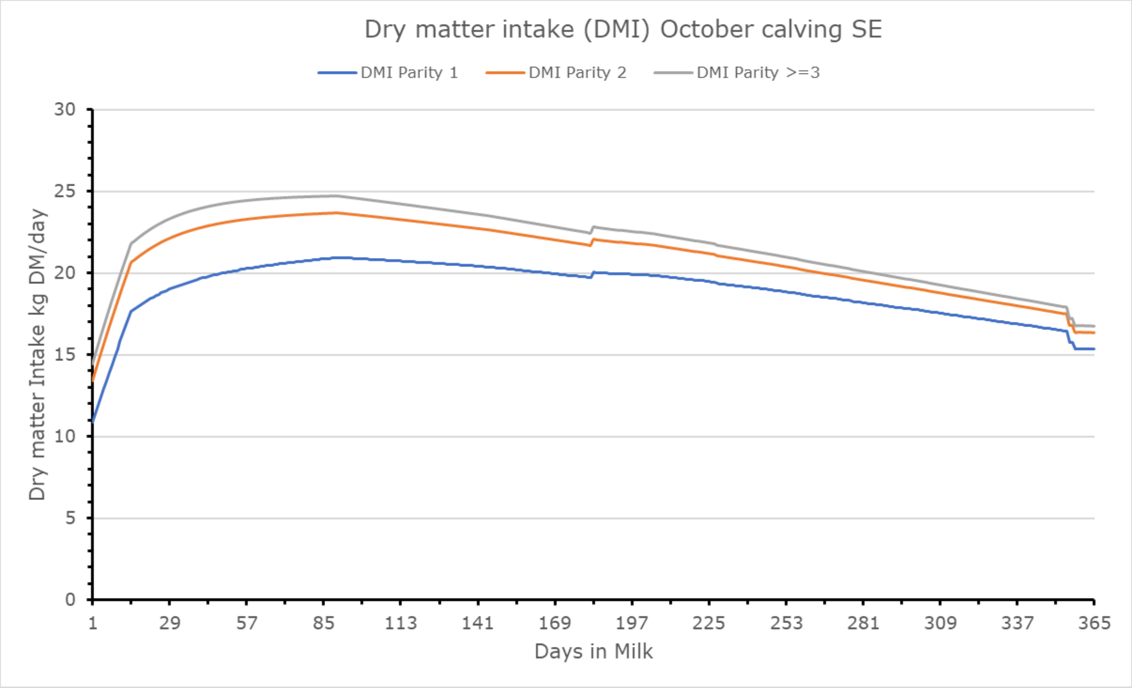

Figure 28 *Course of dry matter intake(expressed in kg DM/day) over the first lactation period for cows calving in October in the SE scenarios.*

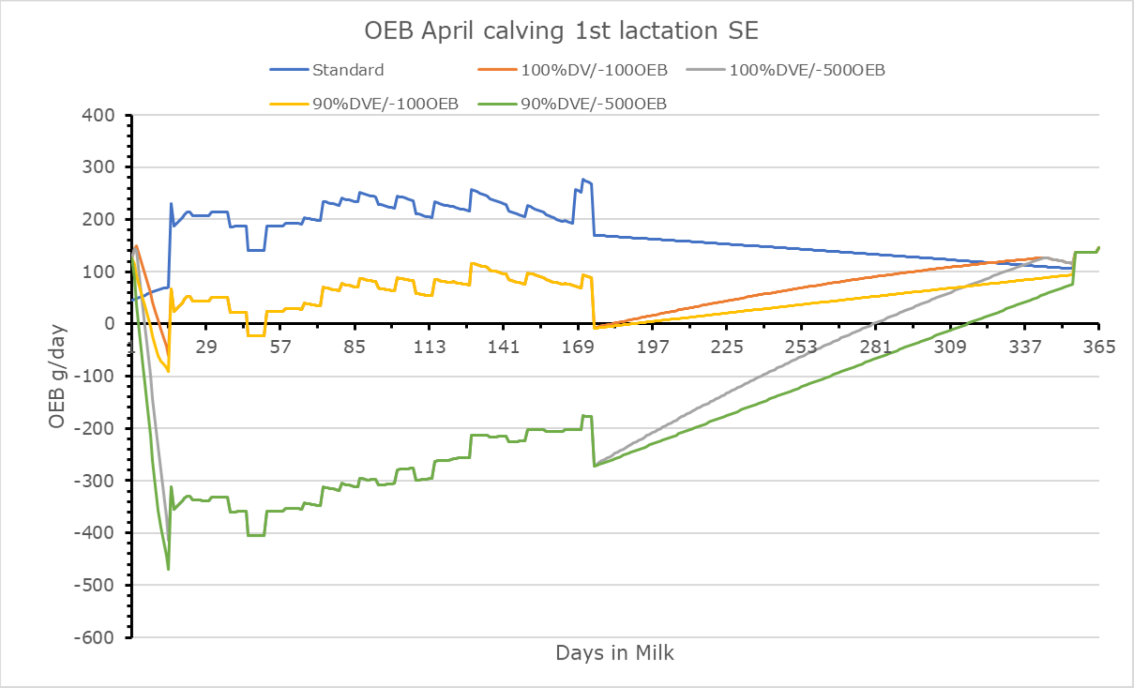

Figure 29 *Course of the degradable protein balance over the first lactation period for cows calving in April in the SE scenarios.*

