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Amount and composition of faeces and urine

Jouni Nousiainen, Kaisa Kuoppala, Jenni Vattulainen, Auvo Sairanen, Annu Palmio, Erkki Joki-Tokola, Sari Luostarinen and Marketta Rinne

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Foreword

The project ”The effects of the estimation methods of cattle feeding and excretion on the national excretion and emission calculations” (Acronym: Narutesti) concentrated on improving the methods for estimating faecal and urine excretion and on updating the input data used. Both dairy and beef cattle were covered in different age groups. The project was funded by the Finnish Ministry of Agriculture and Forestry / Makera during 2018-2020 and conducted jointly by Natural Resources Institute Finland (Luke) and Finnish Environment Institute (SYKE).

The objective of the work was to adequately mimic the complexity of the biological processes involved. The input data for the calculations were collected from several sources including Luke, Finnish Food Authority, ProAgria (rural advisory services), meat-processing industry and several other experts and stakeholders. The input from all contributors is gratefully acknowledged. We would also like to thank Maiju Pesonen and Arto Huuskonen for their input to the beef cattle calculations.

We hope that the work described in this report is helpful in documenting and also developing the cattle production in Finland to improve the sustainability of milk and beef production.

On behalf of the project group,

Marketta Rinne

Abstract

Jouni Nousiainen, Kaisa Kuoppala, Jenni Vattulainen, Auvo Sairanen, Annu Palmio, Erkki Joki-Tokola, Sari Luostarinen and Marketta Rinne

Natural Resources Institute Finland (Luke)

Information of the faeces and urine excreted by different livestock groups is needed in several different functions, including monitoring emissions to air and waters from livestock production and manure management, calculating agricultural nutrient balances, and estimating annual amounts of manure and its nutrients to promote their efficient use. In Finland, Natural Resources Institute Finland (Luke) is responsible for the national excretion calculations.

The official Finnish excretion calculations provide national annual amounts of several components of faeces and urine. The most important ones are N, P and amounts of fresh faeces and urine. Several additional components such as dry matter, organic matter and K are also provided. The input data needed in the calculations is updated annually to match the volume of livestock production of each year while the calculation procedures are updated less frequently and only when the methodology can be clearly improved. The calculations are performed annually giving results for each year separately and thus building a time series of excretion per year.

As cattle is the main livestock sector in Finland, they produce approximately 75% of all manure in Finland, which is 9 750 000 tons annually (Luostarinen et al. 2023). Thus, it is also essential that their excretion is estimated as precisely as possible. The excretion calculations of cattle are conducted separately for different animal categories based on their gender, age and type of production (dairy and beef). The result for each animal category represents an average animal in Finland, and results from individual farms can deviate significantly from it.

The components included in the calculations are nitrogen (N), phosphorus (P), potassium (K), dry matter and organic matter for faeces and urine separately. The annual amounts of all these components are calculated as the difference between nutrient intake and the nutrients retained in the animals and their products, i.e. "nutrient input – nutrient retention = nutrient excretion". While this may sound simple, the actual calculations are complex.

A critical factor of excretion calculations is to accurately estimate the amount and composition of feeds consumed on average by the animals in different cattle categories. These data were obtained by calculating the energy requirement of the animals based on their maintenance requirements and the level of production (milk yield and/or growth rate). The diet composition was based on field data and expert assessments. There is much less uncertainty in estimating the amounts of nutrients retained in the animals themselves (growth including foetus) and in the milk excreted than in the intake of nutrients. The detailed steps in the calculations are described in the report.

Based on the results for year 2021 as an example, the annual N, P and K excretion of one dairy cow were 145, 22.9 and 125 kg, respectively. For a beef bull aged over 12 months, the annual N, P and K excretions were 69.3, 8.22 and 73.1 kg, respectively.

Keywords: bull, beefcow, calf, dairy, emission, faeces, heifer, input, manure, milk, nitrogen, nutrient, output, phosphorus, potassium, retention, suckler cow, urine

Tiivistelmä

Jouni Nousiainen, Kaisa Kuoppala, Jenni Vattulainen, Auvo Sairanen, Annu Palmio, Erkki Joki-Tokola, Sari Luostarinen ja Marketta Rinne

Luonnonvarakeskus (Luke)

Eri kotieläinlajien sonta- ja virtsatietoja tarvitaan moniin eri tarkoituksiin. Eritystiedon käyttökohteita ovat muun muassa kotieläintaloudesta ja lannankäsittelystä aiheutuvat päästöt ilmakehään ja vesistöihin, maatalouden ravinnetaselaskelmat, vuosittaisten lantamäärien arviointi sekä lantamäärän ravinnemäärän tehokkaan käytön edistäminen. Vastuu Suomen kansallisesta erityslaskennasta on Luonnonvarakeskuksella.

Kansallinen erityslaskenta tuottaa vuosittain useiden muuttujien määrän kotieläinten sonnassa ja virtsassa. Tärkeimpiä tietoja ovat typpi (N), fosfori (P)ja sonnan sekä virtsan tuoremäärät. Useita muita muuttujia, kuten kuiva-aineen, orgaanisen aineen ja kaliumin määrät, on myös laskettavissa. Laskentaan käytettävä lähtöaineisto päivitetään vuosittain vastaamaan kyseisen vuoden kotieläintuotantoa (eläinmäärät, tuotostaso, rehuannoksen koostumus). Itse laskenta ja siinä käytettävät laskentakaavat päivitetään harvemmin ja vain, kun menetelmää voidaan selvästi kehittää. Laskenta tuottaa jokaiselle vuodelle omat tuloksensa, jotka yhdessä muodostavat erityslaskennan aikasarjan.

Naudat ovat Suomen kotieläintuotannon suurin eläinryhmä, ja ne tuottavat keskimäärin 75 % kaikesta Suomen lannasta, noin 9 750 000 tonnia vuosittain (Luostarinen ym. 2023). Tämän vuoksi on tärkeää, että nautojen eritys on arvioitu mahdollisimman tarkasti. Nautojen erityslaskenta suoritetaan erikseen eri nautaryhmille sukupuolesta, iästä ja tuotantotavasta (maito ja liha) riippuen. Jokaisen nautaryhmän tulos edustaa keskimääräistä nautaa Suomessa, ja yksittäisten tilojen tulokset voivat erota merkittävästi tästä keskiarvosta.

Erityslaskennassa lasketaan erikseen typen, fosforin, kaliumin (K), kuiva-aineen ja orgaanisen aineen määrät sonnassa ja virtsassa. Näiden eri komponenttien vuosittaiset määrät lasketaan ravintoaineiden saannin ja pidättymisen erotuksena, toisin sanoen ” saanti – pidättyminen = eritys”. Menetelmä voi kuulostaa yksinkertaiselta, mutta varsinaiset laskelmat ovat monimutkaisia.

Yksi erityslaskennan kriittisimmistä lähtötiedoista on eri nautaryhmien keskivertoeläinten kuluttamien rehujen määrä ja koostumus. Rehunkulutuksen arviointia varten tarvitaan eläinten keskimääräinen energiankulutus ylläpitoa ja tuotantoa varten (maitomäärä ja/tai kasvunopeus). Rehuannoksen koostumus perustuu kentältä kerättyyn aineistoon ja asiantuntija-arvioihin. Ravintoaineiden pidättymisessä eläimeen itseensä (kasvu, mukaan lukien sikiö) ja erittymisessä maitoon on paljon vähemmän epävarmuustekijöitä kuin ravintoaineiden saannissa. Laskennan yksityiskohtaiset vaiheet on kuvattu raportissa.

Käyttäen vuotta 2021 esimerkkinä vuotuinen eritys lypsylehmää kohti oli 145 kg typpeä, 22,9 kg fosforia ja 125 kg kaliumia. Yli 12 kuukautta vanhalle lihasonnille vastaavat luvut olivat 69,3 kg typpeä, 8,22 kg fosforia ja 73,1 kg kaliumia.

Avainsanat: emolehmä, eritys, fosfori, hieho, kalium, karja, lanta, lehmä, liha, maito, pidättyminen, päästö, ravinne, sonni, sonta, typpi, vasikka, virtsa

Abbreviations

Abbreviation	Definition
ALW	Average live weight
BAT	Best available technique
BCS	Body condition score
$BCS_{3.1}$	Body condition score 3.1
$BCS_{3.5}$	Body condition score 3.5
BW	Birth weight
C_{age}	Age at calving
CP	Crude protein
CP_dig	Crude protein digestibility
Diet_ash	Diet ash concentration
Diet_CP	Diet crude protein concentration
Diet_OM	Diet organic matter concentration
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake
$dMW_{3.1}$	Dam's mature weight at BCS 3.1
$dMW_{3.5}$	Dam's mature weight at BCS 3.5
DOMI	Digestible organic matter intake
EBW	Empty body weight
EBWash%	Ash concentration of EBW
EBWfat%	Fat concentration of EBW
EBWphosporus%	Phosphorus concentration of EBW
EBWpotassium%	Potassium concentration of EBW
EBWprot%	Crude protein concentration of EBW, %
EBWwater%	Water concentration of EBW, %
ECM	Energy corrected milk
K	Potassium
LW	Live weight
LWC	Live weight change
LWG	Live weight gain
ME	Metabolizable energy
ME_{req}	ME requirement
ME_{diet}	ME in diet
MEr_{LWC}	Metabolizable energy requirement for live weight change
MEr_{milk}	Metabolizable energy requirement for milk production
MEr_{pregn}	Metabolizable energy requirement for pregnancy
MJ	Megajoule
MW	Mature weight
$MW_{3.1}$	Mature weight at BCS of 3.1
$MW_{3.5}$	Mature weight at BCS of 3.5
N	Nitrogen
OM	Organic matter
OMI	Organic matter intake
OMD	Organic matter digestibility
P	Phosphorus
S_age	Slaughter age

Contents

1. Introduction

Natural Resources Institute Finland (Luke) is responsible for the national livestock excretion calculations in Finland (Laki ruoka- ja luonnonvaratilastoista. 562/2014). Data on excretion of animals is needed for several purposes ranging from estimating emissions during manure management into air (greenhouse gases from manure, air pollutants) and waters [phosphorus (P) and nitrogen (N)], to estimating the quantity and composition of manure produced in Finland and setting the targets to improve manure utilization (nutrient balances, circular economy). As cattle produce 75% of all manure in Finland (Luostarinen et al. 2023), it is essential that their excretion is estimated as precisely as possible.

The excretion calculations provide the amounts of dry matter (DM), organic matter (OM) and nutrients [N, P, potassium (K)] excreted by animals in faeces and urine. The excretion calculations form the basis for many other calculations and evaluations (Figure 1), so it is critical that the calculations are as correct as possible. The excretion calculations for the national herd are calculated annually with updated information of the number of animals, production levels and diet composition. The calculations form a time series that allows to evaluate the trends in excretion, and subsequent emissions.

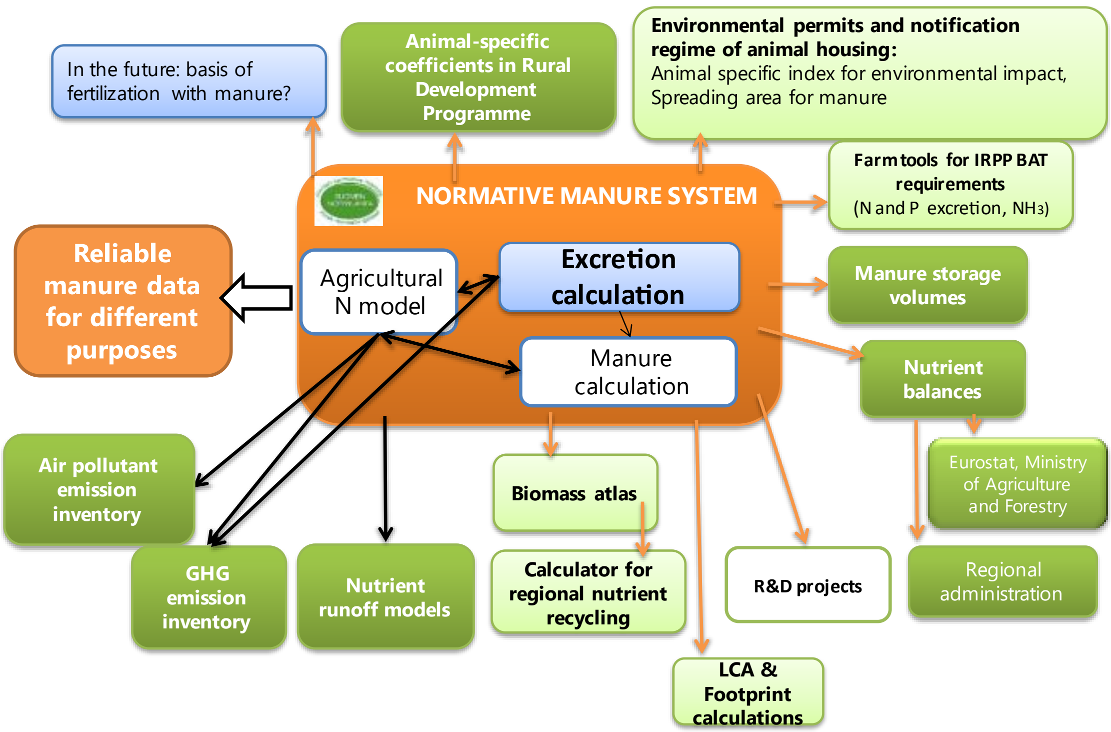

Figure 1. The nutrient excretion calculations form the basis of several other calculations (IRPP BAT = Best Available Techniques of Intensive Rearing of Poultry or Pigs).

The amounts of nutrients excreted are calculated as the difference between nutrient intake and the nutrients retained in the animals and their products, i.e., as "nutrient input – nutrient retention = nutrient excretion" (Figure 2). The components included into the calculations are N, P, K, dry matter and organic matter. This report documents the calculations for cattle, and reports for pigs, poultry, sheep and goats, and horses will be published separately.

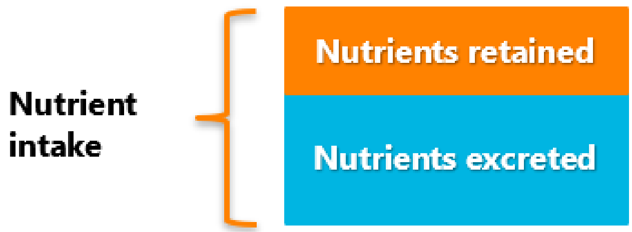

Figure 2. The principle of nutrient calculations: excretion is intake minus retention.

The excretion calculations of cattle are conducted separately for different animal categories based on their age and type of production (Table 1). Calculations consider, for example, differences between the growth, diet, and culling age during the different steps. The results of excretion calculations are shown as a weighted average from these animal categories depending on the needs of various end-users of the data.

The number of animals is one critical input value for the national calculations, and the data is obtained from the official national statistics (OSF: Number of livestock. 2023). Number of animals from the first of May 2021 are presented in Table 2. For more accurate calculations, where animal groups from Table 1 are needed, number of animals are calculated as an average of first of December of the previous and current year (i.e., for year 2021, the average values of 1 December 2020 and 2021 is used). The result describes the number of animals present at those individual days. An animal moves from one category to another during a year while growing so that it is not the absolute amounts of animals (e.g., for calves at 0-6 months of age, the real number within that year is twice the amount presented). However, as the excretion is calculated by day and then multiplied by the number of days over the whole year, the total amount of excretion will be covered. The proportions of dairy and beef breeds in the categories of bulls, calves and heifers raised for beef are calculated based on the statistics and slaughter data obtained from Finnish Food Authority.

For the official calculations, National Green House Gas inventory below as an example, results of the calculations are pooled into five cattle categories and are reported as follows: dairy cows, suckler cows, heifers over one year old, bulls over one year old, and calves under 12 months old (Table 2) (Forsell et al., 2022). Then again, for example for the environmental legislation, more categories such as in Table 1 are needed (Ympäristönsuojelulaki. 527/2014). Figure 3 shows the relative amounts of animals in different cattle groups in 2021 (OSF: Number of livestock. 2023, and Finnish Food Authority, 2023).

The results of the calculations present the annually excreted nutrients, faeces, and urine. The amounts of excreted faeces and urine by each of the reported cattle categories in 2021 are shown in Figures 4 and 5.

Table 1. The animal categories of cattle in nutrient excretion calculations in Finland.

Animal category	Age, months
Dairy cows	After 1st calving
Suckler cows	After 1st calving
Dairy and beef heifers for replacement	0–6
	6–12
	>12
Dairy breed bulls for beef	0–6
	6–12
	>12
Beef breed bulls for beef	0–6
	6-12
	>12
Dairy breed heifers for beef	0–6
	6–12
	>12
Beef breed heifers for beef	0–6
	6–12
	>12

Table 2. Categories for the official reporting of excretion calculations for Green House Gas inventory and the number of animals in 2021. Source: OSF: Number of livestock. 2023.

