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Excretion calculations of sheep and goats in Finland

Jouni Nousiainen, Jenni Vattulainen, Kaisa Kuoppala and Marketta Rinne

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Tiivistelmä

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Luonnonvarakeskus (Luke)

Virallinen erityyslaskenta tuottaa vuosittain eri kotieläinten sonnassa ja virtsassa eritetyn kuiva-aineen, orgaanisen aineen ja ravintoaineiden määrän. Luonnonvarakeskus (Luke) on vastuussa Suomen kansallisesta erityyslaskennasta. Laskennan tuloksia käytetään esimerkiksi arvioitaessa päästöjä lannan käsittelyssä, ilmakehään (kasvihuonekaasut, ammoniakki) ja vesiin [fosfori (P), typpi (N), kalium (K)], arvioitaessa Suomessa tuotetun lannan määrää ja koostumusta sekä määriteltäessä sen hyödyntämisen tavoitteita (ravinnetaseet, kiertotalous). Eritettyjen ravinteiden määrä lasketaan rehuista saatujen ravintoaineiden ja eläimeen sekä niistä saataviin tuotteisiin pidättyneiden ravintoaineiden erotuksena, eli "ravintoaineiden saanti – ravintoaineiden pidättyminen = ravinteiden erittyminen". Laskennassa mukana olevat komponentit ovat kuiva-aine, orgaaninen aine, N, P ja K.

Lampaiden ja vuohien erityyslaskenta suoritetaan vuosittain erikseen eri eläinryhmille eläinten sukupuolen ja iän mukaan. Eläimen syömän rehun koostumuksen ja määrän täsmällinen arviointi on yksi erityyslaskennan kriittisimmistä tekijöistä. Tässä laskennassa rehun kulutus arviointiin laskemalla eläinten energiantarve tuotantovaiheittain. Dieetin koostumus perustui sidosryhmiltä kerättyyn tietoon ja asiantuntija-arvioihin. Laskennan suurin epävarmuustekijä on ravintoaineiden saannin arvioinnissa. Laskennan yksityiskohdat on kuvattu tässä raportissa.

Vuoden 2025 lähtötiedoilla karitsoineen uuhien vuotuinen keskimääräinen N- ja P-eritys olivat 9,09 ja 1,21 kg. Yhdeksän kuukautta vanhan teuraskaritsan vastaavat kokonaiselle vuodelle lasketut eritykset N:n ja P:n osalta olivat 10,2 ja 1,37 kg.

Avainsanat: erityys, fosfori, kalium, lanta, lammas, pidättyminen, sonta, typpi, virtsa, vuohi

Abstract

Jouni Nousiainen, Jenni Vattulainen, Kaisa Kuoppala and Marketta Rinne

Natural Resources Institute Finland (Luke)

The official excretion calculations provide the Finnish national annual amounts of dry matter, organic matter and nutrients excreted by different livestock into faeces and urine. Natural Resources Institute Finland (Luke) is responsible for the national excretion calculations in Finland, and the results are used e.g. in estimating emissions during manure management and use into air (greenhouse gases, ammonia) and waters [phosphorus (P), nitrogen (N), potassium (K)], in estimating the quantity and composition of manure produced in Finland and in setting the targets to improve its utilization (nutrient balances, circular economy). The amounts of nutrients excreted are calculated as the difference between nutrient intake in feed and the nutrients retained in the animals as well as in their products, i.e. as "nutrient input – nutrient retained = nutrient excretion". The components included in the calculations are dry matter, organic matter, N, P and K.

Excretion calculations of sheep and goats are conducted annually for different animal groups based on their gender and age. The feeds consumed by the animals is one of the most critical aspects of excretion calculations. In this report, the consumption of feeds was evaluated based on energy requirements of animals at different production levels. The composition of diets was based on data gathered from stakeholders and on expert evaluations. The highest uncertainty lies in the actual amount of nutrients consumed by the animals. The detailed steps of calculations are described in this report.

Based on the results with year 2025, the annual N and P excretion of one adult ewe were 9.09 and 1.21 kg, respectively. Similar excretions for nine-month-old lamb raised for slaughter were 10.2 and 1.37 kg (when estimated for a whole year), respectively.

Keywords: faeces, goat, manure, nitrogen, output, phosphorus, potassium, sheep, retention, urine

Abbreviations

ALW	Average live weight
BAT	Best available technique
BW	Birth weight
CP	Crude protein
Diet_ash	Diet ash concentration, g/kg DM
Diet_OM	Diet organic matter concentration, g/kg DM
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake
DOM	Digestible organic matter
DOMI	Digestible organic matter intake
EBW	Empty body weight
EBWash%	Ash concentration of EBW, %
EBWfat%	Fat concentration of EBW, %
EBWphosphorus%	Phosphorus concentration of EBW, %
EBWpotassium%	Potassium concentration of EBW, %
EBWprot%	Crude protein concentration of EBW, %
EBWwater%	Water concentration of EBW, %
FCM	Fat corrected milk, kg
K	Potassium
LW	Live weight
LWC	Live weight change
ME	Metabolizable energy, MJ
ME _{breeding}	ME requirement for breeding for rams, MJ/day
ME _{diet}	ME concentration in diet, MJ/kg DM
ME _{gestation}	Metabolizable energy requirement for pregnancy, MJ/day
ME _{growth}	ME requirement for growth, MJ/day
ME _{req}	ME requirement, expressed as MJ/day
ME _{lactation}	Metabolizable energy requirement for lactation, MJ/kg day
ME _{main}	Metabolizable energy requirement for maintenance, MJ/day
MJ	Megajoule
MW	Mature weight
N	Nitrogen
OM	Organic matter
OMI	Organic matter intake
OMD	Organic matter digestibility
P	Phosphorus
SW	Slaughter weight
U _{ash}	Excretion of urine in ash, g/d

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U_{om}	Excretion of OM in urine, g/d
U_w	Urinary water excretion
WF	Water factor

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1. Introduction

Natural Resources Institute Finland (Luke) is responsible for the national 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, ammonia) and waters [phosphorus (P) and nitrogen (N)], to estimating the quantity and quality of manure produced in Finland and setting the targets to improve its utilization (nutrient balances, circular economy).

The excretion calculations provide the amounts of dry matter (DM), organic matter (OM) and nutrients 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.