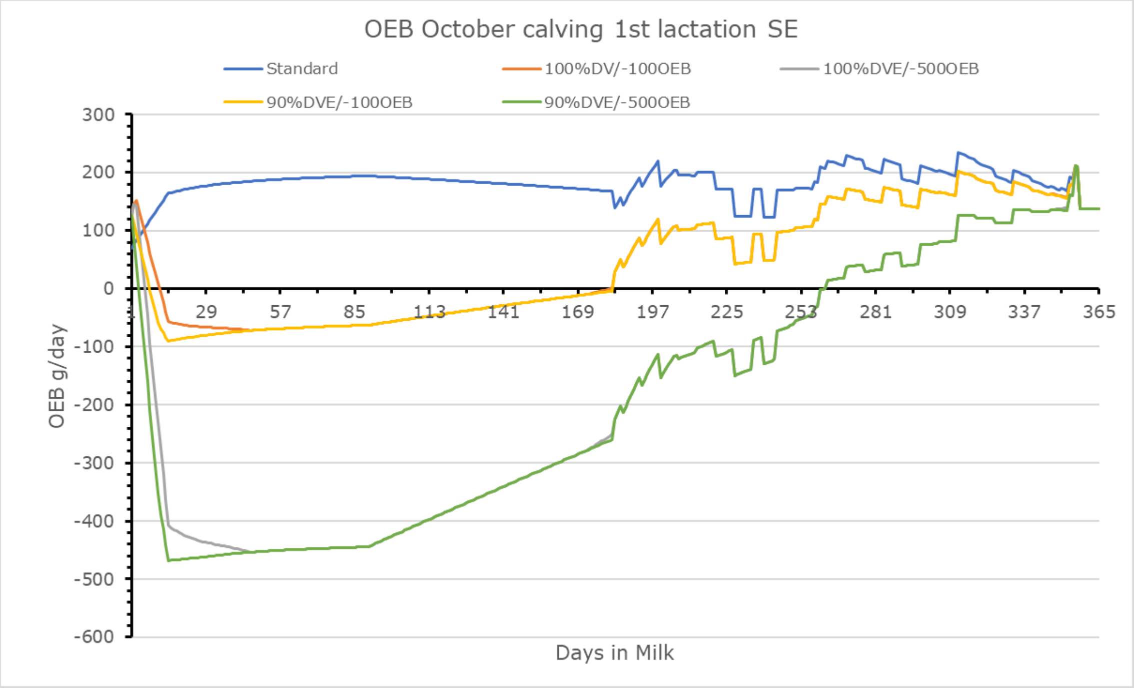

Figure 30 *Course of the degradable protein balance over the first lactation period for cows calving in October in the SE scenarios.*

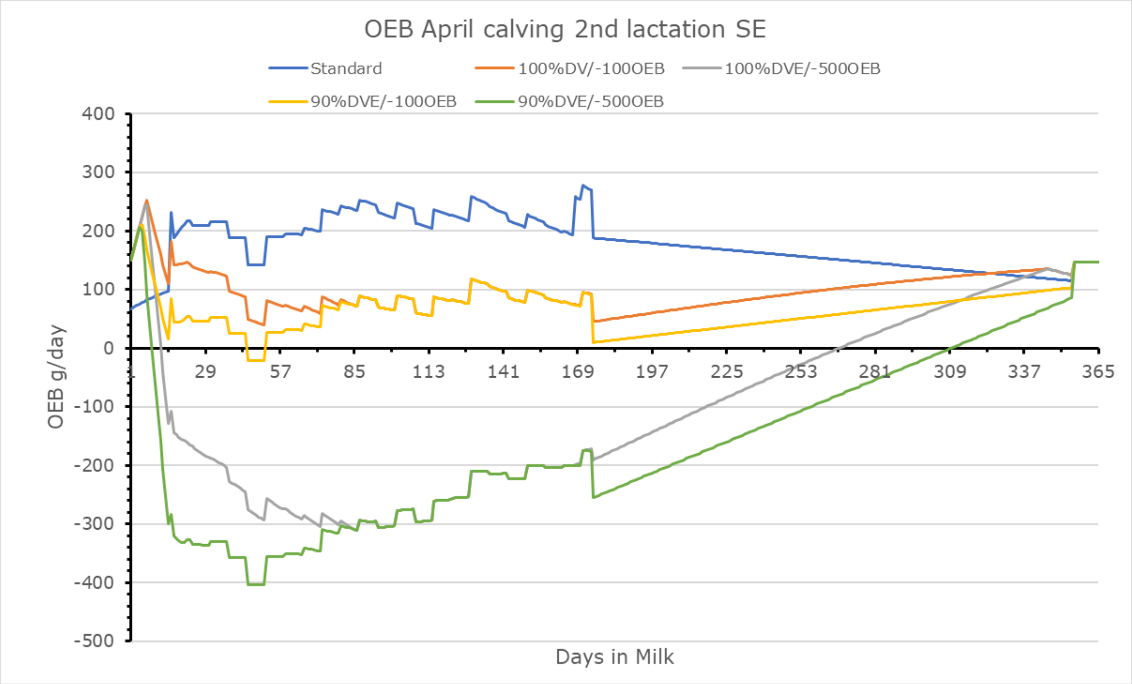

Figure 31 *Course of the degradable protein balance over the second lactation period for cows calving in April in the SE scenarios.*