Animal category	Age, months	Number of animals in 2021
Dairy cows	After 1st calving	253 527
Suckler cows	After 1st calving	63 698
Heifers	>12	136 469
Bulls	>12	101 472
Calves	0–12	288 872

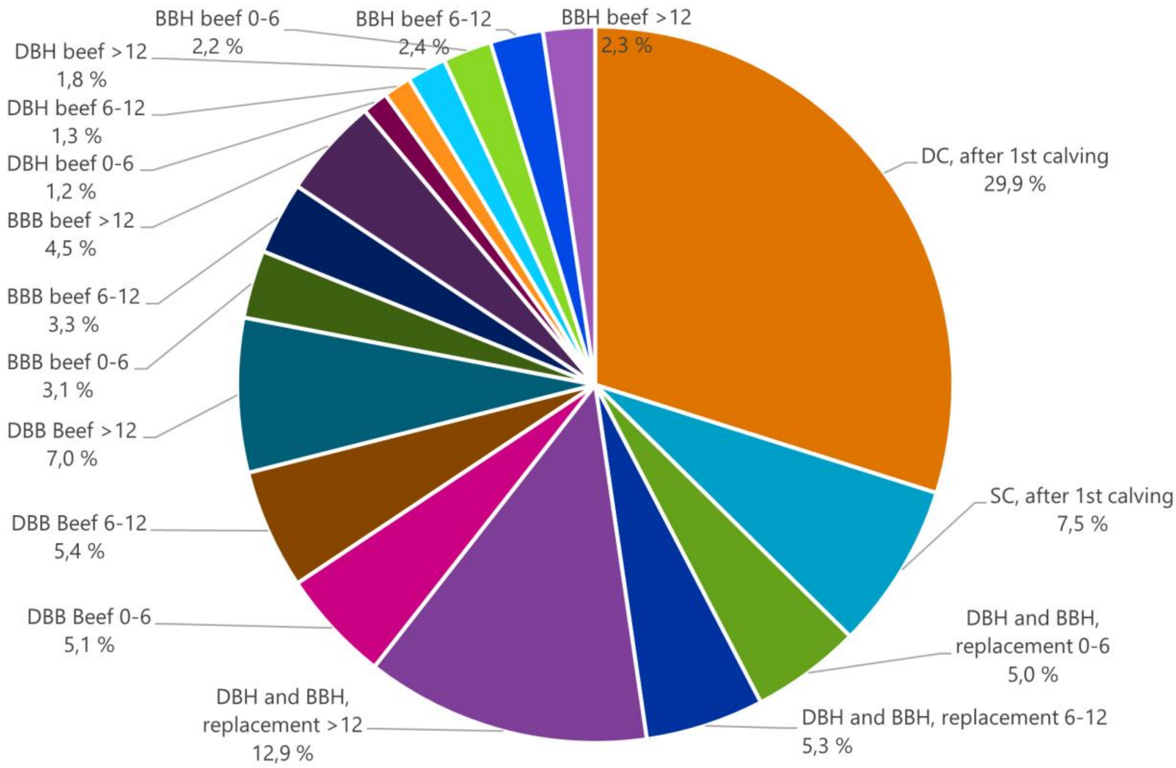

Figure 3. Relative amounts of different cattle categories in year 2021. DC= dairy cows, SC= suckler cows, DBH = dairy breed heifers, BBH = beef breed heifers, DBB= dairy breed bulls, BBB= beef breed bulls. Number represents ages of the group. 0-6 = 0–6 months old, 6–12 = 6–12 months old, >12 = >12 months old. Source: OSF and Finnish Food Authority, 2023.

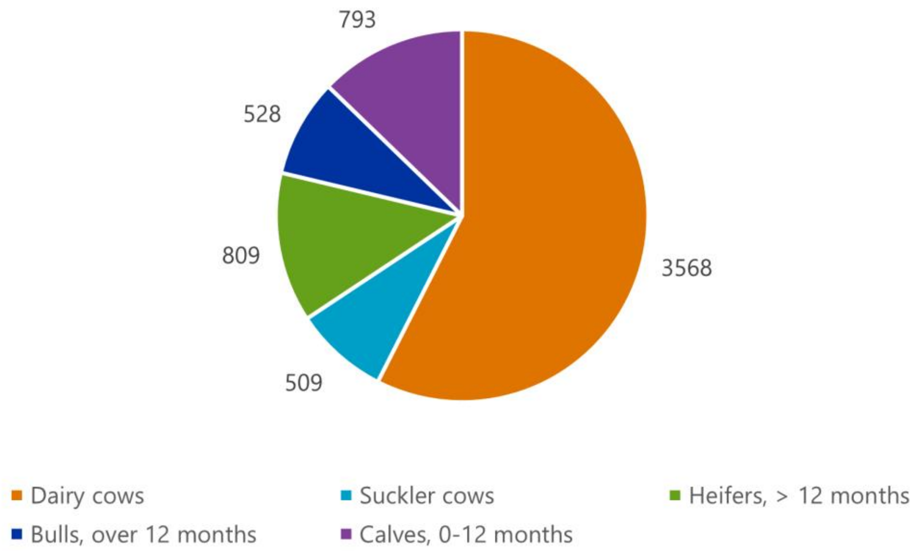

Figure 4. Total amount of excreted faeces in 2021, expressed as million kilograms of fresh matter, excreted per year.

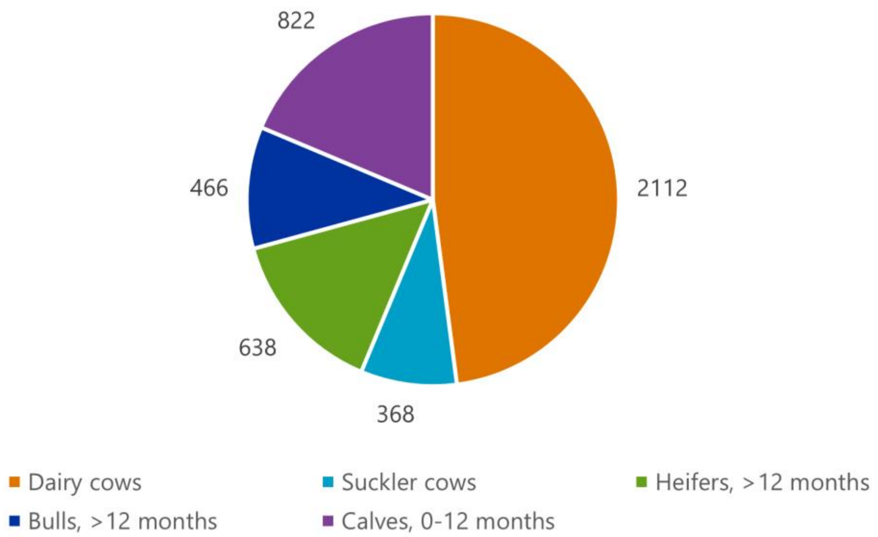

Figure 5. Total amount of excreted urine in 2021, expressed as million litres, excreted per year.

The critical factor of nutrient excretion calculations is to accurately estimate the amounts and nutrient concentrations of feeds consumed by the animals. There is much less uncertainty in estimating the amounts of nutrients retained in the animals themselves (growth including foetus) and in the milk excreted. The detailed steps in the calculations are described in the following chapters. Finally, an overview of the main results for year 2021 is presented in Chapter 6 and in the Appendices.

Nitrogen (N) and crude protein (CP) are used interchangeably in the report so that N × 6.25 = CP, except for milk, where N × 6.38 = CP. Equations shown in this report are presented with three meaningful digits, whereas in the actual calculations, more digits are used to create more precise outcomes of the calculations. Some data, such as weights of animals at different phases of their life, are not readily available from the field, so that they have been modelled. This also facilitates production of consistent data for the time series evaluations. The year in the calculations is considered to be 365 days, and the effect of leap year has not been taken into account.

2. Dairy cows

2.1. Outline of the dairy production systems

Dairy production in Finland comprised altogether approximately 5000 farms in 2021. The number of dairy cows was 253 500 and the total milk yield nationally was 2 247 000 000 litres. The number of dairy farms and cows has decreased steadily throughout the years, from 285 500 cows and 11 200 dairy farms in 2011 (OSF: Number of livestock. 2023). The average milk yield per cow has on the opposite increased, from 7 859 litres in 2011 to the average of 8900 litres in 2021 (OSF: Milk and milk products statistics. 2023). The most common dairy breeds are Holstein (56.4 %) and Ayrshire (Nordic red: 41.7%), but some other breeds can be found in small numbers (ProAgria, 2023). The amount of native Finncattle was 0.8 % in 2021. The current calculations cover the whole national herd. In case of small (Jersey) or native Finncattle cows, the results can be scaled for their smaller inputs and outputs for individual farm evaluations.

Dairy production systems are tightly linked to beef production, since most (63.5%, Table 29) of the slaughtered animals annually are from dairy breed origin (Niemi & Väre 2018, Finnish Food Authority 2023). The average culling age of dairy cow was 5.34 years in 2021 (Finnish Food Authority 2023). A general description of the Finnish livestock sector is available in “Best available techniques in livestock farming” report (Manni et al. 2023).

The mass balance calculations for dry matter (DM), organic matter (OM), N, P and K are based on the data about animals, milk production, feed composition and digestibility. Large data of physiological and milk production experiments conducted in Luke (previously MTT) was used for basal information and constants. Calculations for dairy cows are conducted separately for lactating cows and non-lactating cows. Final amounts of excretion per cow per year are average values weighted by the number of days of lactation and non-lactation period.

The source data for the national calculations is obtained annually from the registries of the Natural Resources Institute Finland (Luke; annual milk production and number of animals) and Finnish Food Authority (slaughter age, carcass weight and carcass quality at slaughter). Data of daily feed allowances and diet composition are obtained from ProAgria.

2.2. Calculation of live weight

The live weight (LW) of cows is needed for the determination of energy requirements, retention and excretion of nutrients. LW describes the current weight of an animal at a certain age (see Appendix 8). LW is first solved from the average carcass weight (CW). The CW are obtained from the Finnish Food Authority (Table 29). LW at slaughter is calculated from CW using Equation [2] (Table 5), which is based on the average dressing percentage of the cows (dressing percentage × 0.01). Calculation of dressing percentage [Eq. 1] is based on McKiernan et al. (2007) and Finnish expert evaluations (Tables 3 and 4). Dressing percentage for dairy cows was 43.1 in 2021 (Table 29).

Initial data for calculating dressing percentage originates from the Finnish Food Authority and it comprises the number of slaughtered cows, sum of CW, average carcass fat and conformation scores, and also the breeds of slaughtered animals, which is needed to define the breed coefficient (Table 4). Body condition score (BCS) is then calculated from the slaughter data [Eq. 9] (Table 5). The calculation of BCS is based on Edmonson et al. (1989) and Fox et al. (1999). The data is edited with SAS program (SAS Inc. 2002-2012, Release 9.4; SAS Inst. Inc., Cary, NC, USA) to obtain the average fat score on a scale 1-5 and subsequently to calculate the fat coefficient as described in Table 3. The breed coefficient is determined based on the breed of the animals (Table 4). Cattle group 1 refers to large modern dairy breeds (Holstein, Ayrshire/Nordic Red and Brown Swiss), group 2 to smaller, native dairy breeds and Jersey, Group 3 is for British type suckler cow breeds (Hereford, Aberdeen Angus, Highland, Dexter and Galloway) and group 4 for continental type suckler cow breeds (Charolais, Limousin, Simmental and Blonde d'Aquitaine) (see Chapter 5).

Table 3. Fat coefficients to calculate dressing percentage. Based on McKiernan et al. (2007).

Carcass weight, kg	Carcass weight scale	Fat score	Fat coefficient
<200 kg	1	1	39.0
		2	40.0
		3	41.0
		4	42.5
		5	46.5
200–250 kg	2	1	42.5
		2	43.5
		3	47.5
		4	49.5
		5	50.5
>250 kg	3	1	43.5
		2	44.5
		3	46.0
		4	49.0
		5	51.3

Table 4. Breed coefficients for calculating the dressing percentage**.** Based on McKiernan et al. (2007).

Cattle group	Breed coefficient
1 Dairy cow breeds	-1
2 Small dairy cow breeds	-1
3 British beef breeds	0
4 Continental beef breeds	2

Mature weight (MW) describes the weight of an animal that no longer grows and is achieved approximately at six years of age in cattle (Appendix 8). After solving the LW at slaughter, MW at BCS 3.5 ($MW_{3.5}$) is solved by using Richard's function [Eq. 3–6] (Table 5). The $MW_{3.5}$ is solved by giving known values for the other parameters (LW and Age) in the Richards' function. The given values are LW (LW at slaughter, 685 kg in 2021) and age at slaughter (culling age), which was 5.34 years in 2021 (Table 29). When doing so, the only remaining unknown parameter (MW) in the Richards' equation is solved using the NLIN procedure in SAS program. Richard's function is also used to estimate the LW of other cattle groups. The $MW_{3.5}$ for dairy cows was 766 kg in 2021.

Equations in Table 5 are based on Finnish data and Fox et al. (1999). The LW change (LWC, [Eq 7–8]) is based on equation 18 in Fox et al. (1999). LW and LWC are needed for different production stages for the calculation of energy requirement for maintenance and the LWC (Table 6).

Table 5. Equations for calculating the LW of dairy cows.

No	Equation
1.	Dressing percentage = Fat coefficient – 1.25 + breed coefficient (Table 4; based on McKiernan et al. 2007)
2.	LW at slaughter = CW, kg / (Dressing percentage × 0.01)
3.	LW, without pregnancy, lactating cow, kg = 0.941 × $MW_{3.5}$ – 28.4 + 5.66 × S_age (based on Fox et al. 1999)
4.	LW, without pregnancy, non-lactating cow, kg = 0.938 × $MW_{3.5}$ – 16.8 + 3.36 × S_age (based on Fox et al. 1999)
5.	LW, with pregnancy, lactating cow, kg = 0.945 × $MW_{3.5}$ – 26.7 + 5.85 × S_age (based on Fox et al. 1999)
6.	LW, with pregnancy, non-lactating cow, kg = 0.974 × $MW_{3.5}$ + 13.1 + 3.03 × S_age (based on Fox et al. 1999)
7.	LWC, kg/day, lactating cows = 0.093+ 0.00008 × $MW_{3.5}$ – 0.019 × S_age
8.	LWC, kg/day, non- lactating cows = 0.038+ 0.00002 × $MW_{3.5}$ – 0.008 × S_age
9.	BCS = 0.1327 × EBWfat (%) + 0.50 (based on Fox et al. 1999, Table 5)

LW = live weight, kg; CW = carcass weight; $MW_{3.5}$ = mature weight in body condition score 3.5, kg; S_age = age at slaughter, years, LWC = live weight change, kg/day

2.3. Energy requirements

Feed intake and nutrient concentrations of the diets are the key features in nutrient excretion calculations. Because of lacking measurements of actual feed intake of the national herd, it is estimated based on total energy requirements (ME_{req}) and the ME content (ME_{diet}) of the average diet. The composition of the diet is described in Chapter 2.4.

Energy requirements for maintenance (MEr_{main}), and milk production (MEr_{milk}) are calculated according to Finnish nutrient requirements (Luke 2023) using Eq. [10] and [11] (Table 6). As a result of animal breeding, the feed efficiency of cows is continuously improving (Leino et al. 2023), but that effect is not visible in excretion calculations unless the nutrient requirement values in the Feed Tables are updated. The requirement of ME for pregnancy (MEr_{pregn}) and

LW change (MEr_{LWC}) are calculated using Eq. [13–16] (Table 6). The annual milk yield and the concentrations of milk fat and protein are obtained from Finland's Official Statistics (OSF: Milk and milk products statistics. 2023). These data are collected from Finnish dairies and farms. The length of the lactation period (days in milk) and dry period (days non-lactating) are calculated using Eq. [18] and [19] (Table 6), from the cows' average age at slaughter, obtained from Finnish Food Authority. The values for lactation period and non-lactation period were 320 and 45 days, respectively, using data from 2021. The average non-lactation period is shorter than that of individual cows between drying off and next calving because cows in their last lactation contribute to days in milk but not to days non-lactating. Interval between drying off and next calving (dry period) was 66 days in 2021 (ProAgria 2022).

The cow's weight fluctuates greatly over the production cycle due to growing until mature size is reached, changes in calf (+placenta etc.) weight and changes in the body condition of the cow (Figure 6), but in the calculation we only present one annual average value for the LW, which was 723 kg in 2021. However, since the ME required for LW deposition is somewhat greater than the ME obtained from LW loss (Luke 2023), an additional ME requirement caused by the fluctuation in BCS is added. This value was 1.98 MJ ME/day for lactating cows and 6.75 MJ ME/day for non-lactating cows in 2021.