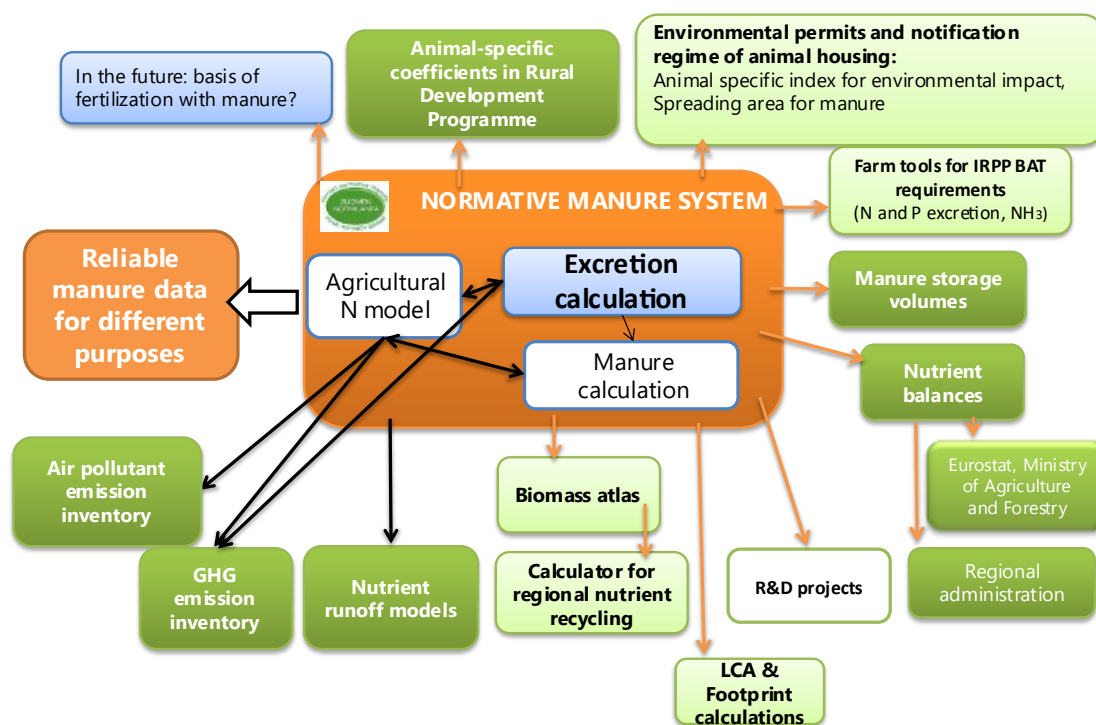


Figure 1. The nutrient excretion calculations form the basis of several other calculations (IRPP BAT = Intensive rearing of pigs and poultry Best available practises).

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 uptake = nutrient excretion" (Figure 2). The components included in the calculations are DM, OM, N, P and K. In the report, crude protein (CP) is used to describe diet composition, and it is calculated as $N \times 6.25$, except for milk, where coefficient 6.38 is used.

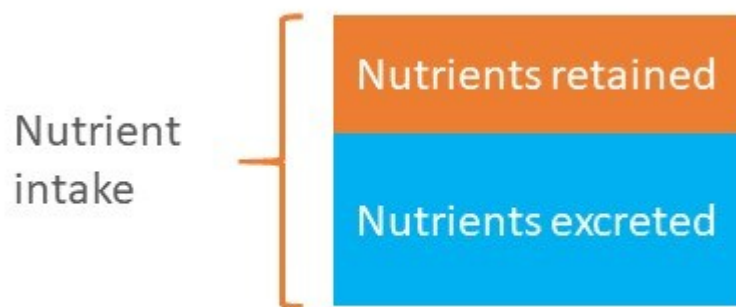


Figure 2. The principles of excretion calculations.

The results of the calculations present the amount of faeces, urine and nutrients excreted annually. Updated initial data includes the number of animals in different categories and slaughter data, when applicable. Feeding data is updated in every few years and when necessary. Recently, basis of calculations has been published for cattle (Nousiainen et al. 2023), horses (Saastamoinen et al. 2024) and pigs (Perttilä et al. 2025).

Sheep and goat production in Finland included a total amount of 118 100 sheep and 7 580 goats in 2025. The number of sheep varies a bit yearly and has been on its peak in 2016 when the number of sheep was 157 000. The number of goats has varied less than that of sheep throughout the years since 1990 and has stayed between 7 000 – 10 000 animals per year (Finnish Food Authority 2026). The number of sheep and goats is calculated four times during a year by the Finnish Food Authority, and calculated average from these numbers is used as a basis for the calculations.

Equations and methods used in the excretion calculations of sheep and goats are based on literature, scientific research conducted in Finland by Luke (and formerly MTT), and on the information collected by Finnish Food Authority (slaughter data), official statistics of animal numbers in Finland (Luke 2026a) and data from ProAgria (production, lambing, growth etc). The calculations and the equations used in the calculations are similar to the ones used with the excretion calculations of cattle in Finland (Nousiainen et al. 2023), since there are many similarities in the nutritional physiology with cattle, sheep and goats, all of them representing ruminants.

The most critical part of calculating the excretion data is estimating the accurate amount and composition of feeds consumed by the animals. Different age and gender groups are fed differently between and within different farms, and since there is no accurate data gathered about the composition of the actual feeds in sheep and goat production, the calculations of diets are based on feeding recommendations, nutrient requirements, literature, and expert evaluations.

Nutrient uptake contains growth of the animal and its wool, as well as growth of foetuses during pregnancy. Nutrients in milk are calculated as excreted, although separated from the actual excretion (faeces and urine).

The excretion calculations provide valuable information for many authorities and are constantly under further development and self-evaluation to offer the best possible information available.

In this report, three meaningful digits are being used. In the actual calculations more digits are used to create more precise outcome of the calculations. Although the calculations aim to offer the best possible evaluation about the excretion of livestock species, it should be noted, that since the actual diets, intakes and animal growths may vary greatly from the calculated results, they represent national averages and may differ from the actual excretion rates of individual animals and farms.

2. Sheep

In Finland, sheep production is concentrated on meat and wool production as sheep milk production is practically non-existent. The number of sheep slaughtered in total is around 50 000 to 60 000 animals per year. In 2025, the number of lambs slaughtered was 37 900 and the number of other sheep slaughtered was 10 700. The amount of sheep meat produced was 1 009 400 kg and the average carcass weight was 20.8 kg (Luke 2026b). Wool production within merino wool breeds can be estimated to be 3.4 kg per adult sheep per year (Theron et al. 2023), and in total 285 000 kg annually. Native breeds, such as Finnsheep, produce less wool, around 3 kg annually (Finnsheep ry 2025). The proportion of native breed from the whole Finnish sheep population was 49% in 2025 (Finnish Food Authority 2026).

ProAgria is the official breeding organization of sheep in Finland, and it maintains the productivity surveillance data of Finnish sheep (ProAgria 2026). For the calculations, the number of sheep is obtained yearly from Finnish Food Authority. Sheep are calculated four times a year (the first of January, April, July and October) and in the calculations, a weighted average of these calculations is used. Most of the lambs are born in the spring and move to another age class before the next animal calculation is held, and therefore summing up the results of the calculations of these four dates would create a false impression of the actual number of the animals.

For the excretion calculations, sheep are divided into five different categories based on their age and gender (Table 1). Further on, different categories are subdivided into smaller categories depending on the feeding season (outdoor/indoor), gender, and production stage (growing, idle, gestation, lactation). Different animal categories are needed in different stages of the calculations and, for example, when calculating the diets, more categories are used than when calculating the empty body weight (EBW) of the animal.

There are some differences in the calculations between different sheep breeds, especially considering the mature weights (MW) and growth of sheep. Native breeds are on average smaller and slower to grow compared to other breeds, and when calculating MW and growth, a weighted average was used to acknowledge this difference. In the results, different breeds were pooled into bigger groups, depending on their age, gender, and production stage.

Ewes were divided into several different categories depending on whether they were in the lactation, gestation, or idle stage of their production. The term hogget is used for a young ewe that has not yet lambed and is used similarly as the term heifer for cows. Barren ewes are calculated separately from lambing ewes. The average amount of lambs born per ewe was 1.24 per year (Table 2). The number of gestations was calculated based on the number of ewes and lambs born yearly, and was assumed to be one per ewe, since barren ewes were not included in calculations of gestations.