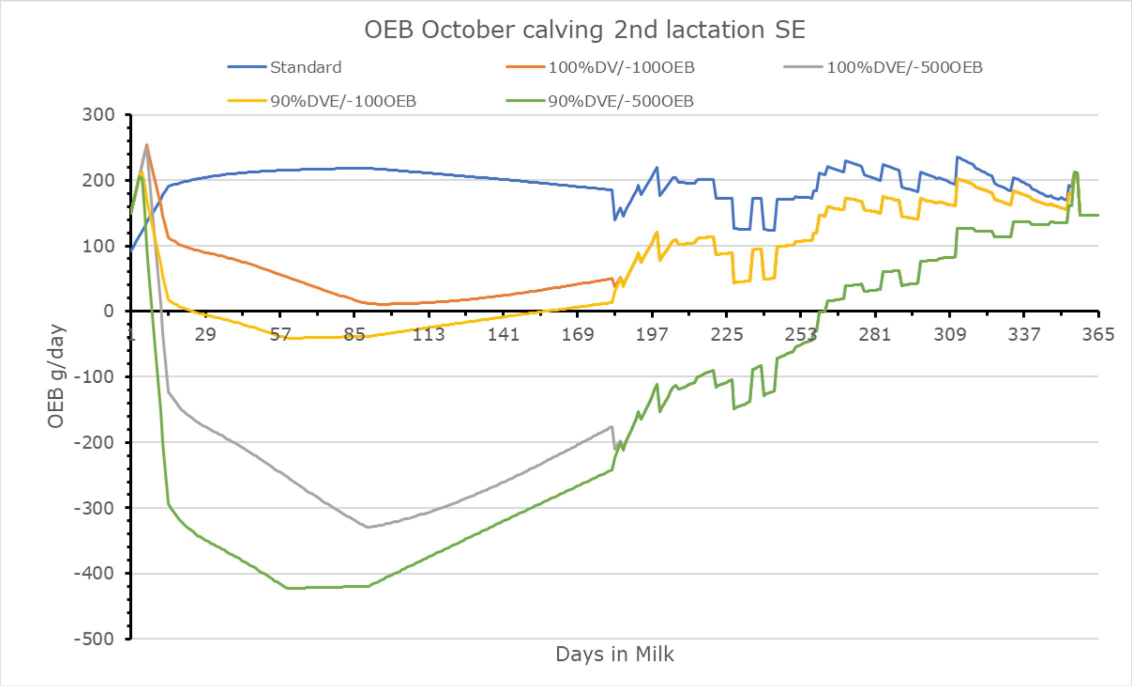

Figure 32 *Course of the degradable protein balance over the second lactation period for cows calving in October in the SE scenarios.*

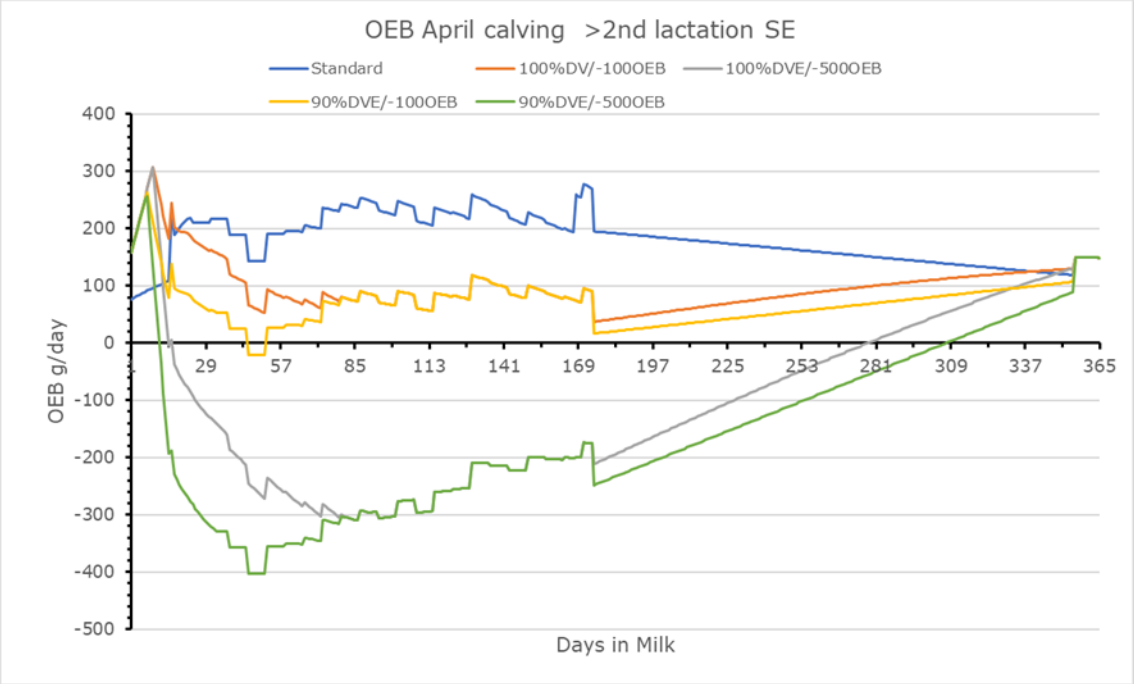

Figure 33 *Course of the degradable protein balance over the >second lactation period for cows calving in April in the SE scenarios.*