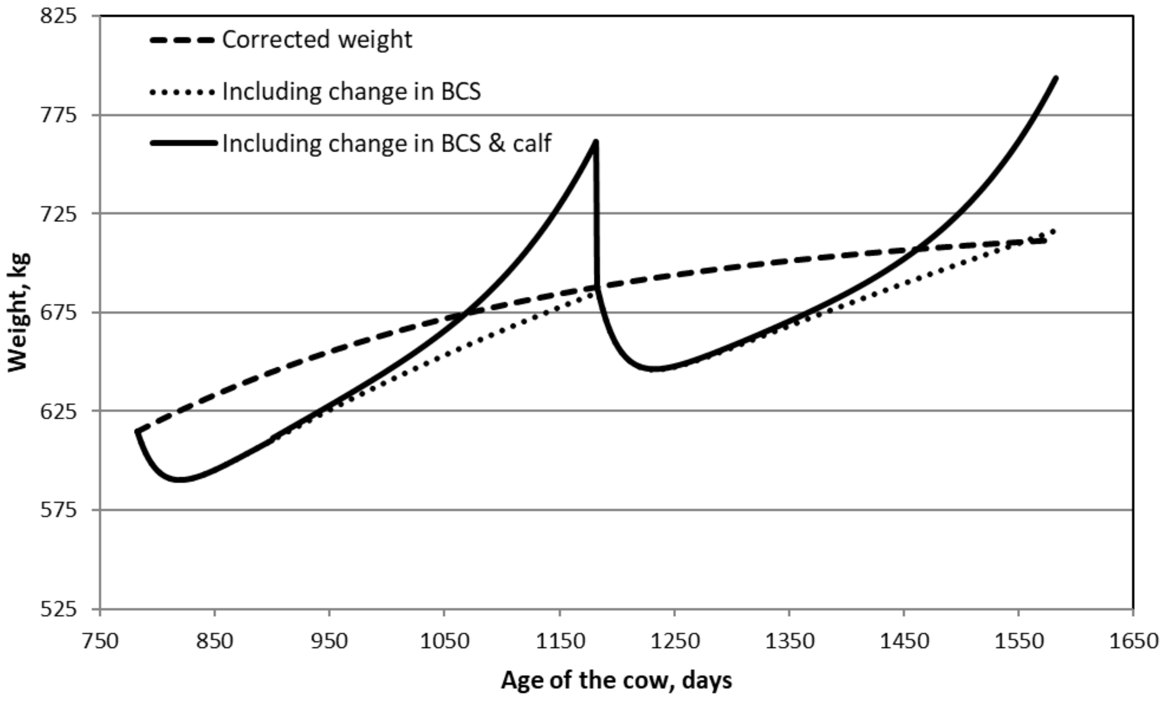

Figure 6. Schematic presentation of cow weight change over first two lactations. The solid line shows the weight change including the weight of the calf (foetus, placenta, foetal membranes, foetal water, and growing uterus) and the change in average body condition score (BCS), i.e., the observed LW. The line with dots shows the weight change when the effect of calf has been corrected for. The broken line shows the weight of the cow if she would not become pregnant and would constantly stay in body condition score 3.5. Based on Fox et al. (1999) and Roche et al. (2006).

Table 6. Equations for calculating the energy requirements for dairy cows.

No	Equation
10.	MEr_{maint}, MJ/day = 0.515 × $LW^{0.75}$ (Luke 2023)
11.	MEr_{milk}, MJ/kg ECM = 5.15 × ECM, kg/d (Luke 2023)
12.	ECM, kg/d = milk yield, kg × (38.3 × Milk fat, g/kg + 24.2 × Milk protein, g/kg + 783.3) / 3140 (Sjaunja et al. 1990)
13.	MEr_{pregn}, lactating cows, MJ/d = 1.67 – 0.0037 × $MW_{3.5}$ + 0.00000357 × $MW_{3.5}^2$ (AFRC 1993)
14.	MEr_{pregn}, non – lactating cows, MJ/d = 61.1 – 0.133 × $MW_{3.5}$ + 0.0013 × $MW_{3.5}^2$ – 0.270 × S_age (AFRC 1993)
15.	MEr_{LWC}, lactating cows, MJ/d = 0.00147 × $MW_{3.5}$ - 0.328 + 15.6 × LWC (Luke 2023)
16.	MEr_{LWC}, non-lactating cows, MJ/d = 0.00793 × $MW_{3.5}$ + 43.5 × LWC (Luke 2023)
17.	ME_{req}, MJ/day = MEr_{maint} + MEr_{milk} + MEr_{pregn} + MEr_{LWC}
18.	Days lactating = 365 × (1 - (0.0737 + 0.00917 × S_age)) (Finnish data)
19.	Days non-lactating = 365 × (0.0737 + 0.00917 × S_age) (Finnish data)

MEr_{maint} = requirement of metabolizable energy for maintenance, MJ/day; MEr_{milk} = requirement of metabolizable energy for milk production, MJ/kg ECM; MEr_{pregn} = requirement of metabolizable energy for pregnancy, MJ; MEr_{LWC} = requirement of metabolizable energy for live weight change, MJ; ME_{req} = requirement of metabolizable energy, MJ/day; LW = live weight, kg; ECM = energy corrected milk yield; $MW_{3.5}$ = mature weight, kg in body condition score 3.5; LWC = live weight chance, kg/d; S_age = age at slaughter, years

2.4. Diet composition and intake

The average chemical composition of the diet of dairy cows is annually obtained from ProAgria. The data originates from herds which belong to milk recording scheme and use the feed monitoring of CowCompass for their herd. The periodical (daily) calculations of CowCompass for the dairy herds are gathered from the data separately for lactating and non-lactating cows. The number of calculations per herd in the data is variable, so a mean value is calculated for each herd, and these herd mean values are used to calculate the overall mean. The average concentrations of corrected metabolizable energy (ME, MJ/kg DM), crude protein (CP), P and K (g/kg DM) for cows were calculated from the annual data for 2021 (Table 7). The ME correction based on feeding level and diet composition was calculated according to Luke (2023) and it is only used for lactating and non-lactating dairy cows, not for any other cattle group. The feed data includes the grazing season. Feeding of dairy cows comprises from silage (53%), grazing (1%), cereal grains (19%), compound feeds (12%) and other feeds (15%) (ProAgria 2022).

Table 7. Mean composition of the daily ration of lactating and non-lactating dairy cows for year 2021 (ProAgria 2022).

	Lactating cows	Non-lactating cows
Uncorrected metabolizable energy[1], MJ/kg DM	11.6	10.3
Corrected metabolizable energy[1], MJ/kg DM	10.8	10.5
Gross energy, MJ/kg DM	18.8	18.6
In DM, g/kg		
Ash	71.6	77.8
Crude protein	170	139
Crude fat	46.8	40.1
Non-structural carbohydrates	314	207
Neutral detergent fibre	397	536
Phosphorus (P)	4.39	3.48
Potassium (K)	18.6	24.5

[1]Feeding level corrected ME-value (Luke 2023); DM = Dry matter

Dry matter intake (DMI, kg/d) is calculated as the ME requirement divided by the corrected diet ME concentration [Eq. 20]. Intake of organic matter (OMI) and nutrients is calculated by multiplying the nutrient concentrations in feed DM by DMI [Eq. 21–24] (Table 8).

Table 8. Equations for calculating the intake of dry matter, organic matter, nitrogen, phosphorus, and potassium.

No	Equation
20.	DMI, kg/d = ME_{req}, MJ/d / ME_{diet}, MJ/kg DM
21.	OMI, kg/d = DMI × (1000 - diet_ash)
22.	Intake of N, g/d = (CP, g/kg DM / 6.25) × DMI, kg/d
23.	Intake of P, g/d = P, g/kg DM × DMI, kg/d
24.	Intake of K, g/d = K, g/kg DM × DMI, kg/d

DMI = dry matter intake; ME_{req} = requirement of metabolizable energy; ME_{diet} = diet ME concentration; OMI = organic matter intake; diet_ash = diet ash concentration; CP = crude protein; N = nitrogen; P = phosphorus; K= potassium

2.5. Retention of nutrients

Retention of N, P, K, and ash to cow's LWC and to pregnancy (including foetus, placenta, foetal membranes, foetal water, and growing uterus) is calculated using Equations [25–32] for lactating cows and Equations [33–40] for non-lactating cows (Table 9). Equations are based on Fox et al. (1999). The number of calves per cow per year and the birth weight of calf (BW) are calculated based on Finnish data and Berglund (1987), Kärki (1996) and Sundberg (2005), using Equations [41-43] (Table 9). Equations [42] and [43] are used to calculate the calf's BW excluding the effect of the calf's gender. The average BW of the calves based on Equations

[42] and [43] was 44.4 kilograms for primiparous cows and 51.9 kilograms for multiparous cows, respectively, in 2021.

Retention of nutrients in the hair of all cattle groups is excluded from the calculations. The amount is relatively small (approximately 1.5 g N per day; NRC 2001), and the shredded hair and scurf ends up in the manure, so that the conclusions from calculations are not biased by neglecting it.

Table 9. Equations for calculating the retention of nutrients in lactating and in non-lactating dairy cows.

No	Equation
Retention of nutrients in lactating cows	
25.	N retained, cow, g/d = (3.94 + 0.0041 × $MW_{3.5}$ – 0.785 × S_age) / 6.25 (Fox et al. 1999)
26.	P retained, cow, g/d = 1.18 + 0.0016 × $MW_{3.5}$ - 0.236 × S_age (Chizzotti et al. 2007, 2009; Fox et al. 1999; Schultz et al. 1974)
27.	K retained, cow, g/d = 0.138 + 0.0018 × $MW_{3.5}$ - 0.0274 × S_age (Chizzotti et al. 2007, 2009; Fox et al. 1999; Schultz et al. 1974)
28.	Ash retained, cow, g/d = 7.03 + 0.00975 × $MW_{3.5}$ -1.40 × S_age (Fox et al. 1999)
29.	N retained, pregnancy, g/d = (9.50 -0.0223 × $MW_{3.5}$ +0.00002 × $MW_{3.5}^2$ + 0.104 × S_age) / 6.25 (ARC 1980)
30.	P retained, pregnancy, g/d = 0.371 – 0.0008 × $MW_{3.5}$ + 0.0000008 × $MW_{3.5}$ + 0.0035 × S_age (ARC 1980)
31.	K retained, pregnancy, g/d = 0.117 – 0.00028 × $MW_{3.5}$ + 0.00000027 × $MW_{3.5}$ + 0.0016 × S_age (ARC 1980)
32.	Ash retained, pregnancy, g/d = 2.22 – 0.0052 × $MW_{3.5}$ + 0.000005 × $MW_{3.5}^2$ + 0.024 × S_age (ARC 1980)
Retention of nutrients in non-lactating cows	
33.	N retained, cow, g/d = (1.23 + 0.0131 × $MW_{3.5}$ – 0.245 × S_age)/6.25 (Fox et al. 1999)
34.	P retained, cow, g/d = 0.871 + 0.00059 × $MW_{3.5}$ – 0.174 × S_age (Chizzotti et al. 2007, 2009; Fox et al. 1999; Schultz et al. 1974)
35.	K retained, cow, g/d = 0.0898 + 0.0002 × $MW_{3.5}$ – 0.0179 × S_age (Chizzotti et al. 2007, 2009; Fox et al. 1999; Schultz et al. 1974)
36.	Ash retained, cow, g/d = 5.17 + 0.00351 × $MW_{3.5}$ – 1.03 × S_age (Fox et al. 1999)
37.	N retained, pregnancy, g/d = (211 – 0.459 × $MW_{3.5}$ + 0.0004 × $MW_{3.5}^2$ – 0.759 × S_age) / 6.25 (ARC 1980)
38.	P retained, pregnancy, g/d = 9.60 – 0.0208 × $MW_{3.5}$ +0.00002 × $MW_{3.5}^2$– 0.0398 × S_age (ARC 1980)

39.	K retained, pregnancy, g/d = 2.22 – 0.0048 × $MW_{3.5}$ +0.00000462 × $MW_{3.5}^2$-0.0078 × S_age (ARC 1980)
40.	Ash retained, pregnancy, g/d = 48.9 -0.107 × $MW_{3.5}$ + 0.000102 × $MW_{3.5}^2$– 0.174 × S_age (ARC 1980)
41.	Number of calves / multiparous cow / year = 0.531 + 0.0378 × S_age (Finnish data)
42.	BW, both genders, primiparous cow = 10.4 + 0.0584 × $MW_{3.5}$ – 0.000018 × $MW_{3.5}^2$ (based on Berglund (1987), Kärki (1996) and Sundberg (2005))
43.	BW, both genders, multiparous cow = 99.9 – 0.226 × $MW_{3.5}$ + 0.000213 × $MW_{3.5}^2$ (based on Berglund (1987), Kärki (1996) and Sundberg (2005))

N = nitrogen; P = phosphorus; K= potassium; S_age = age at slaughter, years; $MW_{3.5}$ = mature weight in body condition score 3.5; BW = calf's birth weight

2.6. Excretion

To be able to estimate the quantity and composition of faeces, the digestibility of DM (DMD) is calculated [Eq. 46] (Table 10). DMD is calculated from the digestibility of organic matter (OMD) using Equation [45] which is calculated from dividing the intake of digestible organic matter (DOMI) [Eq. 44] by the intake of organic matter [Eq. 21]. Output of faeces is calculated by first solving the excreted indigestible dry matter [Eq. 47] and then using Equation [48]. The output of urine is calculated using Equation [49]. For DM content of faeces, an average value of 150 g/kg is used based on values determined in feeding experiments conducted at Luke.

Table 10. Equations for calculating the intake of digestible organic matter, digestibility of organic and dry matter, excreted indigestible dry matter, and output of faeces and urine.

No	Equation
44.	Intake of digestible OM (DOMI), kg/d = (ME_{diet} × DMI) / 16 (Luke 2023)
45.	Digestibility of OM (OMD), g/g = DOMI / (DMI × diet_OM × 0.001) (Luke 2023)
46.	Digestibility of DM (DMD), g/g = (0.977 × OMD × 1000 + 1.4) / 1000 (modified from Ramin & Huhtanen 2013)
47.	Indigestible DM excreted, kg/d = DMI, kg/d × (1 - DMD)
48.	Output of faeces, kg/d = indigestible DM, kg/d / DM concentration of faeces, g/g
49.	Output of urine, l/d = (2.7 + 0.053 × K intake, g/d) (Eriksson 2011)

OM = organic matter; ME_{diet} =diet ME concentration, MJ/kg DM; DMI = dry matter intake; K = potassium, DM = dry matter

Nutrients in the lactating cow are either used for maintenance of the body, retained in the body of the cow or her calf, or excreted in milk, faeces, or urine. Equations used for calculating the excretion in dairy cows are described in Table 11. The concentration of N in milk (5.58 g/kg) is calculated from the concentration of protein in milk by dividing it with 6.38 (OSF: Milk and milk products statistics. 2023). The concentrations of DM, ash, P and K of milk (130 g/kg, 54, 6.9 and 12 g/kg DM in 2021, respectively) are obtained from the Finnish Feed Tables [Equations 50–53] (Luke 2023). Nitrogen content of urine in Equations [58–61] are based on Nehring et al. (1965). OM excreted in faeces is calculated as in Eq. [67]. DM excreted in faeces is calculated as in Eq. [68].

Table 11. Nutrient contents of milk, urine, and faeces of dairy cows.

No	Equation
50.	N in milk, g/d =N concentration in milk DM, g/kg × milk DM yield, kg/d (Luke 2023)
51.	P in milk, g/d = P concentration in milk DM × milk DM yield, kg/d (Luke 2023)
52.	K in milk, g/d = K concentration in milk DM × milk DM yield, kg/d (Luke 2023)
53.	Ash in milk, g/d = ash concentration in milk DM × milk DM yield, kg/d (Luke 2023)
54.	N in urine, g/d = N in urine, g/d = N intake - N in milk - N in cow - N in calf - N in faeces
55.	P in urine, g/d = 3 mg × LW (Damgaard Poulsen & Kristensen 1998)
56.	K in urine, g/d = K intake - K in milk - K in cow - K in calf - K in faeces
57.	Ash in urine, g/d = Ash intake, g/d - ash retained in cow, g/d - ash retained in pregnancy, g/d - ash in faeces, g/d
58.	Nitrogenous OM in urine, g/d = N in urine, g/d × 2.638 (Nehring et al. 1965)
59.	Urea in nitrogenous OM in urine, g/d = 0.395 × diet_CP, g/kg DM - 0.207) × 0.01 × nitrogenous OM in urine, g/d (Nehring et al. 1965)
60.	Non-nitrogenous OM in urine, g/d = (-1.13 × diet_CP, g/kg DM + 228) × 0.01 × Urea in urine, g/d (Nehring et al. 1965)
61.	OM in urine = nitrogenous OM in urine + non-nitrogenous OM in urine (Nehring et al. 1965)
62.	DM in urine, g/d = Ash in urine + OM in urine
63.	N in faeces, g/d = -17.7 + 6.3 × DMI + 0.108 × N intake (Nousiainen et al. 2011)
64.	P in faeces, g/d = P intake - P in milk - P in urine - P in cow - P in calf
65.	K in faeces, g/d = K intake × 0.225 (Tuori et al. 2006)
66.	Ash in faeces, g/d = intake of indigestible DM – intake of indigestible OM
67.	OM in faeces, kg/d = OMI, kg/d – DOMI, kg/d
68.	DM in faeces, kg/d = DM intake, kg/d – digestible DM intake, kg/d

N = nitrogen; P = phosphorus; K= potassium; DM = dry matter; OM = organic matter; diet_CP = diet crude protein concentration, g/kg DM, LW = live weight, kg, OMI = organic matter intake, DOMI = digestible organic matter intake

3. Dairy replacement calves and heifers

The nutrient excretion calculations for dairy replacement calves and heifers are based mainly on the same equations as used for dairy cows. Calculations are divided into three age categories: 0-6, 6-12 and >12 months. The age of a dairy heifer at 1st calving was on the average 769 days (25.3 months) in 2021 (ProAgria, 2022) and after 1st calving the animal is included in the dairy cow category.

3.1. Calculation of live weight

Estimation of manure and nutrient output of replacement heifers starts by calculation of the BW [Eq. 69] and the LW of the heifer using Richard's function from MW [Eq. 70] (Table 12).

Equations used to estimate BWs of calves and heifers are based on datasets by Berglund (1987), Kärki (1996) and Sundberg (2005). Equations are built based on dams' MW and BW of calves of different breeds and genders. Dams' MW influences the BW of the calf, and based on this BW, the MW of a heifer can be estimated more precisely.

First, the BW of a dairy replacement calf is iterated based on breed, gender, and dam's MW in BCS 3.5 ($dMW_{3.5}$) [Eq. 69]. This BW equation gives more precise outcome of the actual BW than Equations [42–43] and takes the gender of the calf into notice. Then, by using Richard's function, the MW of a dairy replacement calf and heifer is calculated using the BW [Eq. 70]. The MW is solved from the function by setting the same BW as calculated in Eq. [69] as a result, i.e. as LW. When solving BW, age of the calf is one day.