Rams were divided into four different categories depending on their age and production activity. Lamb categories were based on their age. The average slaughter age for lambs in 2025 was 8.9 months for ewes and 7.9 months for rams (Finnish Food Authority 2026). Lambs kept for over 9 months of age are mainly raised for replacement sheep.

Table 1. Number of sheep by different production period, an average weight in each category and number of animals in 2025 (Finnish Food Authority 2026).

Animal category	Production period	Average live-weight, kg	Number of animals	Slaughtered per year	Average age at slaughter, months
Lamb	0–2 months	11.4	8 500	37 363	8.40
	2–5 months	29.1	15 100		
	5–9 months	45.3	16 800		
	9–12 months	58.9	6 300		
Hoggets and ewes, 12 months and over	Idle	61.5	8 900	data not available	data not available
	Gestation				
	Pregnancy 1–2 weeks				
	Pregnancy 3–6 weeks				
Lambled ewes, 12 months and over	Idle, gestation	71.2	48 600	9 131	38.7
	Pregnancy 1–2 weeks				
	Pregnancy 3–6 weeks				
	Lactation				
Barren ewes	Idle, grazing	71.2	6 900	data not available	data not available
Rams	1–2 years, idle	79.2	2 200	1 154	13.8
	1–2 years, breeding				
	>2 years, idle	85.0	4 800	879	39.3
	><2 years, breeding				
Total			118 100	48 530	

Table 2. The average production data of sheep in Finland in 2025 (Finnish Food Authority 2026).

Production data	
Number of gestations, per ewe per year	1.00
Born lambs, per ewe per year	1.24
Number of foetuses, average	1.46
Weaned lambs, per ewe per year	1.10
Weaning age, weeks	6–14
Average birth weight of lambs, kg	4.65

2.1. Calculation of live weight and empty body weight

The live weight (LW) was calculated by following the Equations [1–6] (Table 3). LW was first calculated from the slaughter weight (SW) using Equations [1–3]. SW was obtained from Finnish Food Authority and was calculated from the sum of carcass weights (Table 18) divided with the number of slaughtered animals.

The LW gain was estimated with Richards’ function, which was first used to solve MW. The MW was solved by giving known values for the other parameters (LW and Age at slaughter) in the Richards’ function, which are obtained annually from the Finnish Food Authority. When doing so, the only remaining unknown parameter (MW) in the Richards’ function was solved using the NLIN procedure in SAS program (SAS Inc. 2002–2012, Release 9.4; SAS Inst. Inc., Cary, NC, USA). After MW solving, the Richards’ curve was used to give the estimate for LW gain. LW gain was calculated for different growth periods for each animal category. For example, for ewes, six different growth periods were calculated separately.

The MW of animals was defined separately for different animal groups and breeds (Table 17). MW represents the weight the animal should reach according to its weight curve if it lived until maturity, and it varies between breeds and gender. For example, native breeds are on average smaller than meat breeds, and ewes are smaller than rams. Empty body weight (EBW) was then calculated following Equations [7–9] (Table 4). EBW can also be calculated from the slaughter data. EBW was needed in the calculation of nutrient retention.

In the equations, age equals age in days at the time of slaughter, which in average was 246–274 days for lambs and 348 - 1883 days for lambing ewes and rams in 2025.

Table 3. Equations for calculating the live weight of sheep based on Muir et al. (2008).

No	Equation
1.	LW, lambs, native breed= SW / 0.42
2.	LW, lambs, meat breed = SW / 0.44
3.	LW, sheep, native breed =SW / 0.39
4.	LW lambs, ewe, under 12 months = $MW \times (1 - 0.781 \times e^{-0.0057 \times Age})^2$
5.	LW lambs, ram, under 12 months and adult rams = $MW \times (1 - 0.796 \times e^{-0.00581 \times Age})^2$
6.	LW ewe, with lambs = $MW \times (1 - 0.781 \times e^{-0.00570 \times Age})^2$

LW= live weight, SW = slaughter weight, MW= mature weight, Age=age in days

Table 4. Equations for calculating empty body weight for newborn lambs, lambs at the age of 2–5 months and sheep over 5 months of age, based on ARC (1980).

No	Equation
7.	EBW lambs, at birth = $0.94 \times LW$
8.	EBW lambs, 2–5 months = $(LW - 0.9047) / 1.09$
9.	EBW, over 5 months = $(LW - 3.161) / 1.09$

EBW= empty body weight, LW= live weight

2.2. Energy requirements

Energy requirements for different animal groups were calculated based on Equations [10–15] in Table 5. Metabolizable energy (ME) requirements (MJ/d) for different sheep categories are shown in Appendix 1 and were based on nutrient requirements from NRC (2007) and Kuoppala et al. (2024). ME is required for maintenance, growth, gestation, and lactation. Energy required for growth accounts also for the energy required for wool production.

Equations to solve the energy requirements used in calculations were based on AFRC (1993), NRC (2007) and Finnish feeding recommendations by Kuoppala et al. (2024).

Table 5. Equations for calculating the energy requirements for maintenance, growth, gestation, and lactation, based on AFRC (1993) and NRC (2007) and Kuoppala et al. (2024).

No	Equation
10.	$ME_{main.} = 0.1032 \times ALW + 2.261$
11.	$ME_{growth, lambs} = -0.00528 \times LWC + 2.65 \times LWC + 0.958 \times ALW \times LWC$
12.	$ME_{growth, adults} = 26.3 \times LWC$
13.	$ME_{gestation} = (28.0 \times 5.00 + 14.0 \times 9.50) / 365$
14.	$ME_{lactation} = ((-0.667 \times (n \times n) + 7.00 \times n + 5.667) \times 60.88) / 365$
15.	$ME_{breeding, rams} = 50.0 \times 6.30 / 365$

ME_{main} = Metabolizable energy requirement for maintenance, ME_{growth} = Metabolizable energy requirement for growth, $ME_{gestation}$ = Metabolizable energy requirement for gestation, $ME_{lactation}$ = Metabolizable energy requirement for lactation, $ME_{breeding}$ = Metabolizable energy requirement for breeding for rams, ALW=average live weight, n= number of lambs under ewe, LWC= live weight change as growth, kg/day

2.3. Diet composition and intake

Diet composition and intake of nutrients were calculated based on diet examples provided by ProAgria (personal communication, Alanco-Ollqvist, ProAgria) and literature (NRC 2007). Diet compositions used in the calculations are shown in Tables 6–9. Dry matter intake (DMI) varies within the age categories of sheep. The exact amount and compositions of diets were the most inaccurate part of the calculations, since there was no data available about the exact composition of diets fed to different sheep categories. There were also some differences between the mineral recommendations given by ProAgria and the literature (NRC 2007), and in the calculations, the feed examples were supplemented with sodium to correct this difference. Sodium was also added in the calculated diets, to replace some of the mineral supplements.

Two different feeding periods (during housing and grazing) were used when determining the diet types. Grazing season in Finland is significantly shorter than the housing season. A weighted average was used to calculate feeding for the whole year, so that 1/3 of the year was grazing season, and 2/3 was indoor feeding.