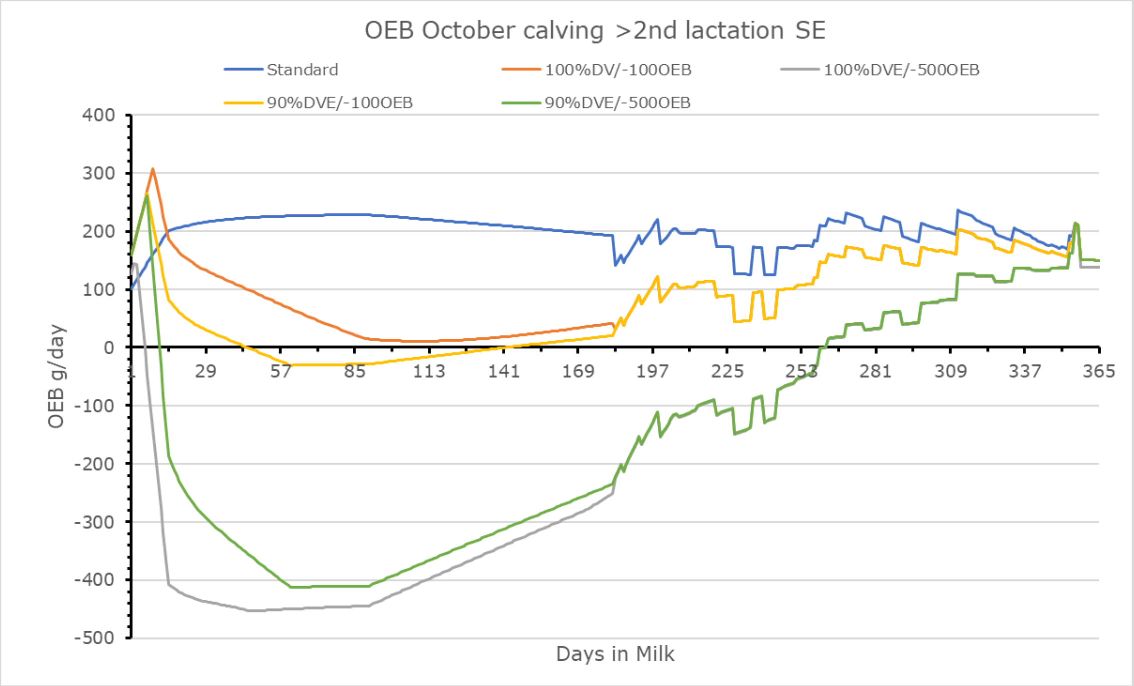

Figure 34 *Course of the degradable protein balance over the >second lactation period for cows calving in October in the SE scenarios.*

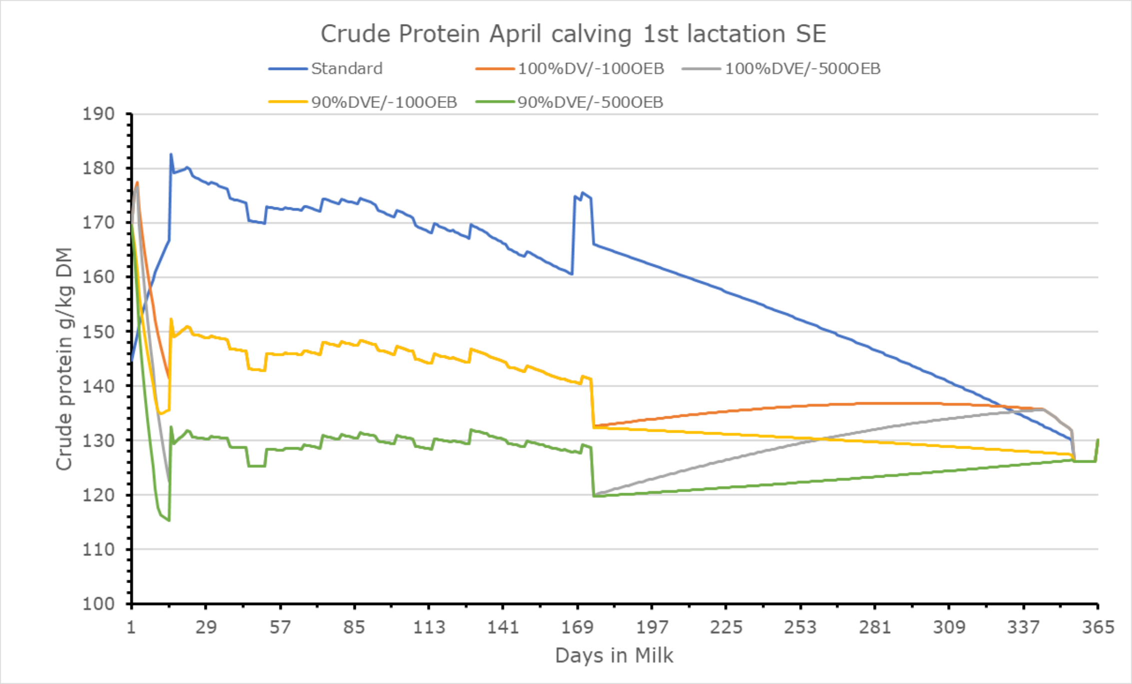

Figure 35 *Course of crude protein level (expressed in g/kg DM) over the first lactation period for cows calving in April in the SE scenarios.*