Table 12. Equations used to calculate the BW and LW of dairy replacement calf and heifer.

No	Equation
69.	BW, dairy cow calf = $71.3 - 0.137 \times dMW_{3.5} + 0.000138 \times dMW_{3.5}^2$
70.	LW dairy heifer = $MW \times (1 - 0.748 \times e^{-0.00289 \times Age})^2$ (based on Perotto et al. 1992)
71.	LWG, kg/day = (LW at Age_2 – LW at Age_1) / (Age_2–Age_1)

BW = calf's birth weight, $dMW_{3.5}$= dam's MW in body condition score 3.5, LW= live weight, Age= age, days, LWG = live weight gain, kg/day, Age_1 = age at the beginning of the growth interval, days, Age_2 = Age at the end of the growth interval, days

Live weight is calculated for different stages of the growth to be able to estimate the average growth per day (LWG) [Eq. 71] and required amount of metabolizable energy and nutrients from the diet. For replacement heifers, eight different growth intervals are calculated (1–30 days, 30–60 days, 60–91 days, 91–182 days, 182–365 days, 365–629 days, 629–730 days, and 730–769 days, first number being Age_1 and second number being Age_2).

The average LW gains for dairy replacement heifers between the ages of 0–6, 6–12 and >12 months were 1.06, 0.98, and 0.67 kg/day, respectively, in 2021.

3.2. Energy requirements

Energy requirements for dairy breed replacement heifers are calculated similarly as for heifers raised for beef for growth and maintenance (Chapter 4.3). Energy requirements for pregnancy are calculated as presented in Table 13.

The estimation of ME intake is based on Finnish nutrient requirements (Luke 2023). The ME consumption is estimated to be identical between replacement and beef calves of dairy breed under 6 months of age (Tables 14 and 21). Above this age, the ME consumption of replacement animals is lower than that of beef calves. The additional energy needed for the pregnancy is added to the last age category (>12 months).

Table 13. Equations for calculating energy requirements for pregnancy for heifers.

No	Equation
72.	MEr_{preg}, days 365 – 629 = $3.29 - 0.083 \times C_{age} + 0.000005 \times C_{age}^2 + 0.041 \times BW - 0.00004 \times C_{age} \times BW$
73.	MEr_{preg}, days 629 – 731 = $359 - 0.90 \times C_{age} + 0.00056 \times C_{age}^2 + 1.75 \times BW - 0.0020 \times C_{age} \times BW$
74.	MEr_{preg}, days 731 – 769 = $709 - 1.78 \times C_{age} + 0.001 \times C_{age}^2 + 4.52 \times BW - 0.0049 \times C_{age} \times BW$

C_{age}= age at calving, 769 days in 2021, BW = calf's birth weight

3.3. Diet composition and intake

The diets used in calculations for dairy replacement calves and heifers are based on feeding records collected by ProAgria (Table 14). Dairy calves are fed with full milk for the first five days after birth and after that they are given mainly milk replacer until weaned at the age of 2 months. The calves under 2 months of age have free access to concentrate and forage. After this, the diet is mainly based on grass silage. The diet changes depending on the LW and production stage of the calves and heifers.

Dry matter and nutrient intake are calculated similarly as for dairy cows (Chapter 2.4, Table 8).

Table 14. The energy and mineral contents of the diet of dairy replacement heifers in different age categories.

Age, months	0–6	6–12	>12
Metabolizable energy MJ/kg DM	12.0	12.2	10.8
Gross energy, MJ/kg DM	18.6	19.0	18.6
In DM, g/kg			
Ash	80.0	59.7	75.6
Crude protein	158	164	144
Crude fat	50.4	46.7	41.1
Non-structural carbohydrates	366	350	256
Neutral detergent fibre	346	380	483
Phosphorus (P)	4.75	3.68	3.30
Potassium (K)	17.1	18.4	23.3

DM = Dry matter ME = metabolizable energy; N =nitrogen; P = phosphorus; K = potassium

Nutrient intake for replacement heifers and calves is calculated similarly as for heifers raised for beef.

3.4. Retention of nutrients

The intake of nutrients (N, P, K) is divided into retained and excreted fractions. Retention of the nutrients and growth of animals is calculated as described in Chapter 4.5. Retention to growth is calculated for eight different intervals (see Chapter 3.1). Pregnancy is included into the retained fraction as the calculation ends just before calving. Retention to pregnancy is calculated as in Equations [33–40].

The nutrient retention for calves between 0–6 months is the same as for dairy breed heifers raised for beef (see Chapter 4, Equations [95–100]) and the nutrient retention for animals over 6 months is calculated according to Equations [101–104].

3.5. Excretion

Feed intake and nutrient excretion are calculated separately for age categories 0–2, 2–6, 6–12, 12–24 and 24–26 months, which match with the management practices of the lifespan of a replacement heifer. The results are pooled into three categories (0–6, 6-12 and >12 months) to match the official reporting (Tables 1 and 2), depending on the end-user. The excretions follow the method described in Chapter 2.6. Final amounts of excretion per animal per year are weighted average values within reported categories.

4. Dairy and beef breed bulls and heifers raised for beef

4.1. Outline of the beef production systems

In 2021, the total amount of beef produced in Finland was 86 million kilograms and the number of cattle slaughtered was 259 000, of which approximately 52 % were bulls, 27 % cows and 21 % heifers (OSF: Meat production. 2023). Bull calves born on dairy farms and heifer calves which are not needed for dairy herd replacement are delivered at the age of few weeks to farms specializing in beef production. Calves of suckler cows are reared with their dams in the herd until weaning at around the age of six months, and then typically delivered to farms specialized on beef production. Male calves used for beef production are not castrated so that steers are not used in the Finnish system.

Beef production in Finland is mostly based on dairy breeds (Niemi & Väre 2018). Most common breeds used in milk production are Ayrshire (Nordic Red) and Holstein. The most common beef breeds in Finland are Aberdeen Agnus, Charolais, Hereford, Limousin and Simmental (Faba, 2022). However, the decrease in the dairy cattle population during recent years is foreseen to reduce the level of beef production. Therefore, beef producers are increasing suckler cow production. The number of suckler cows has more than doubled during the 2000's in Finland. However, their number (63 700) is still relatively low compared with dairy cows (253 500) in year 2021 (OSF: Number of livestock. 2023).

4.2. Calculation of live weight

The estimation for BW and LW of calves, bulls and heifers raised for beef is similar to the estimation of BW and LW of dairy replacement calves and heifers (Chapter 3.1.) and is based on data obtained from Faba.

First, the BW of a calf is iterated based on breed, gender, and dam's MW in BCS 3.1 ($dMW_{3.1}$) [Eq. 75–76] (Table 15). Equations are used to calculate the BW for dam's MW in BCS 3.1 between the weights of 550–750 kg, interval being 25 kg. For dairy breed bull calves, MW in BCS 3.5. for dams is used [Eq. 77]. For dairy breed heifers raised for beef, Equation [69] (Table 12) is used. Then, by using Richard's function in Table 17 [Eq. 80–84], the MW is iterated using the BW from Eq. [75–77] in the same way as for dairy heifers and calves (Table 12).

Table 15. Equations for calculating the BWs of calves raised for beef.

No	Equation
75.	BW, beef breed cow calf = $0.0849 \times dMW_{3.1} - 0.0000363 \times dMW_{3.1}^2$
76.	BW, beef breed bull calf = $0.0883 \times dMW_{3.1} – 0.0000349 \times dMW_{3.1}^2$
77.	BW, dairy breed bull calf = $77.0 – 0.149 \times dMW_{3.5} + 0.000151 \times dMW_{3.5}^2$

BW = birth weight, $dMW_{3.1}$= dam's mature weight in BCS 3.1, $dMW_{3.5}$= dam's mature weight in BCS 3.5

Live weight (LW) for the slaughtered bulls and heifers is estimated by defining dressing percentage. Calculation of dressing percentage is based on data collected from six feeding and beef production experiments of bulls (26 diet observations) and heifers (16 diet observations). Data of dressing percentages of bulls are based on several datasets (Huuskonen et al. 2007, Huuskonen et al. 2009a, Pesonen et al. 2012, Pesonen et al. 2013, Huuskonen et al. 2014, Vestergaard et al. 2019), and that of heifers on Huuskonen et al. (2009b), Lamminen et al. (2006), Manninen et al. (2004; 2006), Rinne et al. (1998) and Vestergaard et al. (1993, 2019)

Annual dressing percentages are calculated from national data of slaughtered bulls and heifers, which comprises number of animals slaughtered, their CW, carcass classification and age at slaughter. Carcass fat and conformation of slaughtered bulls and heifers is classified with EUROP system (EC 2023), but the conventional 5-point grading scale for fat and conformation is enlarged to 15 grading points as described by Hickey et al. (2007). The calculated Equations [Eq. 78–79] used to predict LW by carcass quality classification of bulls and heifers are presented below (Table 16).

Table 16. Equations for calculating the dressing percentages of beef bulls and heifers based on Finnish experimental data.

No	Equation
78.	Dressing percentage, bull, % = 48.9 + 0.894 × carcass conformation (1-15) – 0.190 × carcass fat (1- 15)
79.	Dressing percentage, heifer, % = 41.2 + 1.48 × carcass conformation (1-15) + 0.351 × carcass fat (1-15)

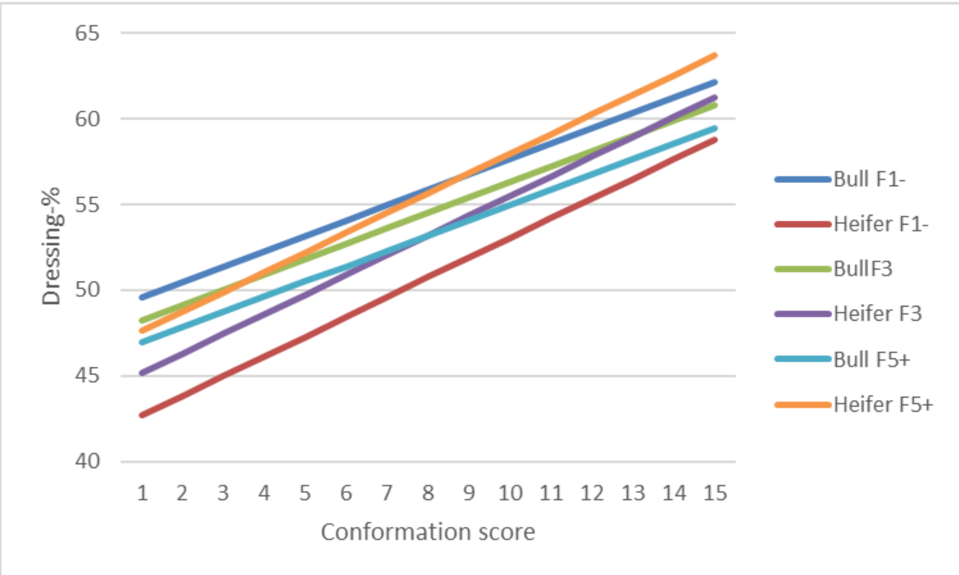

Figure 7. The effect of carcass fat and conformation score on the dressing percentage (based on Eq. [63] and [64]). The results have been presented separately for fat scores 1-, 3 and 5+ (on a scale from 1 to 5).

The LW gain is estimated with Richards´ function, similarly as for dairy cows (see chapter 3.1.). It is first used to solve the MW and birth BW of bulls and heifers. After solving MW, Richards´ function is used to estimate the LW gain. Calculations are made for both genders and breed types [Eq. 80–84], as described in Table 17. Equation [83] is iterated to predict LW gain of a heifer for beef production and for replacement beef heifer (suckler cow production).

For beef bulls and heifers, six to seven age intervals are used to calculate the growth (LWG) and LW for these intervals. These intervals are 1–30, 30–61, 61–91, 91–182, 182–365, 365–563 or 365–730 and 730–862 days for dairy breed heifers raised for beef, depending on the slaughter age. For beef breed heifers these growth intervals are 1–30, 30–61, 61–91, 91–182, 182–365, 365–522 or 365–730 and 730–913 days, for dairy breed bulls 1–30, 30–61, 61–91, 91–182, 182–365, 365–600 or 365–730 and 730–862 days and for beef breed bulls 1–30, 30–61, 61–91, 91–182, 182–365, 365–591 or 365–730 and 730–1041 days. LWG is calculated similarly as for dairy replacement heifers using Eq. [71].

Table 17. Equations for calculating the LW of beef cattle.

No	Equation
80.	LW dairy bull = MW × (1 - 0.788 × $e^{-0.00259 \times Age}$)^2 (based on Brown et al. 1972)
81.	LW beef bull = MW × (1 - 0.796 × $e^{-0.00249 \times Age}$)^2 (based on Brown et al. 1972)
82.	LW beef heifer = MW × (1 - 0.756 × $e^{-0.00277 \times Age}$)^2 (based on DeNise et al. 1985)
83.	LW small breed[1)] dairy heifer = MW × (1 - 0.763 × $e^{-0.00285 \times Age}$)^2
84.	LW small breed[1)] dairy bull = MW × (1 - 0.802 × $e^{-0.00255 \times Age}$)^2

LW =live weight, kg; MW = mature weight, kg (see Table 15 for MW); Age = age, days
[1)]Finn cattle and Jersey

4.3. Energy requirements

Energy consumption of growing bulls and heifers is estimated based on Finnish nutrient requirements (Luke 2023) for calves and growing animals. These requirements are based on the equation presented by AFRC (1993), but coefficients are modified according to Finnish research results [Eq. 85–88] (Table 18). Energy requirements are presented for dairy breed bulls and heifers. Beef breed bulls and heifers are assumed to grow with 10 % lower energy consumption than pure dairy breed animals (Luke 2023). Metabolizable energy (ME) intake is calculated separately for animals younger than 6 months and older than 6 months using the Equations in Tables 19 and 20.

Table 18. Equations used in calculation of metabolizable energy (ME) intake (MJ/d) of dairy and beef breed bulls and heifers younger than 6 months (based on nutrient requirements; Luke 2023).

No	Breed	Equation
85.	Dairy breed heifer	ME, MJ/d = ((28005 – 741 × BW + 193 × LW + (-6007) × (LW / BW)))/182
86.	Dairy breed bull	ME, MJ/d = ((31715 – 774 × BW + 175 × LW + (- 5868) × (LW / BW)))/182
87.	Beef breed heifer	ME, MJ/d = ((31796 – 862 × BW + 212 × LW + (-6641) × (LW / BW)))/182
88.	Beef breed bull	ME, MJ/d = ((43662 – 1091 × BW + 225 × LW + (-7807) × (LW / BW)))/182

ME = metabolizable energy, MJ; LW = calculated live weight at age of 182 days, kg; BW = calf birth weight, kg

Table 19. Equations used in calculation of ME intake (MJ/d) of growing bulls and heifers older than 6 months calculated from nutrient requirements (Luke, 2023).

No	Gender	Equation
89.	Heifer	$ME, MJ/d = (26.4 + 0.010 \times ALW – 41.0\times LWG - 0.00006 \times ALW^2 + 35.2 \times LWG^2 + 0.12 \times ALW \times LWG) \times C$
90.	Bull	$ME, MJ/d = (41.5 + 0.12 \times ALW - 52.72 \times LWG - 0.00007 \times ALW^2 + 28.8 \times LWG^2 + 0.09 \times ALW \times LWG) \times C$

ME = metabolizable energy; LWG = Live weight gain, kg/d, C = 1.0 for dairy breed and 0.9 for beef breed heifers and bulls, ALW = average live weight as calculated in Table 20, kg

A parameter of average live weight (ALW) in Table 19 describes the ALW during each calculated age interval. ALW is calculated separately for both genders and breed types as shown in Table 20 [Eq. 91-94].

Table 20. Equations used in calculation of average LW (ALW, kg) of bulls and heifers (integrals from equations presented in Table 16).

No		Equation
91.	Dairy heifer	$ALW, kg = (((MW / (2 \times -0.00289)) \times (2 - 0.748 \times e^{(-0.00289 \times Age2)})^2 + MW \times Age2) - ((MW / (2 \times -0.00289)) \times (2-0.748 \times e^{(-0.00289 \times Age1)})^2 + MW \times Age1)) / (Age2 - Age1)$
92.	Dairy bull	$ALW, kg = (((MW / (2 \times -0.00259)) \times (2 - 0.788 \times e^{(-0.00259 \times Age2)})^2 + MW \times Age2) - ((MW / (2 \times -0.00259)) \times (2-0.788 \times e^{(-0.00259 \times Age1)})^2 + MW \times Age1)) / (Age2 - Age1)$
93.	Beef heifer	$ALW, kg = (((MW / (2 \times -0.00277)) \times (2 - 0.756 \times e^{(-0.00277 \times Age2)})^2 + MW \times Age2) - ((MW / (2 \times -0.00277)) \times (2-0.756 \times e^{(-0.00277 \times Age1)})^2 + MW \times Age1)) / (Age2 - Age1)$
94.	Beef bull	$ALW, kg = (((MW / (2 \times -0.00249)) \times (2 - 0.796 \times e^{(-0.00249 \times Age2)})^2 + MW \times Age2) - ((MW / (2 \times -0.00249)) \times (2-0.796 \times e^{(-0.00249 \times Age1)})^2 + MW \times Age1)) / (Age2 - Age1)$

ALW = average live weight of the period from Age1 to Age 2; MW = mature live weight (kg); Age 1= age in the beginning of period, Age2 = age in the end of period

4.4. Diet composition and intake

Diets used in calculations are based on expert evaluations, designed to fulfil the energy requirements of a growing bull and heifer.