There were some differences in the diet compositions among different age groups of sheep. For example, lambs at the age of 0–2 months are fed mainly on ewe’s milk, and so the main diet for small lambs was milk. The proportion of forage in the diet grows when the sheep grows older, and at the same time, the composition of the diet changes. Different feeding models were used to define the most accurate feeding of certain animal groups.

Table 6. Diet composition for lambs of different age.

	0–2 months	2–5 months	5– 9 months	9–12 months
Metabolizable energy, MJ/kg DM	19.7	11.2	11.2	10.9
Gross energy, MJ/kg DM	25.1	18.3	18.3	18.3
In DM, g/kg				
Ash	76.1	87.6	87.7	84.4
Crude protein	262	161	159	153
Crude fat	325	41.2	41.6	39.8
Non-structural carbohydrates	323	443	442	455
Neutral detergent fibre	43.0	511	514	521
Phosphorus	6.27	3.58	3.53	3.33
Potassium	6.96	26.0	26.2	25.4

DM= dry matter

Table 7. Diet composition for hoggets in different production stages.

	Idle	Gestation	Gestation 1–2 weeks	Gestation 3–6 weeks
Metabolizable energy, MJ/kg DM	10.0	10.1	11.1	11.0
Gross energy, MJ/kg DM	18.2	18.2	18.3	18.3
In DM, g/kg				
Ash	83.5	85.1	90.2	90.9
Crude protein	140	143	160	162
Crude fat	36.0	37.5	41.0	41.3
Non-structural carbohydrates	407	422	430	413
Neutral detergent fibre	620	595	526	546
Phosphorus	2.71	2.85	3.51	3.38
Potassium	27.3	26.5	27.2	28.6

DM= dry matter

Table 8. Diet composition for ewes in different stages of production.

	Barren ewe	Idle	Gestation	Lactation	Gestation 1–2 weeks	Gestation 3–6 weeks
Metabolizable energy, MJ/kg DM	9.69	10.0	10.1	11.2	11.1	11.0
Gross energy, MJ/kg DM	18.3	18.2	18.2	18.2	18.2	18.3
In DM, g/kg						
Ash	78.2	83.6	85.1	89.6	90.8	91.9
Crude protein	129	140	143	158	160	162
Crude fat	33.8	37.5	37.5	40.7	41.0	41.3
Non-structural carbohydrates	409	406	422	458	429	412
Neutral detergent fibre	644	620	595	491	526	545
Phosphorus	2.52	2.71	2.84	3.97	3.61	3.45
Potassium	26.0	27.3	26.5	24.7	27.2	28.6

DM= dry matter

Table 9. Diet composition for rams in different stages of production.

	1–2 years, idle	1–2 years, breeding	>2 years, idle	>2 years, breeding
Metabolizable energy, MJ/kg DM	9.50	10.9	9.50	10.9
Gross energy, MJ/kg DM	18.2	18.3	18.2	18.3
In DM, g/kg				
Ash	81.2	84.8	81.3	84.8
Crude protein	128	156	128	156
Crude fat	33.4	39.6	33.4	39.6
Non-structural carbohydrates	412	436	412	436
Neutral detergent fibre	647	544	647	544
Phosphorus	3.68	3.78	3.68	3.76
Potassium	25.8	27.1	25.8	27.1

DM= dry matter

The intake of dry matter, organic matter and nutrients are calculated as shown in Equations [16–20] (Table 10).

Table 10. Equations for calculating the intake of dry matter, organic matter and the intake of nitrogen, phosphorus and potassium.

No	Equation
16.	$DMI, \text{ kg/d} = ME_{req} \text{ MJ/d} / ME_{diet} \text{ MJ/kg DM}$
17.	$OMI, \text{ kg/d} = DMI \times (1000 - diet_ash)$
18.	$\text{Intake of N, g/d} = (CP, \text{ g/kg DM} / 6.25) \times DMI, \text{ kg/d}$
19.	$\text{Intake of P, g/d} = P, \text{ g/kg DM} \times DMI, \text{ kg/d}$
20.	$\text{Intake of K, g/d} = K, \text{ g/kg DM} \times DMI, \text{ kg/d}$

DMI= dry matter intake; ME_{req} = Metabolizable energy requirement; ME_{diet} = metabolizable energy in the diet; OMI= organic matter intake; diet_ash = diet's ash concentration, g/kg DM; N= nitrogen; CP= crude protein; P= phosphorus; K= potassium

2.4. Retention of nutrients

For growth, different equations had to be used depending on the age of the animal to determine the retention of nutrients in EBW.

For a newborn sheep, the retention of nutrients was calculated as shown in Table 11 [Eq. 21–26]. An average birth weight was 4.3 kg.

Table 11. Equations for calculating the crude protein, fat and ash mass of the newborn lamb based on their live weight (ARC 1980).

No	Equation
21.	CP mass, kg = $0.168 \times LW$
22.	Fat mass, kg = $0.03 \times LW$
23.	Ash mass, kg = $0.04 \times LW$
24.	P mass, kg = $0.007 \times LW$
25.	K mass, kg = $water\% \times 0.00323$
26.	$Water\% = 100 - protein\% - fat\% - ash\%$

CP = crude protein; LW= live weight; P = phosphorus; K = potassium

For older animals, Equations shown in Table 12 were used to calculate the mass percentages in the EBW. Carcass fat and CP percentages were calculated based on literature (Johnson et al. 2012). Dressing percentage was based on literature and was 44% for meat breed lambs, 42% for native breed lambs, and 39% for older sheep (Shija et al. 2013). Carcass fat percentage was 20.5% on average and CP percentage was 17.3% on average for all sheep (Table 17).

Table 12. Equations for calculating the mass percentages in empty body weight based on Rattray et al. (1973 and 1974), Kellaway et al. (1973) and Wan Zahari (1989).

No	Equation
27.	$EBWfat\% = 0.885 \times carcass\ fat\%$
28.	$EBWprot\% = 1.0093 \times carcass\ CP\%$
29.	$EBWwater\% = 96.6 - 0.972 \times EBWfat\% - 1.065 \times EBWprot\%$
30.	$EBWash\% = 100 - EBWfat\% - EBWprot\% - EBWwater\%$
31.	$EBWphosphorus\% = 10.0 \times 0.140 \times EBWash\%$
32.	$EBWpotassium\% = 0.121 \times EBWprot\% \times 0.10$

EBW= empty body weight

To be able to estimate the final amount of retention, the change of nutrient mass in EBW was calculated (Table 13). Mass in the end equalled the mass in the EBW at the time of slaughter, and mass in the beginning was the mass equivalent to a newborn a lamb or at the end of previous growth period.

Table 13. Equations for calculating the final mass of fat, crude protein, water, ash, phosphorus and potassium in the empty body weight.

No	Equation
33.	Coefficient = $(\log_{10}(\text{mass in the end}) - \log_{10}(\text{mass in the beginning})) / (\log_{10}(\text{end EBW}) - \log_{10}(\text{beginning EBW}))$
34.	Constant = $\text{Coefficient} \times \log_{10}(\text{beginning EBW}) \times -1 + \log_{10}(\text{mass in the beginning})$
35.	Final mass in EBW = $10^{(\text{constant} + \text{coefficient} \times \log_{10}(\text{EBW}))}$

EBW = empty body weight

The increase of CP, P, K and ash in the animal per day was calculated as shown in the Table 14. Maximum age (max age) was the age in days at the end of the growth period, and the minimum age (min age) was the age in days at the start of the growth period.