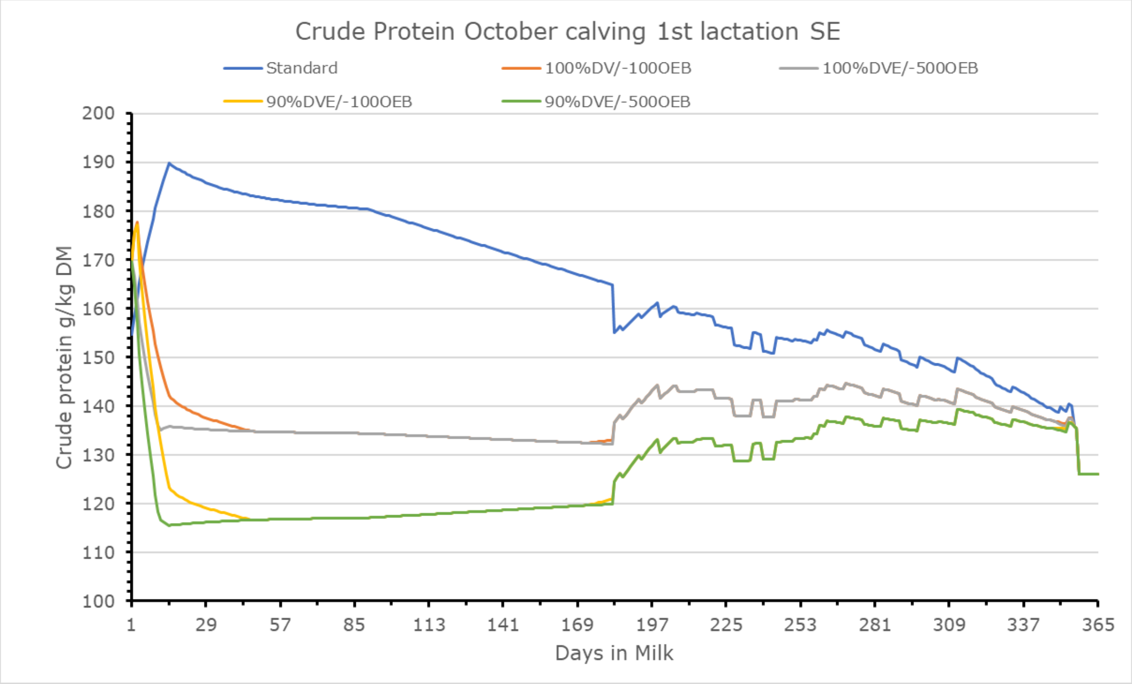

Figure 36 *Course of crude protein level (expressed in g/kg DM) over the first lactation period for cows calving in October in the SE scenarios.*

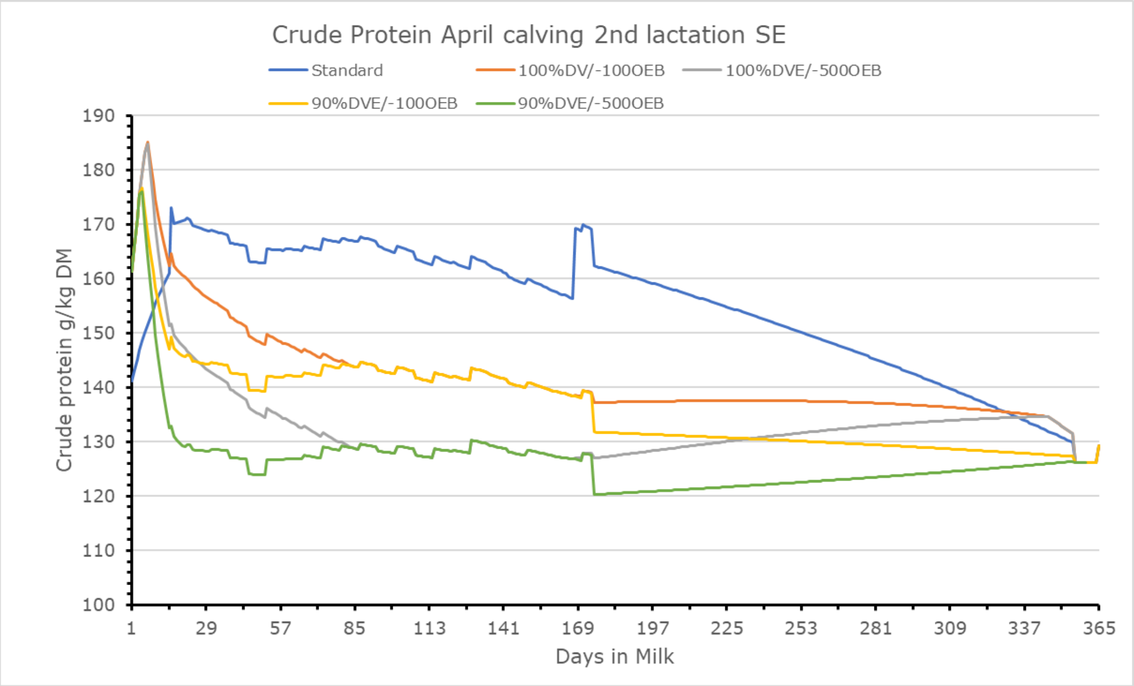

Figure 37 *Course of crude protein level (expressed in g/kg DM) over the second lactation period for cows calving in April in the SE scenarios.*