The model diet for dairy breed calves is as follows: They receive milk for the first five days after their birth and after that they are given milk replacer until they are weaned at the age of two months. They have free access to starter compound feed and grass silage after the first week of age. After weaning, the diet is mainly based on silage, protein concentrate (rapeseed meal) and mixture of barley and oats. Diets are slightly adjusted depending on the LW of the calves.

Beef breed bulls and heifers are fed with milk and grazed until they are weaned at the age of around six months. After this, diet is mainly based on grass silage and concentrate feeds.

The chemical compositions of the average diets are presented in Tables 21 and 22.

Table 21. The average diet composition fed to bulls.

	Dairy breed bull			Beef breed bull		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Metabolizable energy, MJ/kg DM	12.0	12.4	11.6	14.8	11.9	11.4
Gross energy, MJ/kg DM	18.5	19.0	18.8	20.7	18.9	18.7
In DM, g/kg						
Ash	81.5	57.3	68.2	87.8	64.3	70.6
Crude protein	157	166	156	192	160	153
Crude fat	48.1	47.2	44.3	148	45.5	43.5
Non-structural carbohydrates	385	362	303	335	325	289
Neutral detergent fibre	328	367	429	237	405	444
Phosphorus (P)	4.97	3.75	3.46	5.85	3.56	3.41
Potassium (K)	15.9	17.5	21.3	16.1	20.0	22.1

ME = Metabolizable energy; DM = dry matter

Table 22. The average diet composition fed to heifers.

	Dairy breed			Beef breed			Beef replacement		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Metabolizable energy, MJ/kg DM	12.0	11.5	10.6	14.9	11.3	10.6	14.9	11.2	10.1
Gross energy, MJ/kg DM	18.6	18.8	18.6	20.8	18.7	18.6	20.8	18.7	18.5
In DM, g/kg									
Ash	80.2	69.4	76.7	83.3	71.6	76.7	83.4	72.2	77.9
Crude protein	158	154	141	192	151	142	192	151	135
Crude fat	50.3	43.9	40.2	149	42.8	38.5	149	42.8	38.5
Non-structural carbohydrates	366	296	246	337	283	246	337	279	230
Neutral detergent fibre	346	436	496	238	451	495	238	456	518
Phosphorus (P)	4.76	3.44	3.29	5.74	3.38	3.28	5.74	3.37	3.28
Potassium (K)	17.1	21.7	23.4	16.1	22.4	23.4	16.1	22.5	23.1

ME = Metabolizable energy; DM = dry matter

4.5. Retention of nutrients

Retention of nutrients is estimated using the nutrient content in empty body weight (EBW) in the beginning of growth (newborn calf) and in the end of the examined period (slaughter age in beef animals and 1st calving in replacement heifers) according to ARC (1980). The estimation begins with the calculation of EBW. EBW is calculated from LW using Eq. [95–97] (Table 23). LW is estimated as described in Eq. [75–77] and [80-84]. Before 3 months of age the equations [95–97] are weighted according to estimated diet composition.

Table 23. Equations for calculating EBW.

No		Equation
95.	Newborn calf on milk only diet	EBW, kg = 0.94 × LW (ARC 1980)
96.	Replacement heifer or beef cattle, before 3 months of age (concentrate rich diet)	EBW, kg = (LW – 9.81) / 1.09 (ARC 1980)
97.	Replacement heifer or beef cattle, after 3 months of age	EBW, kg = (LW - 15.3) / 1.09 (ARC 1980)

EBW = empty body weight, kg; LW = live weight, kg

For a newborn calf, the nutrient concentrations are calculated from LW using Equations [98–100] (Table 24). Phosphorus mass for a calf of 40 kg LW is 320 g (8 g/kg LW) and potassium mass 84 g (2.1 g/kg LW) (ARC 1980).

Table 24. Equations for calculating the nutrient concentration in empty body for newborn calf.

No	Equation
98.	Protein mass, kg = 0.185 × LW (ARC 1980)
99.	Fat mass, kg = 0.040 × LW (ARC 1980)
100.	Ash mass, kg = 0.043 × LW (ARC 1980)

LW = live weight, kg

The concentrations of fat, protein, water, and ash in EBW is calculated as described in [Eq. 101–104] (Table 25). For replacement animals, the body condition score (BSC) during 1st calving is assumed to be 3.5 for dairy breed heifers, and 3.1 for beef breed heifers (scale 1–5).

Table 25. Equations used for calculating the composition percentages of EBW for replacement animals. Equations [102–104] are based on Schultz et al. (1974), Ferrell et al. (1976; 1984; 1998), Arnold et al. (1985), Gibb et al. (1992), Kirchgessner et al. (1993), Andrew et al. (1994), Chizzotti et al. (2007) and Yan et al. (2009).

No	Equation
101	EBWfat% = 7.54 × BCS – 3.77 (Fox et al. 1999)
102.	EBWprot% = 22.1 - 0.170 × EBWfat% -0.0011 × $\text{EBWfat\%}^2$
103.	EBWwater% = 93.8 - 1.02 × EBWprot% - 0.919 × EBWfat%
104.	EBWash% = 100 - EBWfat% - EBWprot% - EBWwater%

EBW = empty body weight, BCS= body condition score, EBWfat% = fat percentage of the EBW, EBWprot%= protein percentage of the EBW, EBWwater%= water percentage of the EBW, EBWash%= ash percentage of the EBW

For slaughter animals, the carcass fat and protein concentrations are estimated from conformation and fat scores using Equations of Table 26 and after that fat, protein, water, and ash concentrations in EBW are calculated using Equations [105–112] (Table 27).

Table 26. Estimation equations for carcass fat and protein concentrations (%) for slaughter animals. Equation: Y = A + B × Fat score + C × Conformation score + D × Fat score^2. Based on Field et al. (1974) and Kempster et al. (1986).

Animal category	Intercept A	Fat score B	Conformation score C	(Fat score)^2 D
Y = Carcass fat %				
Bull 12–24 months	16.5	-0.480	-0.163	0.119
Bull over 24 months	16.6	-0.479	-0.163	0.119
Cow	15.2	-0.363	-0.405	0.104
Heifer 12–24 months	16.1	-0.481	-0.162	0.119
Heifer over 24 months	16.2	-0.480	-0.164	0.119
Y = Carcass protein %				
Bull 12–24 months	19.3	0.151	0.032	-0.029
Bull over 24 months	19.2	0.151	0.033	-0.028
Cow	19.2	0.144	0.085	-0.025
Heifer 12–24 months	19.2	0.151	0.032	-0.029
Heifer over 24 months	19.1	0.151	0.033	-0.029

Table 27. Equations for calculating the mass percentages of EBW for slaughter animals. Equations [105–112] are based on several international experimental data sets (Schultz et al. 1974, Ferrell et al. 1976, Ferrell et al. 1984, Arnold et al. 1985, Gibb et al. 1992, Kirchgessner et al. 1993, Andrew et al. 1994, Ferrell et al. 1998, Chizzotti et al. 2007, Yan et al. 2009).

No	Equation
105.	EBWfat% = 0.988 × carcass fat%
106.	EBWprot% = 0.993 × carcass protein%
107.	EBWwater% = 93.8 - 1.02 × EBWprot% - 0.919 × EBWfat%
108.	EBWash% = 100 - EBWfat% - EBWprot% - EBWwater%
109.	EBWphosporus% = 0.180 × EBWash% for animals for animals of 1 months
110.	EBWphosporus% = 0.174 × EBWash% for animals for animals of 2 months
111.	EBWphosporus% = 0.168 × EBWash% for animals >3 months (Chizzotti et al. 2007, 2009; Schultz et al. 1974)
112.	EBWpotassium% = 0.00323 × EBWwater% (Chizzotti et al. 2007, 2009; Schultz et al. 1974)

EBW = empty body weight

Then logarithms (base 10; log10) of EBW, fat, protein, and ash mass of a newborn calf (mass in the beginning) and corresponding numbers from final EBW (mass in the end) are calculated as in Eq. [113] (Table 28). After that, the Equations [114–115] are produced to define the final nutrient mass in EBW (based on ARC 1980).

Table 28. Equations for calculating final mass of nutrients in EBW for slaughter animals (ARC 1980).

No	Equation
113.	Coefficient = (log10 (mass in the end) - log10 (mass in the beginning)) / (log10 (end EBW) - log10 (beginning EBW))
114.	Constant = Coefficient × log10 (beginning EBW) × -1 + log10 (mass in the beginning)
115.	Final mass in EBW = $10^{(\text{constant+coefficient} \times \text{log10 (EBW)})}$

EBW = empty body weight

Table 29. Average values calculated from slaughter data of year 2021 (source: Finnish Food Authority).

Animal category	n	Age, d	Slaughter weight, kg	Dressing %	MW, kg	BCS	EBW fat, %	EBW protein, %
Dairy cow	59 990	1 950	295	43.1	767	2.71	22.6	17.8
Suckler cow	8 470	2 822	347	46.5	758	2.99	19.6	18.4
Bull, 12–24 months, dairy breed	76 109	599	357	53.1	1 073	2.73	16.8	19.2
Bull, 12–24 months, beef breed	44 393	591	408	56.5	1 140	2.71	16.7	19.2
Bull, > 24 months, dairy breed	5 414	883	377	53.2	928	2.73	16.8	19.1
Bull, > 24 months, beef breed	4 985	1 041	402	56.1	856	2.70	16.6	19.1
Heifer, 12–24 months, dairy breed	13 957	564	244	49.5	728	2.93	18.3	18.7
Heifer, 12–24 months, beef breed	32 133	522	274	53.7	771	2.93	18.3	18.7
Heifer, >24 months, dairy breed	4 329	863	301	50.3	694	3.35	21.5	18.0
Heifer, >24 months, beef breed	2 618	913	309	53.7	635	3.30	21.1	18.0

MW = mature weight; BCS = body condition score; EBW = empty body weight

4.6. Excretion

The quantity of DM excreted in faeces equals to the intake of indigestible feed DM. DM digestibility of the diet is estimated with [Eq. 45]. Values for organic matter digestibility (OMD) are taken from the Finnish Feed Tables (Luke 2023) and labelling of manufactured feeds. For DM content in faeces, a constant value of 150 g/kg is used. Faecal and urinary output is calculated with Equations [48] and [49]. Equations [46–49] are the same as the ones used in calculations for dairy cattle.

The faecal and urinary DM, OM and ash are calculated similarly as for dairy cows. Faecal N output is calculated as intake of indigestible feed N [Eq. 116] (Table 30). Feed N digestibility is obtained from the Finnish Feed Tables (Luke 2023). The faecal and urinary DM, OM, ash, K, P and urinary N are calculated similarly as for dairy cows with Equations [57–62] and [64–68] (Table 11).

Table 30. Equation to calculate excretion of nitrogen in faeces.

No	Equation
116.	N in faeces (g/d) = N intake – Intake of digestible feed N

N =nitrogen

5. Suckler cows

5.1. Calculation of live weight

The average live weight (LW) and the live weigh gain (LWG) of a suckler cow is calculated from MW in BCS of 3.1 ($MW_{3.1}$) using Equations [117–123] (Table 31), similarly as described in Chapter 2.2. The LW at slaughter [Eq. 123] is calculated from the CW using the dressing percentage. Dressing percentage is calculated similarly as for dairy cows [Eq. 1] and was 46.5 for suckler cows in 2021 (Table 29). CW is calculated from the sum of CW divided with the number of carcasses, which is obtained annually from the Finnish Food Authority.

Table 31. Equations used for calculating the LW of suckler cows (based on Fox et al. 1999).

No	Equation
117.	LW, without pregnancy, lactating cow, kg = $0.950 \times MW_{3.1} - 30.7 + 4.06 \times S\_age$ (Fox et al. 1999)
118.	LW, without pregnancy, non-lactating cow, kg = $0.975 \times MW_{3.1} - 19.7 + 2.61 \times S\_age$ (Fox et al. 1999)
119.	LW, with pregnancy, lactating cow, kg = $0.951 \times MW_{3.1} – 30.8 + 4.11 \times S\_age$ (Fox et al. 1999)
120.	LW, with pregnancy, non- lactating cow, kg = $0.\ 996 \times MW_{3.1} – 17.1+ 3.12 \times S\_age$ (Fox et al. 1999)
121.	LWC, lactating cow= $0.086 - 0.0108 \times S\_age$
122.	LWC, non-lactating cow = $0.059 + 0.00011 \times MW_{3.1} – 0.00785 \times S\_age$
123.	LW at slaughter = CW, kg / (Dressing percentage × 0.01)

LW = live weight, kg; $MW_{3.1}$ = mature weight, kg in body condition score 3.1; S_age = age at slaughter, years, CW = carcass weight, kg

The first calving was at 839 days, calving interval was one year, and the calculated replacement rate (RR) was 0.18 in 2021. Milk output of a medium size suckler cow was estimated to be 1 452 kg/year, and length of lactation 189 days. The calving date is set to be on April 10, which is early enough prior to the starting of the grazing period. The BW of the calves is calculated using Eq. [124–125] (Table 32) and were 42.2 kg and 46.0 kg in 2021 for primiparous and multiparous cows, respectively.

Table 32. Equations used for calculating the BW of calves (based on Eriksson et al. 2004 and Faba suckler cow data recording 2000 - 2018).

No	Equation
124.	BW, both genders, primiparous dam = $(0.0866 \times MW_{3.1} -0.0000356 \times MW_{3.1}^2) \times 0.933$
125.	BW, both genders, multiparous dam = $(0.0866 \times MW_{3.1} – 0.0000356 \times MW_{3.1}^2) \times 1.02$

BW = birth weight of the calf (kg); $MW_{3.1}$ = dam's mature weight at body condition score of 3.1; Equations based on Eriksson et al. (2004) and data from Faba 2000-2018.

5.2. Energy requirements

The calculated energy requirement (ME_{req}) of the modelled suckler cow is based on the Finnish nutrient requirements and included the predicted requirement for maintenance [Eq. 5] and lactation [Eq. 6] (Luke 2023) similarly as for dairy cows. Energy requirements for pregnancy (MEr_{pregn}) and cows LW change (MEr_{LWC}) are calculated using [Eq. 126–130] (Table 33). Lactation period is calculated as in [Eq. 131–132].

Energy requirement for pregnancy for a lactating suckler cow is set to zero, because the energy requirement during the first 3 months of pregnancy is very low.

Table 33. Equations used for calculating the energy requirements for suckler cows based on nutrient requirements (Luke 2023).

No	Equation
126.	MEr_{pregn}, lactating cows, MJ/d = 0
127.	MEr_{pregn}, non-lactating cows, MJ/d = 0.999 + 0.00826 × $MW_{3.1}$ + 0.221 × S_age
128.	MEr_{LWC}, lactating cows, MJ/d = 0.000782 × $MW_{3.1}$ + 32.4 × LWC
129.	MEr_{LWC}, non-lactating cows, MJ/d = 0.00254 × $MW_{3.1}$ + 29.5 × LWC
130.	$ME_{req} = MEr_{maint} + MEr_{milk} + MEr_{pregn} + MEr_{LWC}$
131.	Days lactating = 365 × (1 - (0.441 + 0.00523 × S_age))
132.	Days non-lactating = 365 × (0.441 + 0.00523 × S_age))

MEr_{pregn} = requirement of metabolizable energy, MJ for pregnancy, MJ/d; MEr_{LWC} = requirement of metabolizable energy, MJ for live weight change; ME_{req} = requirement of metabolizable energy, MJ; $MW_{3.1}$ = mature weight, kg in body condition score 3.1; LWC = live weight chance, kg/d; S_age = age at slaughter, years

5.3. Diet composition and intake

The diet offered to suckler cows includes the following three forages: pasture grass, grass silage and dry hay. Grazing period is estimated to be 122 days. Hay and grass silage are fed during the indoor feeding period. The chemical composition and nutritive values of feeds is presented in Table 34. The diet is supplemented only with a mineral feed.

Table 34. Mean composition of the daily ration of lactating and non-lactating suckler cows.

	Lactating cows	Non- lactating cows
Metabolizable energy, MJ/kg DM	10.5	8.9
Gross energy, MJ/kg DM	18.2	18.2
In DM, g/kg		
Ash	102	77.2
Crude protein	157	99.0
Crude fat	34.5	27.3
Non-structural carbohydrates	146	168
Neutral detergent fibre	560	628
Phosphorus (P)	3.85	2.78
Potassium (K)	28.9	20.8

DM = Dry matter

Dry matter and nutrient intake are calculated similarly as for dairy cows, based on energy requirements and diet composition.

5.4. Retention of nutrients

Feed N, P and K retained into cow LW gain or pregnancy is calculated using Equations [133–148] (Table 35). Retention of nutrients in lactating cows during pregnancy is extremely small, and therefore, in the calculations it is set to be zero.

Table 35. Equations for calculating retention of nutrients in lactating and non-lactating suckler cows. Effects of weight change on nutrient contents are calculated based on Fox et al. (1999) and P and K changes similarly as four young stock (Equations [105–115]).