Table 14. Equations for calculating the retention of different nutrients and ash during the growth.

No	Equation
36.	CP retention, kg/day = $(\text{CP mass in the beginning} - \text{CP mass in the end}) / (\text{max age} - \text{min age})$
37.	P retention, kg/day = $(\text{P mass in the beginning} - \text{P mass in the end}) / (\text{max age} - \text{min age})$
38.	K retention, kg/day = $(\text{K mass in the beginning} - \text{K mass in the end}) / (\text{max age} - \text{min age})$
39.	Ash retention, kg/day = $(\text{ash mass in the beginning} - \text{ash mass in the end}) / (\text{max age} - \text{min age})$

CP = crude protein; Max age = age in days at the end of growth period; Min age = age in days at the beginning of growth period; P = phosphorus; K = potassium

Finally, to be able to calculate the retention of nutrients during the growth, following Equations [40–43] were used (Table 15).

Table 15. Retention of nutrients and ash during the growth per day.

No	Equation
40.	N retained, g/d = $\text{CP retention, kg/day} / 6.25$
41.	P retained, g/d = $\text{P retention, kg/day} / 1000$
42.	K retained, g/d = $\text{K retention, kg/day} / 1000$
43.	Ash retained, g/d = $\text{ash retention, kg/day} / 1000$

N = nitrogen; CP = crude protein; P = phosphorus; K = potassium

Retention of nutrients in gestation were calculated as in Equations [44–48] (Table 16).

Table 16. Retention of nutrients in the gestation of sheep, based on ARC (1980).

No	Equation
44.	N retained, gestation, g/d = $(n_f \times BW \times 0.0269) / 365$
45.	P retained, gestation, g/d = $(n_f \times BW \times 0.007) / 365$
46.	K retained, gestation, g/d = $(n_f \times BW \times 0.002) / 365$
47.	Ash retained, gestation, g/d = $(n_f \times BW \times 0.04) / 365$
48.	Number of lambs / sheep/ year = 1.2

n_f = number of foetuses, BW = birth weight of lambs; N = nitrogen; P = phosphorus; K = potassium

Table 17. Slaughter data of sheep in 2025 (Finnish Food Authority).

Animal category	n	Age, months	Slaughter weight, kg	Dressing %	MW, kg	EBW fat, %	EBW CP, %
Lambs, meat breed, ewe	2 506	8.80	20.4	44	66.1	20.3	17.2
Lambs, meat breed, ram	3 588	6.90	21.2	44	75.1	20.4	17.2
Lambs, native breed, ewe	12 343	8.90	18.6	42	61.8	20.3	17.2
Lambs, native breed, ram	18 926	8.00	19.8	42	70.2	20.4	17.2
Ewes, meat breed	1 096	38.1	26.7	39	72.7	20.7	17.5
Ewes, native breed	6 650	22.5	44.2	39	60.8	20.6	17.4
Rams, meat breed	181	29.7	28.3	39	87.2	20.7	17.3
Rams, native breed	1 852	23.4	22.1	39	73.0	20.6	17.2

n = number of animals; MW = mature weight; EBW = empty body weight, CP = crude protein

Retention of nutrients into wool were calculated using Equations [49–52] shown in Table 18.

Table 18. Retention of nutrients into wool, based on Burns et al. (1964).

No	Equation
49.	N retained, wool, g/d = Wool growth, kg/d \times 0.158
50.	P retained, wool, g/d = Wool growth, kg/d \times 0.000137
51.	K retained in wool, g/d = Wool growth, kg/d \times 0.045
52.	Ash retained, wool, g/d = Wool growth, kg/d \times 0.0042

N = nitrogen; P = phosphorus

Results of nutrient retention are presented in detail in the Appendices.

2.5. Excretion

Milk yield was calculated based on the number of lambs born [Eq. 53] (Table 19). The lactation period was estimated to be 2 months with average daily milk production of 2.11 kg resulting in 114 kg of milk produced in total. Nutrients excreted in milk were calculated as presented in Equations [53–60] and were based on Peart et al. (1968, 1970), ARC (1980), Cannas et al. (2004), NRC (2007) and Park et al. (2007). Content of P and K in milk were assumed to be constants [Eq. 55 and 57].

Table 19. Equations for calculating the retention of nutrients to milk.

No	Equation
53.	Milk yield, kg/year = $- 63.2 + 98.0 \times n_l - 16.8 \times n_l \times n_l + 1.33 \times 60.9$
54.	N in milk, kg/kg = $(55/1000) / 6.38 = 0.00862$
55.	N retained, milk, g/d = N in milk \times milk, kg/d / 365
56.	P in milk, kg/kg = 0.0013
57.	P retained, milk, g/d = P in milk \times milk, kg/d / 365
58.	K in milk = 0.00138 kg/kg
59.	K retained, milk, g/d = K in milk \times milk, kg/d / 365
60.	Ash in milk, kg/kg = 0.016
61.	Ash retained, milk, g/d = ash in milk \times milk, kg/d / 365

n_l =number of lambs under ewe; N = nitrogen; P = phosphorus; K = potassium

To be able to estimate the amount of faeces, the digestibility of DM (DMD) was calculated as in [Eq. 65] (Table 21). DMD was calculated from digestibility of organic matter (OMD) using [Eq. 64] which was calculated by dividing intake of digestible organic matter (DOMI) by intake of OM [Eq. 63]. For DM concentration of faeces, an average value of 290 g/kg was used based on values determined in feeding experiments conducted at Luke.

For urine output, an estimate of daily water intake by each kg of live weight was needed. This was calculated based on several equations on faecal DM content, urinary water excretion and metabolic water (Wallace et al. 1972; Degen and Young, 1981; More et al. 1983 and Ogejo et al. 2010) Water factor (WF, Table 20) was then used to calculate the water intake [Eq. 70]. Metabolic water was calculated based on the DOMI [Eq. 61]. Equation for calculating urinary water output was different for ewes with lambs, since milk production affects the water intake and thus also the water excretion [Eq. 70].

Table 20. Water factors for different sheep groups based on Wallace and Denham (1970), Wallace et al. (1972), Degen and Young (1981), More et al. (1983), and Ogejo et al. (2010).

Sheep category	Water factor
Lamb, 0–2 months	4.58
Lamb, 2–5 months	2.50
Lamb, 5–9 months	2.50
Lamb, 9–12 months	2.50
Hogget	2.86
Ewe, idle	2.50
Lambing ewe	3.26
Ram 1–2 years	2.50
Ram > 2 years	2.50

Table 21. Equations for calculating the amount of digestible and indigestible dry and organic matter, amount of faeces and urine based on Ramin & Huhtanen (2013).