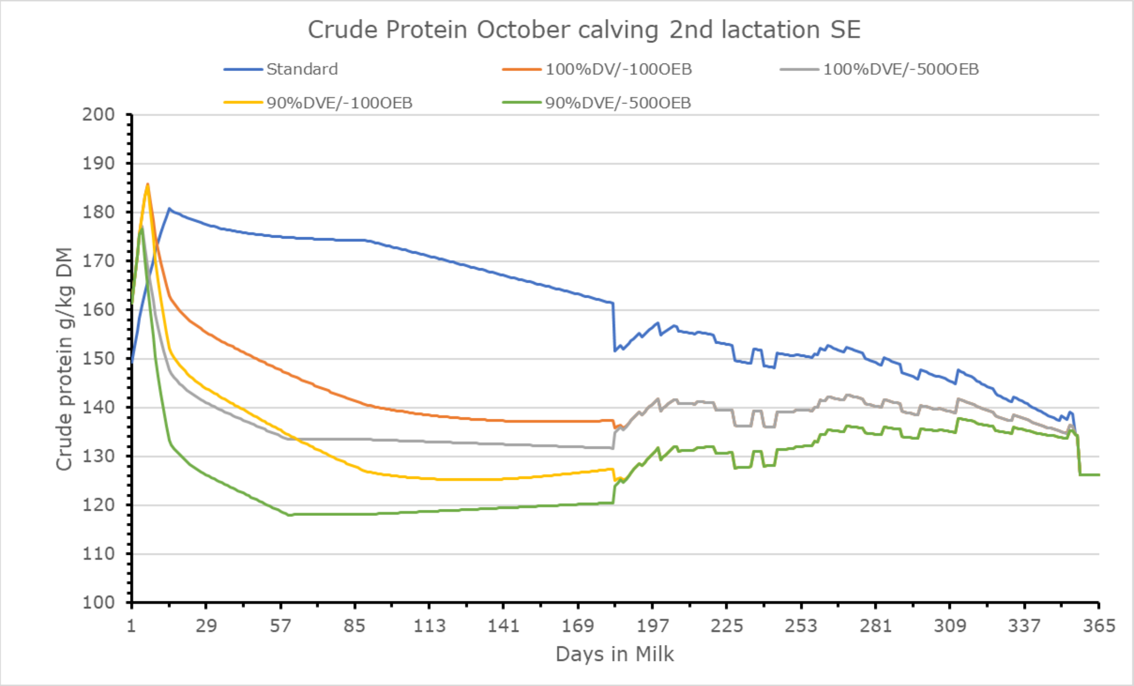

Figure 38 *Course of crude protein level (expressed in g/kg DM) over the second lactation period for cows calving in October in the SE scenarios.*

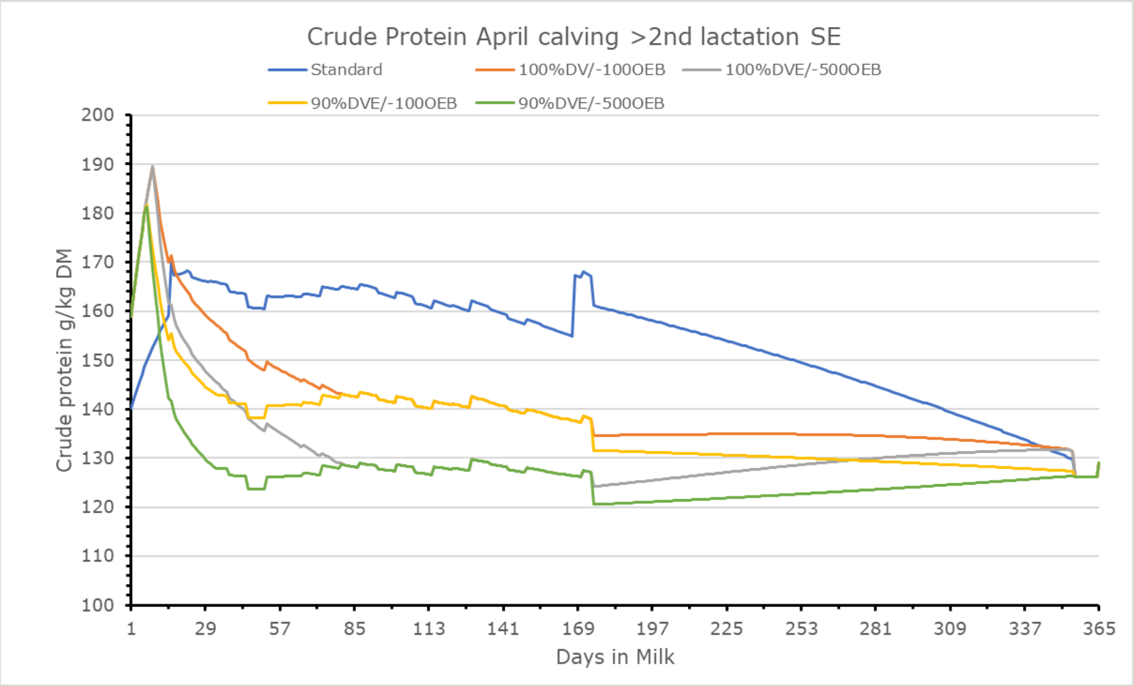

Figure 39 *Course of crude protein level (expressed in g/kg DM) over the >second lactation period for cows calving in April in the SE scenarios.*