No	Equation
Lactating cows	
133.	N retained, cow, g/d = (7.96 + 0.00153 × $MW_{3.1}$ – 1.05 × S_age)/6.25
134.	P retained, cow, g/d = 0.926 + 0.00112 × $MW_{3.1}$ -0.122 × S_age
135.	K retained, cow, g/d = 0.142 + 0.000103 × $MW_{3.1}$ - 0.0187 × S_age
136.	Ash retained, cow, g/d = 5.40 + 0.00664 × $MW_{3.1}$ - 0.726 × S_age
137.	N retained, pregnancy, g/d = 0
138.	P retained, pregnancy, g/d = 0
139.	K retained, pregnancy, g/d = 0
140.	Ash retained, pregnancy, g/d = 0
Non-lactating cows	
141.	N retained, cow, g/d = (2.42 + 0.00992 × $MW_{3.1}$ – 0.32 × S_age)/6.25
142.	P retained, cow, g/d = 0.788 + 0.000576 × $MW_{3.1}$ -0.104 × S_age
143.	K retained, cow, g/d = 0.0927 + 0.000155 × $MW_{3.1}$ - 0.0122 × S_age
144.	Ash retained, cow, g/d = 4.68 + 0.00342 × $MW_{3.1}$ -0.618 × S_age
145.	N retained, pregnancy, g/d = (- 6.53 + 0.0661 × $MW_{3.1}$ -0.0000272 × $MW_{3.1}^2$ + 0.862 × S_age) / 6.25
146.	P retained, pregnancy, g/d = - 0.285 + 0.00289 × $MW_{3.1}$ – 0.00000119 × $MW_{3.1}^2$ + 0.0377 × S_age
147.	K retained, pregnancy, g/d = -0.0722 + 0.000732 × $MW_{3.1}$ -0.0000003 × $MW_{3.1}^2$ + 0.00954 × S_age
148.	Ash retained, pregnancy, g/d = -1.52 + 0.0154 × $MW_{3.1}$ -0.000006 × $MW_{3.1}^2$ + 0.201 × S_age

N = nitrogen; P = phosphorus; K= potassium; S_age = age at slaughter, years; $MW_{3.1}$ = mature weight in body condition score 3.

5.5. Excretion

The N, P and K excreted in milk are calculated with the Equations [149–152] (Table 36). The concentrations of N, P and K in milk are taken from the Finnish Feed Tables and are 38.9 g/kg DM for N, 6.90 g/kg DM for P and 12.0 g/kg DM for K (Luke 2023). The DM and ash concentrations in milk are 130 g/kg and 54 g/kg DM, respectively.

Table 36. Equations for calculating the nutrients excreted in milk.

No	Equation
149.	N excreted in milk, kg = milk output, kg × 3.22 N, g/kg DM × 0.01 / 6.38
150.	P excreted in milk, kg = milk output, kg × 6.90 P, g/kg DM × 0.13 × 0.001
151.	K excreted in milk, kg = milk output, kg × 12.0 K, g/kg DM × 0.13 × 0.001
152.	Ash excreted in milk, kg = milk output, kg × 54.0 ash, g/kg DM × 0.13 × 0.001

N = nitrogen; P = phosphorus; K= potassium; DM = dry matter

DM excreted in faeces is calculated as intake of indigestible DM [Eq. 68]. The DM digestibility is calculated using Eq. [46] (modified from Ramin & Huhtanen 2013). The intake of digestible organic matter (DOM) is calculated based on organic matter digestibility of the corresponding feeds in the Finnish Feed Tables (Luke 2023). For the DM concentration of faeces, a constant value of 150 g/kg is used based on an unpublished dataset from Luke. Faecal output can be calculated when DM excretion and DM concentration in faeces are known [Eq. 48]. Urinary output is calculated using Eq. [49] (Eriksson et al. 2011).

The faecal N excretion per day is calculated separately for lactating and non-lactating suckler cows [Eq. 116] since the digestibility of crude protein is assumed to be slightly different for them. Faecal and urinary DM, OM, ash, P, K, and urinary N are defined with Equations [54–62] and [64–68] (Table 11). Equations are the same as used for dairy cows.

6. Summary of calculated results for all cattle categories

The appendices showing results for all cattle groups are described in chapter 6.1. Chapter 6.2. reports total excretion of nitrogen, phosphorus and potassium in year 2021, and chapter 6.3. shows a time series of the excretion of nitrogen and potassium. In chapter 6.4, a sensitivity analysis was conducted to evaluate the uncertainties of the calculation models.

6.1. Appendix Tables for all cattle groups

Detailed excretion calculation results for different cattle categories using input data from year 2021 are presented in Appendices as follows:

- **Appendix 1:** Initial data for the year 2021
- **Appendix 2:** Dairy cows
- **Appendix 3:** Dairy replacement calves and heifers
- **Appendix 4:** Growing bulls
- **Appendix 5:** Growing heifers raised for beef
- **Appendix 6:** Suckler cows
- **Appendix 7:** Beef replacement heifers
- **Appendix 8:** Description of different weights used in the calculations

Results are reported as per day and per year. Daily results were converted to annual ones by multiplying them with a factor of 365. Results shown in appendices present the results of one animal of that category. Results by each animal category are then multiplied by the annual amounts of animals per category for the official excretion calculations. All calculations from different animal groups represent an average animal from the national herd.

Results shown in the appendices accurately represent only the year the calculations are made from. Calculations are done separately each year with changing initial data (animal numbers, slaughter data, milk yield, diet composition etc.).

The calculations can be modified separately for large and small breeds by changing the LW of cows in the calculations, or by the level of production by changing the annual milk production. Similarly, the effects of diet composition can be demonstrated. For official calculations, it is critical that correct national input data are used. In Appendices 1-7, Finnish values for the year 2021 have been used.

For young cattle (both for dairy and beef) the growing period was divided into three phases:

- Animals younger than 6 months
- Animals at age of 6 to 12 months
- Animals at age over 12 months until calving (dairy replacement animals) or until slaughter (beef cattle).

The average slaughter age of dairy and beef breed bulls and heifers were 600 , 591 , 563 and 522 days, respectively.

The total excretion of faeces, urine, nitrogen, phosphorus, and potassium per animal per day and per year are represented in appendices as described above.

6.2. Total excretion of N, P and K in different animal categories in 2021

Total excretion of nitrogen, phosphorus, and potassium of year 2021 are shown in Figures 8–10, classified by different cattle categories. Note that calves include both bulls and heifers. The higher excretion of heifers compared to bulls is explained by the higher number of heifers (Table 1). Total amounts of faeces and urine excreted are presented in Figures 1 and 2 (see Introduction).

The efficiency of nutrient use is calculated as: nutrient retained / nutrient intake. As an example, the N use efficiency for dairy cows (covering both lactating and non-lactating) in Finland in 2021 was (51.3 kg N in milk + 1.5 kg N retained) / 198 kg N intake = 0.267 (data based on Appendix 2).

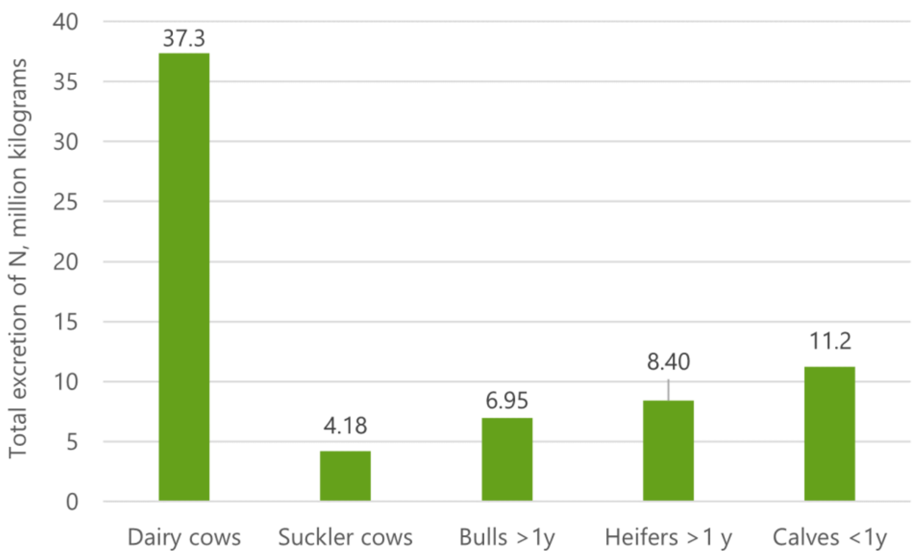

Figure 8. Total excretion of nitrogen, shown as million kilograms per year in 2021.

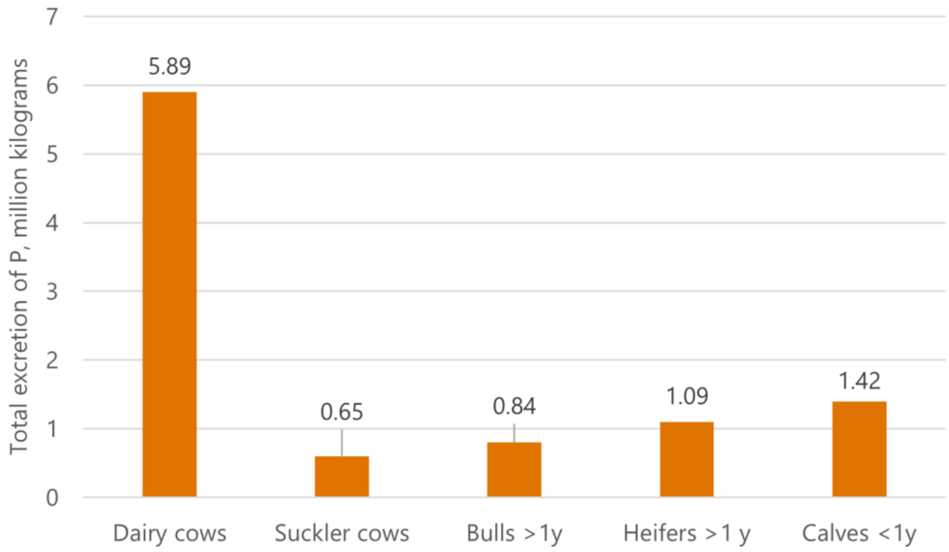

Figure 9. Total excretion of phosphorus, shown as million kilograms per year in 2021.

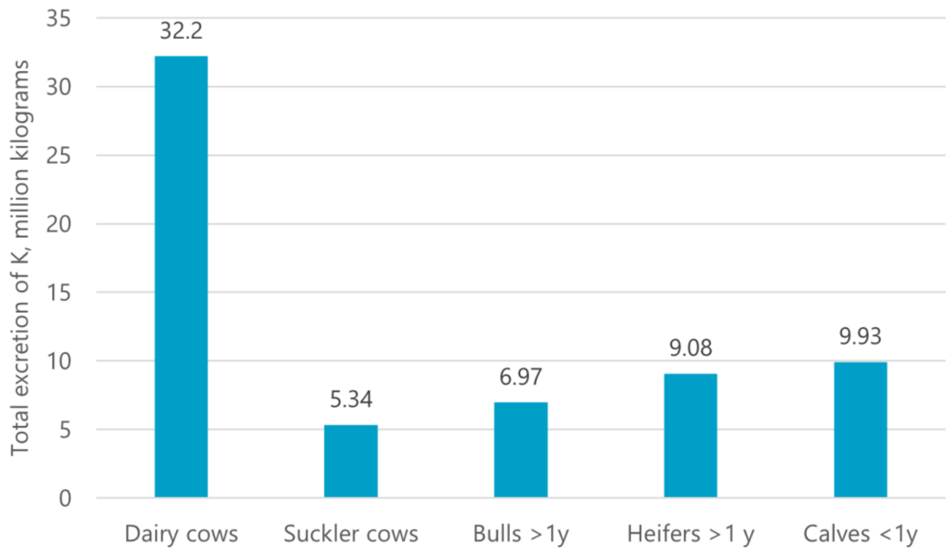

Figure 10. Total excretion of potassium, shown as million kilograms per year in 2021.

6.3. Time series for excretion of nitrogen and phosphorus

Excretion calculations form a continuous time series. The starting point for time series is year 1990, and the time series is updated every year when the calculations are finished.

Figure 11 shows a time series for the nitrogen excretion from year 1990 to 2021. Excretion is presented as thousands of kilograms per year. Different cattle groups are shown by different colours. s

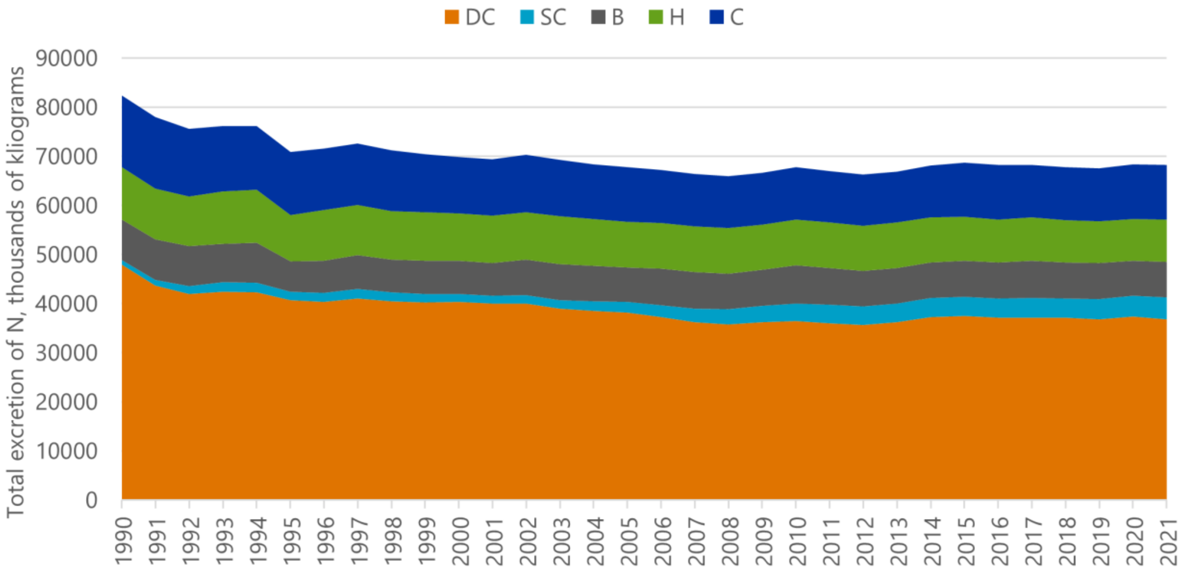

Figure 11. Time series for nitrogen excretion for national cattle herd, shown as thousands of kilograms per year. DC represents dairy cows, SC suckler cows, B stands for bulls, H for heifers and C for calves.

Figure 12 shows a time series for the phosphorus excretion from the year 1990 to 2021.

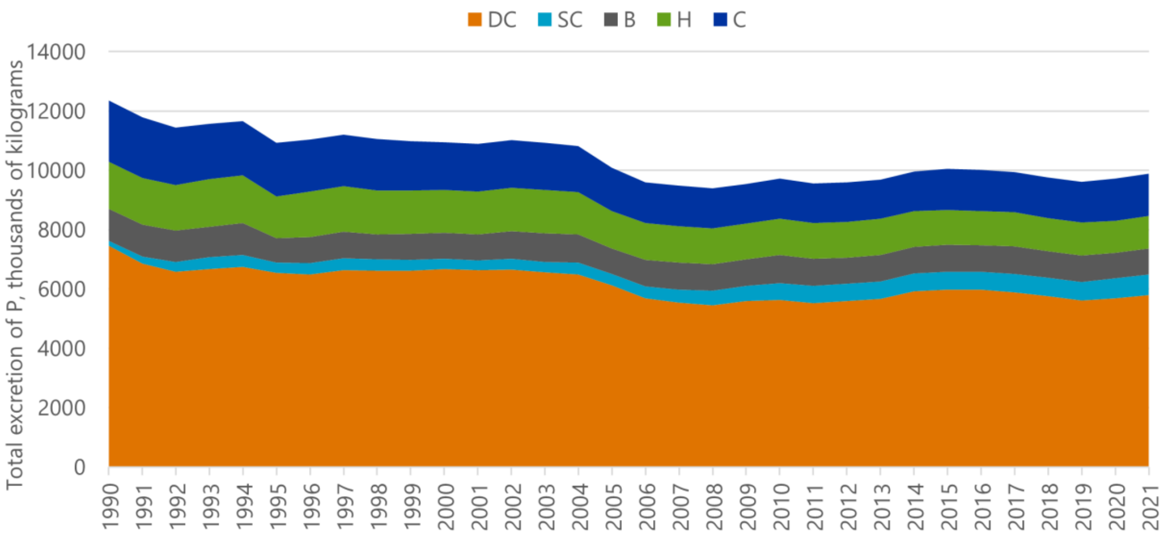

Figure 12. Time series for phosphorus excretion for national cattle herd, shown as thousands of kilograms per year. DC represents dairy cows, SC suckler cows, B stands for bulls, H for heifers and C for calves.

Both nitrogen and phosphorus excretion time series show a drop in the excretion in year 1995. This is due to reduction in the amount of cattle from 1994 (1 233 000) to 1995 (1 147 900) (OSF: Number of livestock. 2023), when Finland joined the European Union. The reduction in phosphorus excretion in 2005 is due to the reduction of phosphorus requirements (MTT 2004).

Figure 13 shows the nitrogen excretion for dairy cows and Figure 14 the nitrogen excretion for bulls. Excretion is shown as per animal per year on the left y-axis (blue line, kilograms of nitrogen), and as total excretion of a cattle category per year on the right y-axis (orange line, millions of kilograms of nitrogen).