No	Equation
62.	Intake of digestible OM (DOMI), kg/d = $(ME_{\text{diet}} \times \text{DMI}) / 16$ (Kuoppala et al. 2024)
63.	OMI (organic matter intake), kg/d = $\text{DMI} \times (1000 - \text{diet_ash})$
64.	Digestibility of OM (OMD), g/g = $\text{DOMI} / (\text{DMI} \times \text{diet_OM} \times 0.001)$ (Kuoppala et al. 2024)
65.	Digestibility of DM (DMD), g/g = $(0.977 \times \text{OMD} \times 1000 + 1.4) / 1000$ (modified from Ramin & Huhtanen 2013)
66.	Indigestible DM excreted, kg/d = $\text{DMI, kg/d} \times (1 - \text{DMD})$
67.	Output of faeces, kg/d = $\text{indigestible DM, kg/d} / \text{DM concentration of faeces, g/g}$
68.	Output of urine, kg/d = $U_w + U_{\text{ash}} + U_{\text{om}}$
69.	$U_w = 0.5991 \times (\text{metabolic water} + \text{water intake}) - 1.2568 \times \text{faecal water, kg/d}$
70.	U_w , lambing ewes = $0.5991 \times (\text{metabolic water} + \text{water intake}) - 1.2568 \times \text{faecal water} - \text{Milk yield, kg/a} \times 0.807$
71.	Water intake = $\text{water factor} \times \text{DMI, kg/d}$
72.	Metabolic water = $\text{DOM intake, kg/d} \times 0.40$

DMI = dry matter intake; OM = organic matter; OMD = organic matter digestibility; DMD = dry matter digestibility; ME_{diet} = metabolizable energy in the diet; U_w = urinary water, U_{ash} = urinary ash; U_{om} = urinary organic matter

The nutrient composition in the faeces and urine was calculated according to Equations [73–85] (Table 22).

Table 22. Equations for calculating the composition of urine and faeces.

No	Equation
73.	$U_{\text{ash}} \text{ g/d} = \text{Ash intake, g/d} - \text{ash retained, g/d} - \text{ash in faeces, g/d}$
74.	Ash in faeces, g/d = $\text{DMI} \times \text{non-digestible ash in diet} \times 0.001$
75.	OM in faeces, g/d = $\text{Output of faeces} - \text{ash in faeces}$
76.	Nitrogenous OM in urine, g/d = $\text{N in urine, g/d} \times 3.59$ (Nehring et al. 1965)
77.	Non-nitrogenous OM in urine, g/d = $\text{Nitrogenous OM in urine, g/d} \times 0.397$
78.	$U_{\text{om}} = \text{nitrogenous OM in urine} + \text{non-nitrogenous OM in urine}$ (Nehring et al. 1965)
79.	DM in urine, g/d = $\text{Ash in urine} + \text{OM in urine}$
80.	N in faeces, g/d = $\text{DMI} \times \text{non-digestible N in diet} \times 0.001$
81.	N in urine, g/d = $\text{N intake} - \text{N retained}$
82.	P in urine, g/kg DMI/d = $0.1 \times \text{diet_P} - 0.0000658 \times \text{diet_P} \times \text{diet_P}$ (Bravo et al. 2003).
83.	P in faeces, g/d = $\text{P intake} - \text{P retained}$
84.	K in faeces, g/d = $\text{K intake} \times 0.0081 + 0.3062$ (Greene et al., 1983)
85.	K in urine, g/d = $\text{K intake} \times 0.3656 + 0.1635$ (Greene et al., 1983)

DMI = dry matter intake; OM = organic matter; DM = dry matter; U_{ash} = urinary ash; U_{om} = urinary organic matter; N = nitrogen; P = phosphorus; K = potassium; LW = live weight

3. Goats

Goats are kept in Finland mainly for milk and meat production. Most of the goats are kept in non-professional farms with only few animals (Virtanen et al. 2013). In 2025, the total amount of goats in Finland was 7 570. The number of slaughtered goats was 1 500 and the total amount of meat produced was 30 100 kg. The average carcass weight was 19.8 kg in 2025 (Luke 2026b). There is no official statistics for goat milk production in Finland, but on average, one goat can produce 500 – 800 litres of milk per year (Virtanen et al. 2013). Since the number of slaughtered goats is relatively small, there is no detailed carcass data available from goats.

For the excretion calculations, the goats were divided into ten subcategories by gender and age (Table 23). Kids were divided by their gender and age into 8 different categories. Buck kids grow faster than doe kids, and this was considered when calculating the growth and its retention.

Table 23. Categorization of goats and their average live weight (Finnish Food Authority).

	Number of animals	Average live weight, kg
Kid, doe 0–2 months	130	5.80
Kid, buck 0–2 months	110	6.48
Kid, doe 2–5 months	190	13.6
Kid, buck 2–5 months	160	15.6
Kid, doe 5–9 months	240	24.6
Kid, buck 5–9 months	180	28.9
Kid, doe 9–12 months	160	33.7
Kid, buck 9–12 months	80	40.2
Doe, over 12 months	4 890	51.3
Buck, over 12 months	1 430	62.3
Total	7 570	44.9

3.1. Calculation of live weight and empty body weight

The LW was calculated as described in Equations [85–86]. Because of the lack of slaughter data specifically for goats, Equations used for sheep were applied in the calculations. The Equations for calculating LW were similar as the ones used for sheep, with different coefficients (Table 24). Calculation of empty body weight (EBW) is calculated as in Equation [88].

Table 24. Equations for calculating the live weight (LW) and empty body weight (EBW) based on Richards (1959), Brown et al. (1972), Fox et al. (1999) and NRC (2007).

No	Equation
86.	$LW_{doe} = MW \times (1 - 0.757 \times e^{-0.00416 \times Age^2})$
87.	$LW_{buck} = MW \times (1 - 0.775 \times e^{-0.00538 \times Age^2})$
88.	$EBW, \text{ over 5 months} = -1.94 + 0.907 \times LW$

LW = live weight; MW = mature weight, Age = age in days EBW = empty body weight

3.2. Energy requirements

Energy requirements for maintenance, gestation, lactation, and growth were calculated following the Equations [89–103] (Table 25) and were based on NRC (2007). Energy requirements are presented in the Appendix 1. Energy requirement for lactation ($ME_{lactation}$) was calculated using fat corrected milk yield (FCM). FCM was calculated by Equation [100] (Gaines & Davidson 1923) and was on average 1.97 kg/day in 2024. Energy requirement for gestation was calculated as an average of the energy requirement of the last three months of gestation and was on average 0.55 MJ/day.

Table 25. Equations for calculating the energy requirements based on ARC (1980), AFRC (1993), Sahlu et al. (2004) and NRC (2007).

No	Equation
89.	$ME_{main, \text{ does under 2 months}} = 484.6 \times (LW^{0.75}) \times 0.001 \times 0.925$
90.	$ME_{main, \text{ bucks under 2 months}} = 484.6 \times (LW^{0.75}) \times 0.001 \times 1.075$
91.	$ME_{main, \text{ does 2–12 months}} = 580 \times (LW^{0.75}) \times 0.001 \times 0.925$
92.	$ME_{main, \text{ bucks 2–12 months}} = 580 \times (LW^{0.75}) \times 0.001 \times 1.075$
93.	$ME_{main, \text{ does over 12 months}} = 510 \times (LW^{0.75}) \times 0.001 \times 1.00$
94.	$ME_{main, \text{ bucks over 12 months}} = 514 \times (LW^{0.75}) \times 0.001 \times 115$
95.	$ME_{growth, \text{ kids under 2 months}} = LWC, \text{ kg/d} \times 1000 \times 13.4 \times 0.001$
96.	$ME_{growth, \text{ kids 2–12 months}} = LWC, \text{ kg/d} \times 1000 \times 23.1 \times 0.001$
97.	$ME_{growth, \text{ goats over 12 months}} = LWC, \text{ kg/d} \times 28.5$
98.	$ME_{lactation} = FCM \text{ kg/d} \times 5.22$
99.	$FCM, \text{ kg/d} = (\text{milk yield, kg/d} \times \text{milk fat-\%}) + (15 \times \text{fat yield, kg/d})$
100.	$ME_{gestation} = 0.70 \times (ME_{req} \text{ MJ/day, 3 months} + ME_{req} \text{ MJ/day, 4 months} + ME_{req} \text{ MJ/day, 5 months}) / 365$
101.	$ME_{gestation, \text{ 3 months}} = 1.19 \times (365/12)$
102.	$ME_{gestation, \text{ 4 months}} = 2.85 \times (365/12)$
103.	$ME_{gestation, \text{ 5 months}} = 5.41 \times (0.12 \times 0.70 \times 365)$