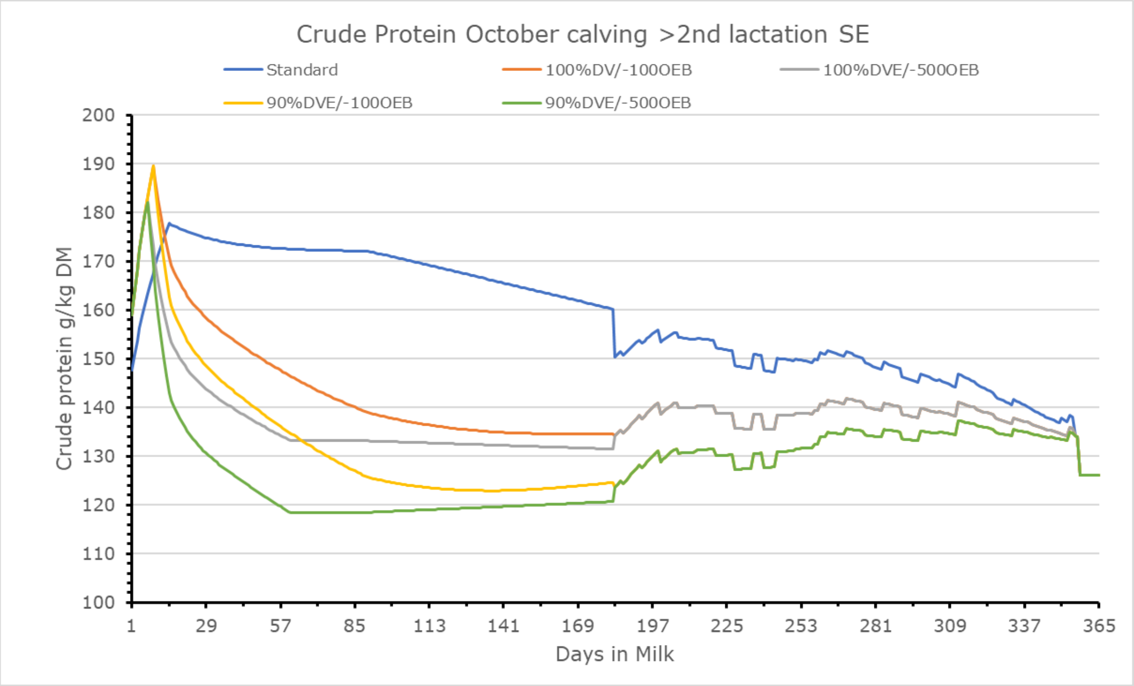

Figure 40 *Course of crude protein level (expressed in g/kg DM) over the >second lactation period for cows calving in October in the SE scenarios.*

Appendix 6 DCM to ANCA connection and intermediate calculation steps

Table 23 *Areas of grassland, maizeland and biodiverse grassland in all different scenarios.*

Scenario	Total area (ha)	Maizeland (ha)	Grassland (ha)	Biodiverse grassland (ha)
SE, basic, derogation	55.47	15.37	40.1	0
SE, increased fresh grass intake, derogation	56.95	15.37	41.58	0
SE, increased grazing time, derogation	57.00	15.37	41.63	0
SE, biodiverse, derogation	63.83	15.37	33.84	14.62
SE, biodiverse with increased fresh grass, derogation	65.32	15.37	35.33	14.62
SE 100% DVE -100 OEB	55.47	15.37	40.1	0
SE 100% DVE -500 OEB	55.47	15.37	40.1	0
SE 90% DVE -100 OEB	55.47	15.37	40.1	0
SE 90% DVE -500 OEB	55.47	15.37	40.1	0
NW, basic	64.7	5.82	58.88	0
NW, increased fresh grass intake	64.7	5.66	59.04	0
NW, increased grazing time	64.7	5.65	59.05	0
NW, biodiverse	69.68	5.23	45.34	19.11
NW, biodiverse with increased fresh grass	71.39	5.24	47.04	19.11
NW 100% DVE -100 OEB	64.7	5.82	58.88	0
NW 100% DVE -500 OEB	64.7	5.82	58.88	0
NW 90% DVE -100 OEB	64.7	5.82	58.88	0
NW 90% DVE -500 OEB	64.7	5.82	58.88	0

Table 24 *Production of pasture grass, grass silage, biodiverse grass and maize silage in all different scenarios.*

Scenario	Pasture grass (kg)	Grass silage (kg)	Biodiverse grass (kg)	Maize silage (kg)	Total roughage production (kg)
SE, basic, derogation	139724	353447	0	239760	732931
SE, increased fresh grass intake, derogation	248179	263234	0	239760	751173
SE, increased grazing time, derogation	248758	263234	0	239760	751752
SE, biodiverse, derogation	139724	276516	73115	239760	729114
SE, biodiverse with increased fresh grass, derogation	248179	263234	73115	239760	824288
SE 100% DVE -100 OEB	139744	353448	0	239760	732952
SE 100% DVE -500 OEB	139760	353448	0	239760	732968
SE 90% DVE -100 OEB	139753	353448	0	239760	732961
SE 90% DVE -500 OEB	139767	353448	0	239760	732975
NW, basic	226096	498087	0	90845	815028
Scenario	**Pasture grass (kg)**	**Grass silage (kg)**	**Biodiverse grass (kg)**	**Maize silage (kg)**	**Total roughage**

					production (kg)
NW, increased fresh grass intake	316019	410152	0	88323	814494
NW, increased grazing time	317150	410152	0	88323	815625
NW, biodiverse	226096	427125	95564	81611	830396
NW, biodiverse with increased fresh grass	316096	262549	95564	81611	755820
NW 100% DVE -100 OEB	226131	498054	0	90841	815026
NW 100% DVE -500 OEB	226149	498038	0	90839	815026
NW 90% DVE -100 OEB	226137	498049	0	90840	815026
NW 90% DVE -500 OEB	226155	498033	0	90838	815026

Tabel 25 *Maximum limits for usage of N for different crops, regions and soil types, used to calculate the level of active N in the different scenarios*[14].