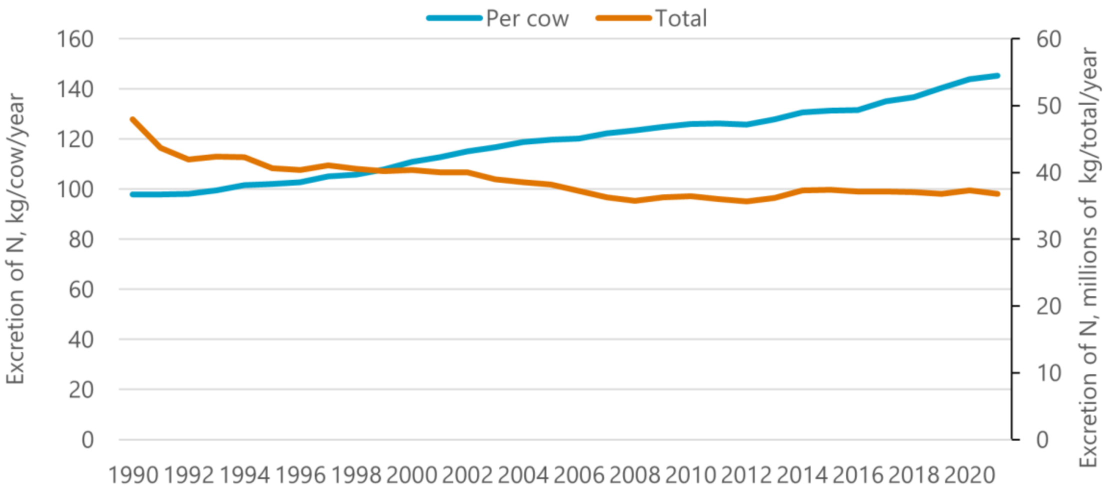

Figure 13. Time series for nitrogen excretion for dairy cows.

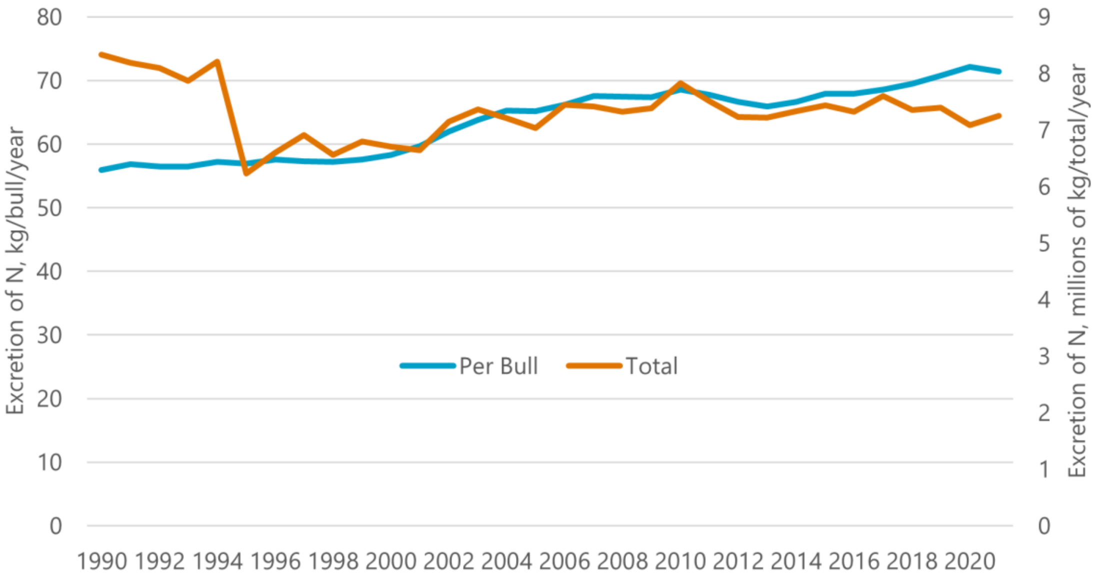

Figure 14. Time series for nitrogen excretion for bulls.

Figure 15 shows the phosphorus excretion for dairy cows and Figure 16 shows the phosphorus excretion for bulls. Excretion is shown as the total excretion of a cattle category per year on the right y-axis (orange line, millions of kilograms of phosphorus) and per animal per year on the left y-axis (blue line, kilograms of phosphorus).

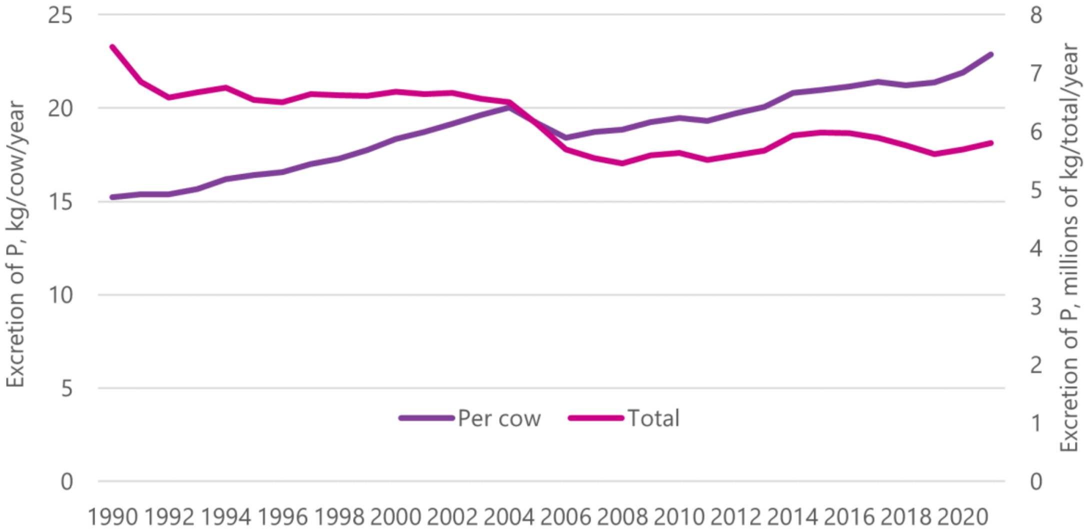

Figure 15. Time series for phosphorus excretion for dairy cows.

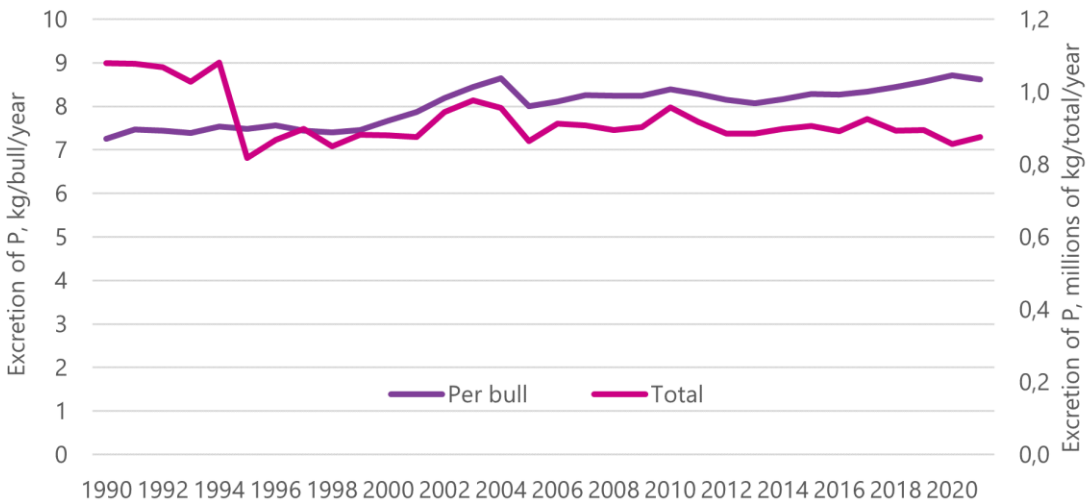

Figure 16. Time series for phosphorus excretion for bulls.

The excretion of phosphorus and nitrogen per animal per year has increased throughout the years. However, when the amount of cattle has steadily decreased during the last decades, the total excretion of nitrogen and phosphorus has also decreased within animal categories. Exception to this is suckler cows, whose amount has on the other hand increased and therefore the excretion of their category has also increased (Figures 12 and 13).

6.4. Sensitivity analysis of dairy cows' excretion

Since the initial data used for excretion calculations is massive and is gathered from different sources, a risk for small errors is real. Sensitivity analysis was therefore conducted for some calculations, so that the effect of these possible errors in the data can be demonstrated.

Sensitivity analyses were conducted so that only one variable from the initial data at a time was changed. These variables were milk yield, live weight (LW), diet crude protein (CP), phosphorus (P) or potassium (K) concentration, and dry matter intake (DMI). Variables were set to increase or decrease 10 % from the average values used in the original calculations. The composition of the diet fed to dairy cows is relatively well known, yet there are some uncertainties considering the exact diet composition fed to dairy cows. Live weight and milk yield on the other hand are well recorded and can be considered as well-known parameters. The effect of the changes on the excretion is described in Figures 17–19.

When considering excretion of nutrients, the diet's nutrient concentration and dry matter intake of an animal were the greatest influencers on the excretion in whole. If the nutrient intake decreases, the excretion decreases, and vice versa if the intake increases, so does the excretion. Since the nutrients are part of the dry matter of the diet, dry matter intake also has an influence on the nutrient intake and hence also on the excretion.

Milk yield changes had only minor effects on the excretions, similarly to cow's LW, which had even smaller effect on the excretion than milk yield. Milk yield's slightly greater effect on the excretions can be explained by the fact that greater milk yield requires more energy, more dry matter intake, and therefore more nutrient intake (Luke 2023).

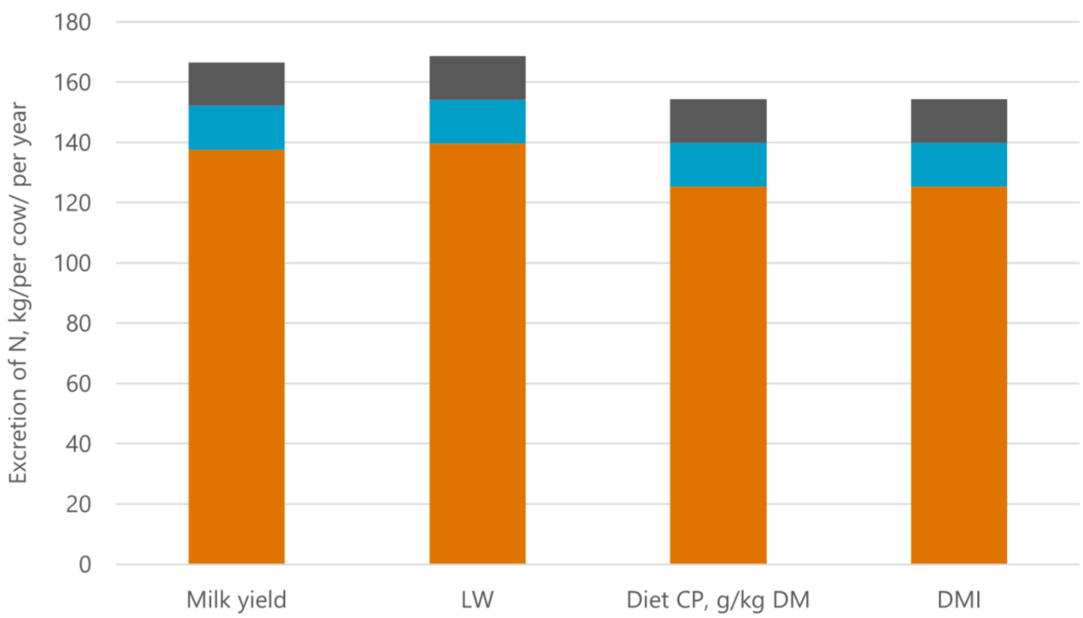

Figure 17. Total nitrogen excretion of a dairy cow (per animal per year) when milk yield, live weight (LW), diet crude protein concentration (Diet CP) or dry matter intake (DMI) was changed (-10% or +10%) in the calculation. Grey colour represents 10 % increase and blue 10 % decrease from the original level. The border between the blue and grey is the average excretion level for dairy cow in 2021.

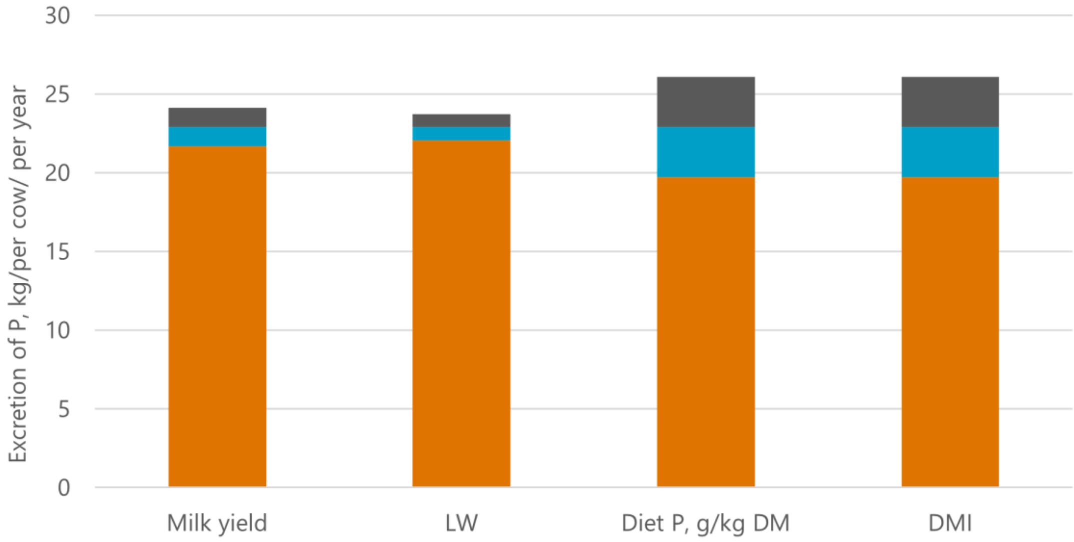

Figure 18. Total phosphorus excretion of a dairy cow (per animal per year) when milk yield, live weight (LW), diet P concentration (Diet P) or dry matter intake (DMI) was changed (-10% or +10%) in the calculation. Grey colour represents 10 % increase and blue 10 % decrease from the original level. The border between the blue and grey is the average excretion level for dairy cow in 2021.

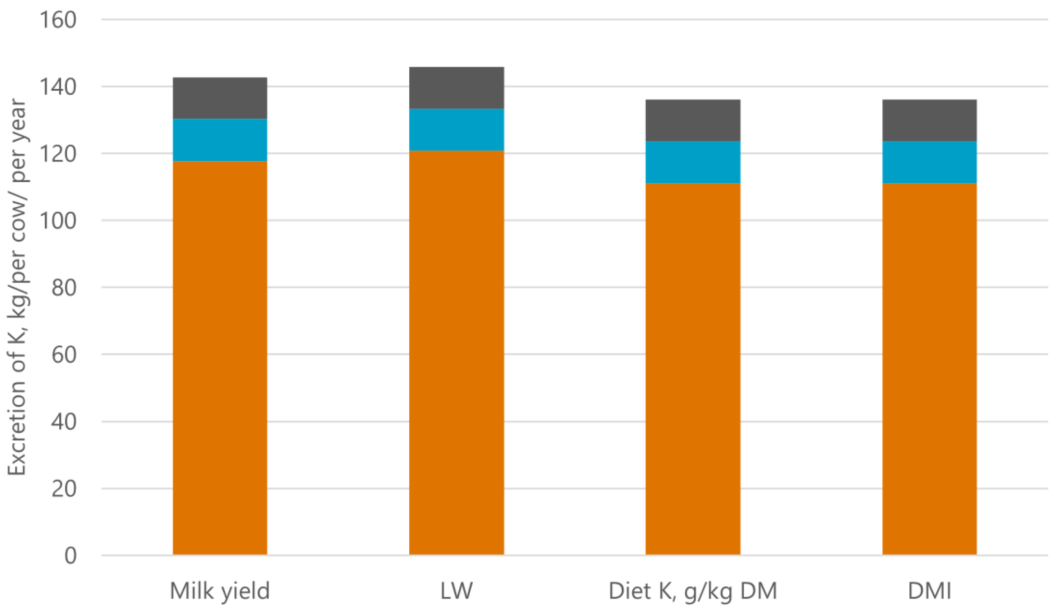

Figure 19. Total potassium excretion of a dairy cow (per animal per year) when milk yield, live weight (LW), diet K concentration (Diet K) or dry matter intake (DMI) was changed (-10% or +10%) in the calculation. Grey colour represents 10 % increase and blue 10 % decrease from the original level. The border between the blue and grey is the average excretion level for dairy cow in 2021.

Sensitivity analysis gives an insight on the effects of the different variables on the excretion, yet it is mainly theoretical, and in reality, a change in one variable would have an effect on other variables as well. For example, if cow's dry matter intake would decrease, it could also have an impact on the cow's milk yield and LW as well, especially if the dry matter intake would contain less metabolizable energy than required. Therefore, to optimize the relation between nutrient intake and excretion, a total approach to the cow's metabolism and production must be taken.

To get more certain results from the excretion calculations and to be able to minimize the errors in the calculations, more data on the actual feeding of the cattle would be useful.

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Appendices

Appendix 1. Initial data for the calculations from 2021.