LW = live weight, FCM = fat corrected milk, kg/day; ME_{main} = Metabolizable energy requirement for maintenance; ME_{growth} = Metabolizable energy requirement for growth; $ME_{gestation}$ = Metabolizable energy requirement for gestation; $ME_{lactation}$ = Metabolizable energy requirement for lactation; LWC = live weight change as growth, kg/d

3.3. Diet composition and intake

Diet composition used in the calculations for Kids is presented in Table 26. Diet composition for adult goats is presented in Table 27. Main composition of the diet for goats is forage. Kids are fed with milk the first two to three months and after that, the main portion of the diet consists of forage (NRC 2007).

Table 26. Diet composition for kids.

	0–2 months	2–5 months	5–9 months	9–12 months
Metabolizable energy, MJ/kg DM	17.0	11.5	10.4	9.68
Gross energy, MJ/kg DM	22.6	18.3	18.2	18.1
In DM, g/kg				
Ash	55.6	89.8	77.4	68.0
Crude protein	210	166	137	111
Crude fat	211	45.5	34.4	24.6
Non-structural carbohydrates	476	462	444	468
Neutral detergent fibre	121	323	326	399
Phosphorus	6.23	3.83	2.89	2.55
Potassium	14.2	25.7	24.0	21.8

DM = dry matter

Table 27. Diet composition for adult goats.

	Doe, lactation	Doe, non-lactating	Buck, idle	Buck, breeding
Metabolizable energy, MJ/kg DM	11.7	10.6	9.52	10.8
Gross energy, MJ/kg DM	18.1	18.2	18.0	18.2
In DM, g/kg				
Ash	82.1	78.6	69.9	74.6
Crude protein	157	143	110	143
Crude fat	33.4	32.9	22.4	32.1
Non-structural carbohydrates	530	454	473	478
Neutral detergent fibre	590	538	456	441
Phosphorus	4.14	3.12	2.90	3.27
Potassium	21.2	24.3	21.0	22.7

DM = dry matter

Daily intakes of DM, OM, N, P and K are calculated based on diet composition as shown in Equations [104–108] (Table 28).

Table 28. Equations for calculating the dry matter, organic matter and nutrient intake.

No	Equation
104.	$DMI, \text{ kg/d} = ME_{req}, \text{ MJ/d} / ME_{diet}, \text{ MJ/kg DM}$
105.	$OMI, \text{ kg/d} = DMI \times (1000 - diet_ash)$
106.	$\text{Intake of N, g/d} = (CP, \text{ g/kg DM} / 6.25) \times DMI, \text{ kg/d}$
107.	$\text{Intake of P, g/d} = P, \text{ g/kg DM} \times DMI, \text{ kg/d}$
108.	$\text{Intake of K, g/d} = K, \text{ g/kg DM} \times DMI, \text{ kg/d}$

DMI = dry matter intake; OMI = organic matter intake; ME_{req} = Requirement of metabolizable energy; ME_{diet} = metabolizable energy in the diet; DM = dry matter; diet_ash = ash content of the diet, g/kg DM; N = nitrogen; CP = crude protein; P = phosphorus; K = potassium

3.4. Retention of nutrients

For calculating the retention of nutrients, similar Equations as for sheep were used. Goats do not have similar wool production as sheep, and hence there was no energy requirement or nutrient retention defined for wool production.

For growth, different equations were used to determine the retention of nutrients in EBW. For a newborn kid, the masses of CP, fat and ash are calculated as in Equations [109–111] (Table 29). The average birth weight of the newborn kid was 3.25 kg (Amoah et al. 1996).

Table 29. Equations for calculating the masses of protein, fat, and ash for newborn kid based on Jagusch et al. (1983)

No	Equation
109.	$CP \text{ mass, kg} = 0.190 \times LW$
110.	$Fat \text{ mass, kg} = 0.0243 \times LW$
111.	$Ash \text{ mass, kg} = 4.67 \times 0.01 \times LW$

CP = crude protein; LW= live weight

For adult goats, first the composition of the empty body is determined following the Equations [112–117] (Table 31). The proportions of fat and CP in EBW were modelled as log-log functions of age, following the principles of classical and modern ruminant body composition models (ARC 1965; Field & Suttle 1967; Johnson et al. 2012 and Souza et al. 2012) and were similar to the Equations used for sheep.

Coefficients to Equations [112] and [113] are described in Table 30.

Table 30. Coefficients for calculating the empty body weight as described in Table 32, based on INRAE (2023).

	A	B	C
Doe, CP coefficient	1.395	-0.0676	0.00324
Buck, CP coefficient	1.388	-0.0637	0.00187
Doe, fat coefficient	-0.376	1.177	-0.199
Buck, fat coefficient	-0.530	1.221	-0.216

CP = crude protein

Table 31. Equations for calculating the composition of the empty body weight (EBW).

No	Equation
112.	$EBW_{fat\%} = 10^{((fatcoefA + fatcoefB) \times agelog\ 10 + (fatcoefC) \times agelog\ 10 \times agelog\ 10)}$
113.	$EBW_{prot\%} = 10^{((protcoefA + protcoefB) \times agelog\ 10 + (protcoefC) \times agelog\ 10 \times agelog\ 10)}$
114.	$EBW_{water\%} = 96.6 - 0.972 \times EBW_{fat\%} - 1.0647 \times EBW_{prot\%}$
115.	$EBW_{ash\%} = 100 - EBW_{fat\%} - EBW_{prot\%} - EBW_{water\%}$
116.	$EBW_{phosphorus\%} = 10 \times 0.140 \times EBW_{ash\%}$
117.	$EBW_{potassium\%} = 0.121 \times EBW_{prot\%}$

EBW= empty body weight; Agelog = age in days¹⁰

After calculating the nutrient mass percentages in EBW, the changes in the mass percentages during different growth periods were calculated following the Equations [118–120] as presented in Table 32.

Table 32. Equations for calculating the final mass of crude protein, fat and ash in the empty body weight at slaughter.

No	Equation
118.	$Coefficient = (\log_{10}(\text{mass in the end}) - \log_{10}(\text{mass in the beginning})) / (\log_{10}(\text{end EBW}) - \log_{10}(\text{beginning EBW}))$
119.	$Constant = Coefficient \times \log_{10}(\text{beginning EBW}) \times -1 + \log_{10}(\text{mass in the beginning})$
120.	$Final\ mass\ in\ EBW = 10^{(constant + coefficient \times \log_{10}(EBW))}$

EBW = empty body weight

Retention of CP, P, K, and ash could then be calculated following the Equations [121–124] (Table 33).