Forage crop	Clay (kg N per ha per period)	NW – sand (kg N per ha per period)	SE – sand (kg N per ha per period)
Grassland, grazing	345	250	250
Grassland, mowing	385	320	320
Maize, no derogation	185	140	112
Maize, with derogation	160	140	112

Table 26a *Different scenarios with their corresponding total volume and N and P content of manure produced, used to calculate the amount of organic and artificial fertilizer.*

Scenario	Total manure volume (ton)	Manure volume litter, feed residues, rinse water (ton)	Solid manure (ton)
SE, basic, derogation	3277	799	0
SE, increased fresh grass intake, derogation	3301	772	0
SE, increased grazing time, derogation	3317	772	0
SE, biodiverse, derogation	3276	780	96
SE, biodiverse with increased fresh grass, derogation	3298	771	87
SE, 100% DVE -100 OEB	3220	780	0
SE, 100% DVE -500 OEB	3179	780	0
SE, 90% DVE -100 OEB	3198	780	0
SE, 90% DVE -500 OEB	3160	780	0
NW, basic	3346	767	0
NW, increased fresh grass intake	3377	760	0
NW, increased grazing time	3377	760	0
NW, biodiverse	3348	766	83
NW, biodiverse with increased fresh grass	3359	761	77
NW, 100% DVE -100 OEB	3290	766	0
NW, 100% DVE -500 OEB	3261	766	0
NW, 90% DVE -100 OEB	3281	766	0
NW, 90% DVE -500 OEB	3252	766	0

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[14] Tabel 2 Stikstof landbouwgrond (rvo.nl)

Table 27b *Different scenarios with their corresponding total volume and N and P content of manure produced, used to calculate the amount of organic and artificial fertilizer.*

Scenario	Phosphate manure production (kg P)	Phosphate manure, feed residues, rinse water (kg P)	Phosphate solid manure (kg P)	Nitrogen manure production (kg N)	Nitrogen manure, feed residues, rinse water (kg N)	Nitrogen solid manure (kg N)
SE, basic, derogation	4816	254	0	16364	780	0
SE, increased fresh grass intake, derogation	4868	220	0	17068	690	0
SE, increased grazing time, derogation	4868	220	0	17151	690	0
SE, biodiverse, derogation	4741	247	301	15825	760	933
SE, biodiverse with increased grazing, derogation	4802	214	266	16551	651	825
SE, 100% DVE -100 OEB	5065	257	0	14280	747	0
SE, 100% DVE -500 OEB	3670	228	0	13443	725	0
SE, 90% DVE -100 OEB	4967	255	0	13965	738	0
SE, 90% DVE -500 OEB	3439	223	0	13041	714	0
NW, basic	5124	243	0	17654	780	0
NW, increased fresh grass intake	5215	218	0	18359	697	0
NW, increased grazing time	5215	218	0	18431	697	0
NW, biodiverse	4975	231	280	16388	692	849
NW, biodiverse with increased grazing	5193	213	263	17871	656	824
NW, 100% DVE -100 OEB	5486	249	0	15777	731	0
NW, 100% DVE -500 OEB	3744	213	0	15056	713	0
NW, 90% DVE -100 OEB	4659	232	0	15647	728	0
NW, 90% DVE -500 OEB	3652	211	0	14901	709	0

Table 28 *The amount of K leaving the farm, calculated for different forage types, based on CBS data.*

	CBS (2014)
Total grassland (ha)	941000
Total maize forage (ha)	226000
K leaving the farm (ton)	
Grass silage	335800
Fresh grass	112500
Maize forage	35900
K leaving the farm (kg/ha)	
Grass silage	356.8544102
Fresh grass	119.5536663
Maize forage	158.8495575

Table 29 *Composition of artificial fertilizers.*

Artificial fertilizer composition	%	%N
Ammonium sulphate, as 100% (NH4)2SO4 (NPK 21-0-0), at regional storehouse/RER Economic	0.08	21
Calcium ammonium nitrate (CAN), (NPK 26.5-0-0), at regional storehouse/RER Economic	0.8	26.5
Urea, as 100% CO(NH2)2 (NPK 46.6-0-0), at regional storehouse/RER Economic	0.12	46.6
Triple superphosphate, as 80% Ca(H2PO4)2 (NPK 0-48-0), at regional storehouse/RER Economic	1	48
Potassium chloride (NPK 0-0-60), at regional storehouse/RER Economic	1	60

Table 30 *On-farm usage of diesel, (green) electricity and gas.*

Utility	Usage
Diesel (l/1000 kg milk)	13.8
Electricity (Kwh/1000 kg milk)	55.2
Gas (m3 gas/1000 kg milk)	1.15
Green electricity (%)	65

Appendix 7 Supply of manure, N and P

Table 31 Supply of manure, nitrogen (N) and phosphorus (P) per NW scenario. Negative supply numbers indicate additional external manure is required for the farm.

Supply	**NW basic**	**NW increased fresh grass**	**NW increased grazing time**	**NW herb-rich grassland**	**NW herb-rich + fresh grass**	**NW 100DVE - 100OEB**	**NW 100DVE - 500OEB**	**NW 90DVE -100OEB**	**NW 90DVE - 500OEB**
Manure (ton)	280	402	-211	4	413	-83	-242	-111	-278
N (kg)	1479	2184	-1032	24	2256	-398	-1119	-528	-1274
P (kg)	429	620	-313	7	638	-138	-278	-157	-312

Table 32 Supply of manure, nitrogen (N) and phosphorus (P) per SE scenario.

Supply	**SE basic**	**SE increased fresh grass**	**SE increased grazing time**	**SE herb-rich grassland**	**SE herb-rich + fresh grass**	**SE 100DVE -100OEB**	**SE 100DVE - 500OEB**	**SE 90DVE -100OEB**	**SE 90DVE - 500OEB**
Manure (ton)	722	768	237	304	782	343	162	276	69
N (kg)	3606	3970	1144	1527	4041	1522	685	1206	283
P (kg)	1061	1132	343	443	1147	540	187	429	75

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

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