	Age, months	Initial weight	Weight gain, kg/day
Dairy cow	>25.3, after 1st calving	647*	0.04
Suckler cow	>28.0, after 1st calving	649*	0.04
Replacement calves and heifers, dairy breed	0–6	47.5	1.05
	6–12	231	0.98
	>12	410	0.67
Dairy heifers for beef	0–6	44.8	0.93
	6–12	214	0.87
	>12	373	0.60
Dairy breed bull	0–6	46.5	1.17
	6–12	260	1.18
	>12	476	0.84
Beef breed bull	0–6	46.4	1.21
	6–12	266	1.28
	>12	501	0.98
Replacement calves and heifers, beef breed	0–6	43.5	0.94
	6–12	215	0.95
	>12	387	0.63
Beef heifers for beef	0–6	43.9	0.96
	6–12	218	0.96
	>12	392	0.75

*Weight at the first calving

Appendix 2. Summary of intake and excretion of nutrients of dairy cow and the amount of faeces and urine, expressed as kg per cow per day and per year in 2021.

Dairy cow	Per day	Per year
Intake of nutrients, kg		
Dry matter, kg	20.1	7 342
Organic matter, kg	18.7	6 813
Nitrogen, kg	0.54	198
Phosphorus, kg	0.09	31.8
Potassium, kg	0.38	139
Excreted in milk		
Nitrogen, kg	0.14	51.3
Phosphorus, kg	0.02	8.24
Potassium, kg	0.04	14.3
Retention		
Nitrogen, kg	0.14	52.6
Phosphorus, kg	0.02	8.93
Potassium, kg	0.04	14.5
Faecal output		
Fresh matter, kg	38.7	14 150
Dry matter, kg	5.81	2 123
Organic matter, kg	5.11	1 865
Nitrogen, kg	0.17	61.1
Phosphorus, kg	0.06	22.1
Potassium, kg	0.09	31.4
Urinary output		
Dry matter, kg	1.31	480
Organic matter, kg	0.76	276
Nitrogen, kg	0.23	84.0
Phosphorus, kg	0.002	0.79
Potassium, kg	0.26	93.6
Volume, litres	22.9	8 374
Total excretion		
Total nitrogen, kg	0.40	145.1
Total phosphorus, kg	0.06	22.9
Total potassium, kg	0.34	125
Faeces + urine*, kg	61.7	22 524

*One litre of urine was assumed to weigh 1 kg in this calculation, although the volume weight of urine is slightly over 1 and variable between different animal groups. The value for lactating cows was 1.033 and 1.042 kg/litre for non-lactating cows according to Holter & Urban (1992).

Appendix 3. Summary of intake and excretion of nutrients of replacement calves and heifers and the amount of faeces and urine, expressed as kg per cow per day and per year in 2021.

The oldest age category has officially been provided with a heading of 12-24 months. Average calving age was 25.6 months, and the oldest category also contains heifers above two years old.

Replacement calves and heifers	Per day			Per year		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Intake of nutrients						
Dry matter, kg	3.77	6.81	8.82	1375	2487	3218
Organic matter, kg	3.47	6.41	8.14	1265	2338	2972
Nitrogen, kg	0.10	0.18	0.20	34.7	65.2	73.9
Phosphorus, kg	0.02	0.03	0.03	6.54	9.16	10.6
Potassium, kg	0.06	0.13	0.21	23.5	45.8	76.3
Retention						
Nitrogen, kg	0.02	0.03	0.02	8.94	9.19	6.59
Phosphorus, kg	0.006	0.007	0.005	2.32	2.57	1.87
Potassium, kg	0.002	0.002	0.001	0.63	0.58	0.37
Faecal output						
Fresh matter, kg	5.73	9.24	17.3	2092	3373	6314
Dry matter, kg	0.86	1.39	2.59	314	506	947
Organic matter, kg	0.73	1.19	2.27	268	436	829
Nitrogen, kg	0.02	0.05	0.06	8.87	16.7	21.5
Phosphorus, kg	0.01	0.02	0.02	4.06	6.24	8.12
Potassium, kg	0.01	0.03	0.05	5.29	10.3	17.2
Urinary output						
Volume, litres	6.12	9.35	13.8	2232	3411	5028
Dry matter, kg	0.30	0.53	0.78	108	195	284
Organic matter, kg	0.16	0.36	0.45	58.3	132	166
Nitrogen, kg	0.05	0.11	0.13	16.9	39.4	45.8
Phosphorus, kg	0.0004	0.001	0.002	0.15	0.35	0.60
Potassium, kg	0.05	0.10	0.16	17.6	34.9	58.7
Total excretion						
Nitrogen, kg	0.07	0.15	0.18	25.8	56.1	67.3
Phosphorus, kg	0.01	0.02	0.02	4.21	6.59	8.72
Potassium, kg	0.06	0.12	0.21	22.9	45.2	75.9
Faeces + urine, kg	11.8	18.6	31.1	4325	6784	11343

Appendix 4. Summary of intake and excretion of nutrients of growing bulls raised for beef and the amount of faeces and urine, expressed as kg per cow per day and per year in 2021.

Dairy breed bull	Per day			Per year		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Intake of nutrients						
Dry matter, kg	3.76	7.33	8.95	1373	2675	3266
Organic matter, kg	3.45	6.91	8.33	1261	2520	3040
Nitrogen, kg	0.09	0.19	0.22	34.5	70.8	80.8
Phosphorus, kg	0.02	0.03	0.03	6.82	9.8	11.2
Potassium, kg	0.06	0.13	0.19	21.8	47.3	70.5
Retention						
Nitrogen, kg	0.03	0.03	0.02	10.9	12.0	8.09
Phosphorus, kg	0.008	0.009	0.007	2.90	3.44	2.39
Potassium, kg	0.002	0.002	0.001	0.73	0.73	0.45
Faecal output						
Fresh matter, kg	5.60	9.67	14.4	2043	3530	5264
Dry matter, kg	0.84	1.45	2.16	306	529	790
Organic matter, kg	0.71	1.25	1.88	260	455	685
Nitrogen, kg	0.02	0.05	0.06	8.84	17.9	21.9
Phosphorus, kg	0.01	0.02	0.02	3.76	6.14	8.22
Potassium, kg	0.01	0.03	0.04	4.91	10.7	15.9
Urinary output						
Volume, litres	5.87	9.57	12.9	2142	3495	4722
Dry matter, kg	0.27	0.54	0.78	99.3	196	284
Organic matter, kg	0.14	0.37	0.49	51.2	137	177
Nitrogen, kg	0.04	0.11	0.14	14.8	40.9	50.8
Phosphorus, kg	0.0004	0.001	0.002	0.16	0.40	0.64
Potassium, kg	0.04	0.10	0.15	16.2	36.0	54.2
Total excretion						
Nitrogen, kg	0.06	0.16	0.20	23.7	59.0	72.7
Phosphorus, kg	0.01	0.02	0.02	3.92	6.55	8.86
Potassium, kg	0.06	0.13	0.19	21.1	46.6	70.1
Faeces + urine, kg	11.5	19.2	27.4	4185	7025	9986

Beef breed bull	**Per day**			**Per year**		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Intake of nutrients						
Dry matter, kg	3.20	7.35	8.90	1 168	2 681	3 248
Organic matter, kg	2.93	6.87	8.25	1 069	2 506	3 010
Nitrogen, kg	0.09	0.19	0.21	32.5	68.1	78.0
Phosphorus, kg	0.02	0.03	0.03	6.31	9.50	10.8
Potassium, kg	0.05	0.15	0.20	18.7	54.4	73.6
Retained						
Nitrogen, kg	0.03	0.04	0.02	11.1	12.8	8.65
Phosphorus, kg	0.01	0.01	0.007	2.96	3.68	2.55
Potassium, kg	0.002	0.002	0.001	0.75	0.78	0.48
Faecal output						
Fresh matter, kg	4.09	11.0	15.5	1 494	4 011	5 655
Dry matter, kg	0.61	1.65	2.32	224	602	848
Organic matter, kg	0.51	1.43	2.02	186	520	738
Nitrogen, kg	0.02	0.05	0.06	6.80	18.0	21.7
Phosphorus, kg	0.009	0.01	0.02	3.20	5.41	7.55
Potassium, kg	0.01	0.03	0.05	4.20	12.2	16.6
Urinary output						
Urine, litres	5.41	10.6	13.4	1 974	3 868	4 884
Dry matter, kg	0.25	0.55	0.77	90.3	200	280
Organic matter, kg	0.13	0.35	0.46	46.8	128	169
Nitrogen, kg	0.04	0.10	0.13	14.6	37.3	47.6
Phosphorus, kg	0.0004	0.001	0.002	0.16	0.42	0.67
Potassium, kg	0.04	0.11	0.15	13.7	41.4	56.5
Total excretion						
Nitrogen, kg	0.06	0.15	0.19	21.4	55.3	69.3
Phosphorus, kg	0.009	0.02	0.002	3.36	5.82	8.23
Potassium, kg	0.05	0.15	0.2	17.9	53.6	73.1
Faeces + urine, kg	9.50	21.6	28.9	3468	7 879	10 539

Appendix 5. Summary of intake and excretion of nutrients of heifers raised for beef and the amount of faeces and urine, expressed as kg per cow per day and per year in 2021.

Dairy breed heifer	Per day			Per year		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Intake of nutrients						
Dry matter, kg	3.38	6.24	7.35	1234	2 277	2 682
Organic matter, kg	3.11	5.81	6.78	1135	2 119	2 475
Nitrogen, kg	0.09	0.15	0.17	31.1	56.2	60.4
Phosphorus, kg	0.02	0.02	0.02	5.88	7.82	8.78
Potassium, kg	0.06	0.14	0.17	21.1	49.5	63.0
Retained						
Nitrogen, kg	0.02	0.04	0.03	8.38	8.55	5.26
Phosphorus, kg	0.01	0.01	0.004	2.21	2.45	1.54
Potassium, kg	0.002	0.001	0.001	0.57	0.52	0.28
Faecal output						
Fresh matter, kg	5.14	10.1	14.9	1 878	3 678	5 443
Dry matter, kg	0.77	1.51	2.24	282	552	816
Organic matter, kg	0.66	1.31	1.96	240	479	716
Nitrogen, kg	0.01	0.01	0.02	7.96	15.3	17.8
Phosphorus, kg	0.01	0.01	0.02	3.53	5.05	6.73
Potassium, kg	0.01	0.03	0.04	4.75	11.1	14.2
Urinary output						
Urine, litres	5.76	9.88	11.8	2 104	3 606	4 322
Dry matter, kg	0.26	0.50	0.64	95.0	184	234
Organic matter, kg	0.14	0.31	0.37	51.1	113	136
Nitrogen, kg	0.04	0.09	0.10	14.8	32.4	37.3
Phosphorus, kg	0.0004	0.001	0.001	0.14	0.32	0.51
Potassium, kg	0.04	0.10	0.13	15.8	37.8	48.5
Total excretion						
Nitrogen, kg	0.06	0.13	0.15	22.8	47.7	55.1
Phosphorus, kg	0.01	0.01	0.02	3.67	5.37	7.25
Potassium, kg	0.06	0.13	0.17	20.5	48.9	62.7
Faeces + urine, kg	10.9	20.0	26.8	3 981	7 285	9 765

Beef breed heifer	Per day			Per year		
Age, months	**0–6**	**6–12**	**>12**	**0–6**	**6–12**	**>12**
Intake of nutrients						
Dry matter, kg	2.88	6.23	7.31	1 050	2 273	2 668
Organic matter, kg	2.64	5.78	6.74	964	2 110	2 461
Nitrogen, kg	0.08	0.15	0.16	29.3	54.9	59.8
Phosphorus, kg	0.02	0.02	0.02	5.50	7.67	8.68
Potassium, kg	0.05	0.14	0.17	17.4	51.0	62.6
Retained						
Nitrogen, kg	0.02	0,03	0.02	8.62	9.36	6.65
Phosphorus, kg	0.006	0.007	0.005	2.29	2.70	1.96
Potassium, kg	0.001	0.001	0.001	0.59	0.56	0.36
Faecal output						
Fresh matter, kg	3.74	10.7	14.9	1 363	3 892	5 449
Dry matter, kg	0.56	1.60	2.24	205	584	817
Organic matter, kg	0.47	1.39	1.96	171	508	717
Nitrogen, kg	0.02	0.04	0.05	6.12	15.2	17.7
Phosphorus, kg	0.01	0.01	0.02	3.07	4.64	6.21
Potassium, kg	0.01	0.03	0.04	3.92	11.5	14.1
Urinary output						
Urine, litres	5.23	10.1	11.8	1 909	3 688	4 304
Dry matter, kg	0.23	0.49	0.62	84.8	179	225
Organic matter, kg	0.13	0.29	0.35	46.5	107	129
Nitrogen, kg	0.04	0.08	0.10	14.6	30.3	35.5
Phosphorus, kg	0.0003	0.001	0.001	0.14	0.33	0.50
Potassium, kg	0.04	0.11	0.13	12.9	39.0	48.2
Total excretion						
Nitrogen, kg	0.06	0.12	0.15	20.7	45.6	53.2
Phosphorus, kg	0.01	0.01	0.02	3.21	4.98	6.72
Potassium, kg	0.05	0.14	0.17	16.8	50.4	62.3
Faeces + urine, kg	8.97	20.8	26.7	3 273	7 579	9 753

Appendix 6. Summary of intake and excretion of nutrients of suckler cows and the amount of faeces and urine, expressed as kg per cow per day and per year in 2021.

Suckler cow	Per day	Per year
Intake of nutrients		
Dry matter, kg	10.3	3 745
Organic matter, kg	9.33	3 405
Nitrogen, kg	0.21	78.4
Phosphorus, kg	0.03	12.6
Potassium, kg	0.26	94.4
Excreted in milk		
Nitrogen, kg	0.02	7.34
Phosphorus, kg	0.004	1.30
Potassium, kg	0.006	2.27
Retained		
Nitrogen, kg	0.02	8.55
Phosphorus, kg	0.005	1.80
Potassium, kg	0.006	2.37
Faecal output, kg		
Fresh matter, kg	22.7	8 286
Dry matter, kg	3.40	1 243
Organic matter, kg	2.91	1 061
Nitrogen, kg	0.07	23.8
Phosphorus, kg	0.03	9.99
Potassium, kg	0.06	21.3
Urinary output		
Urine, litres	16.4	5 991
Dry matter, kg	0.85	309
Organic matter, kg	0.45	164
Nitrogen, kg	0.13	46.0
Phosphorus, kg	0.02	0.80
Potassium, kg	0.19	70.8
Total excretion		
Nitrogen, kg	0.19	69.8
Phosphorus, kg	0.03	10.8
Potassium, kg	0.25	92.1
Faeces + urine, kg	39.1	14 277

Appendix 7. Summary of intake and excretion of nutrients of beef replacement heifers and the amount of faeces and urine, expressed as kg per cow per day and per year in 2021.

Beef heifer for replacement	Per day			Per year		
Age, months	**0–6**	**6–12**	**12 → calving**	**0–6**	**6–12**	**12 → calving**
Intake of nutrients						
Dry matter, kg	2.86	6.20	8.08	1 045	2 263	2 950
Organic matter, kg	2.63	5.75	7.42	960	2 100	2 707
Nitrogen, kg	0.08	0.15	0.18	29.2	54.5	64.0
Phosphorus, kg	0.01	0.21	0.03	5.47	7.62	9.22
Potassium, kg	0.05	0.14	0.19	17.4	51.0	70.8
Retained						
Nitrogen, kg	0.02	0.03	0.02	8.54	9.21	6.31
Phosphorus, kg	0.006	0.007	0.005	2.24	2.61	1.82
Potassium, kg	0.001	0.002	0.001	0.59	0.58	0.37
Faecal output, kg						
Fresh matter, kg	3.72	10.7	17.6	1 358	3 904	6 438
Dry matter, kg	0.56	1.60	2.65	204	586	966
Organic matter, kg	0.47	1.40	2.32	170	510	848
Nitrogen, kg	0.02	0.04	0.05	6.10	15.2	19.4
Phosphorus, kg	0.008	0.01	0.02	3.10	4.69	6.81
Potassium, kg	0.01	0.03	0.04	3.91	11.5	15.9
Urinary output						
Urine, litres	5.22	10.1	13.0	1 906	3 689	4 737
Dry matter, kg	0.23	0.49	0.70	84.7	179	255
Organic matter, kg	0.13	0.29	0.39	46.5	107	141
Nitrogen, kg	0.04	0.08	0.10	14.6	30.1	38.3
Phosphorus, kg	0.0004	0.001	0.002	0.14	0.33	0.59
Potassium, kg	0.04	0.11	0.15	12.9	39.0	54.5
Total excretion						
Nitrogen, kg	0.06	0.12	0.16	20.7	45.3	57.7
Phosphorus, kg	0.01	0.01	0.02	3.23	5.02	7.40
Potassium, kg	0.05	0.14	0.19	16.8	50.4	70.4
Faeces + urine, kg	8.94	20.8	30.6	3 265	7 593	11 175

Appendix 8. Description of different weights used in the calculations.

Weight description	Explanation	Source of information
Birth weight (BW)	Weight when the animal is born.	Equations 41, 42, 68, 74, 75, 76
Live weight (LW)	Weight of a live animal at a certain age. Includes gastrointestinal tract and bladder contents.	Equations 2–6, 69, 79–83, 116–119, 122
Mature weight (MW)	Weight the animal reaches approximately at six years of age. No more structural growth. Includes gastrointestinal tract and bladder contents.	Equations 3–6, 69, 79–83, 116–119
Empty body weight (EBW)	Weight where the gastrointestinal tract and bladder contents have been removed after slaughter.	Equations 94–96
Carcass weight (CW)	Weight of a carcass; skin, head, intestines and legs removed.	Finnish Food Authority

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