Table 33. Crude protein, phosphorus, potassium, and ash retention in goat, kg/day.

No	Equation
121.	$CP\ retention, kg/day = (CP\ mass\ beg - CP\ mass\ end) / (max\ age - min\ age)$
122.	$P\ retention, kg/day = (P\ mass\ beg - P\ mass\ end) / (max\ age - min\ age)$
123.	$K\ retention, kg/day = (K\ mass\ beg - K\ mass\ end) / (max\ age - min\ age)$
124.	$Ash\ retention, kg/day = (ash\ mass\ beg - ash\ mass\ end) / (max\ age - min\ age)$

CP = crude protein; Max age = age in days at the end of growth period; Min age = age in days at the beginning of growth period; P = phosphorus; K = potassium

Finally, to be able to calculate the final retention of nutrients during growth, following Equations [125–128] were used (Table 34).

Table 34. Retention of nutrients in growth, g/day.

No	Equation
125.	N retained, g/d = CP retention, kg/day / 6.25 / 1000
126.	P retained, g/d = P retention, kg/day / 1000
127.	K retained, g/d = K retention, kg/day / 1000
128.	Ash retained, g/d = retention, kg/day / 1000

N = nitrogen; CP = crude protein; P = phosphorus; K = potassium

Retention of nutrients in gestation were calculated as described in the Table 35.

Table 35. Retention of nutrients during gestation based on ARC (1980), Sahlu et al. (2004). and NRC (2007).

No	Equation
129.	N retained, gestation, g/d = $[n_g \times ABW \times 0.934 \times (EBW - \text{prot\% newborn} / 6.25) \times 0.01] / 365$
130.	P retained, gestation, g/d = $(n_g \times ABW \times 0.934 \times EBW - P\% NB \times 0.001) / 365$
131.	K retained, gestation, g/d = $(n_g \times ABW \times 0.93444 \times EBW - K\% NB \times 0.001) / 365$
132.	Ash retained, gestation, g/d = $(n_g \times ABW \times 0.93444 \times EBW - \text{ash\% NB} \times 0.01) / 365$
133.	Number of Kids / doe / year = 1.7

N = nitrogen; ABW = average birth weight, kg; NB = newborn goat; n_g = number of Kids born; EBW = empty body weight; P = phosphorus; K = potassium

3.5. Excretion

To calculate the excretion of nutrients, the digestibility of OM and DM was determined as in Equations [134–140] (Table 37). DM concentration of faeces was 380 g/kg on average (Appuhamy et al. 2014).

Table 36. Water factors used in the Equations, based on ARC (1980), AFRC (1993), Sahlu et al. (2004) and NRC (2007).

Animal group	Water factor
Kid, 0–2 months	4.03
Kid, 2–12 months	2.50
Doe, lactating	5.00
Doe, dry	5.50
Buck	2.50

Table 37. Equations for calculating intake of indigestible organic matter, digestibility of organic and dry matter, excreted amount of dry matter and the output of faeces and urine, based on Appuhamy et al. (2014) and Ramin & Huhtanen (2013).

No	Equation
134.	Intake of digestible OM (DOMI), kg/d = $(ME_{\text{diet}} \times \text{DMI}) / 16$ (Kuoppala et al. 2024)
135.	Digestibility of OM (OMD), g/g = $\text{DOMI} / (\text{DMI} \times \text{diet_OM} \times 0.001)$
136.	Digestibility of DM (DMD), g/g = $(0.977 \times \text{OMD} \times 1000 + 1.4) / 1000$ (modified from Ramin & Huhtanen, 2013)
137.	Indigestible DM excreted, kg/d = $\text{DMI, kg/d} \times (1 - \text{DMD})$
138.	Output of faeces, kg/d = indigestible DM, kg/d / DM concentration of faeces, g/g
139.	Output of urine, kg/d = $(\text{Water intake} - \text{Faecal water}) + U_{\text{om}} + U_{\text{ash}}$
140.	Water intake = Water factor \times DMI

DMI = dry matter intake; OM = organic matter; OMD = organic matter digestibility; DMD = dry matter digestibility; ME_{diet} = metabolizable energy in the diet; U_w = urinary water, U_{ash} = urinary ash; U_{om} = urinary organic matter

The nutrients excreted in milk are calculated as presented in Table 38.

Table 38. Equations for calculating the nutrients excreted in milk based on Kapadiya et al. (2016).

No	Equation
141.	N in milk, kg/kg = $(29/1000) / 6.38 = 0.0045$
142.	N retained, milk, g/d = N in milk \times milk, kg/d
143.	P in milk, kg/kg = 0.0009
144.	P retained, milk, g/d = P in milk \times milk, kg/d
145.	K in milk, kg/kg = 0.002
146.	K retained, milk, g/d = K in milk \times milk, kg/d
147.	Ash in milk, kg/kg = 0.007
148.	Ash retained, milk, g/d = ash in milk \times milk, kg/d

N = nitrogen; P = phosphorus; K = potassium

The division of nutrient excretion between faeces and urine was calculated as shown in Equations [149–159] (Table 39).

Table 39. Equations for calculating the composition of faeces and urine.

No	Equation
149.	$U_{ashr} \text{ g/d} = \text{Ash intake, g/d} - \text{ash retained, g/d} - \text{ash in faeces, g/d}$
150.	$\text{Nitrogenous OM in urine, g/d} = \text{N in urine, kg/d} \times 3.3593$
151.	$\text{Non-nitrogenous OM in urine, g/d} = \text{Nitrogenous OM in urine} \times 0.3965$
152.	$U_{om} = \text{nitrogenous OM in urine} + \text{non-nitrogenous OM in urine (Nehring et al. 1965)}$
153.	$\text{DM in urine, g/d} = \text{Ash in urine} + \text{OM in urine}$
154.	$\text{N in faeces, g/d} = \text{DMI} \times \text{non-digestible N in diet} \times 0.001$
155.	$\text{N in urine, g/d} = \text{N intake} - \text{N retained} - \text{N in faeces}$
156.	$\text{P in urine, g/kg DMI/d} = 0.1 \times \text{diet_P} - 0.0000658 \times \text{diet_P} \times \text{diet_P (Bravo et al. 2003)}$
157.	$\text{P in faeces, g/d} = \text{P intake} - \text{P retained}$
158.	$\text{K in faeces, g/d} = \text{K intake} \times 0.0081 + 0.3062 \text{ (Greene et al., 1983)}$
159.	$\text{K in urine, g/d} = \text{K intake} \times 0.3656 + 0.1635 \text{ (Greene et al., 1983)}$

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

The final amount of excretion of nutrients, DM and OM is presented in Appendices.

4. Summary of calculated results for sheep and goats

4.1. Summary of results

Detailed excretion calculation results for different sheep and goat categories using input data from year 2025 are presented in Appendices as follows:

- **Appendix 1.** Energy requirements for sheep and goats
- **Appendix 2.** Nutrient intake, retention and excretion for lambs
- **Appendix 3.** Nutrient intake, retention and excretion for ewes
- **Appendix 4.** Nutrient intake, retention and excretion for rams
- **Appendix 5.** Nutrient intake, retention and excretion for doe kids
- **Appendix 6.** Nutrient intake, retention and excretion for buck kids
- **Appendix 7.** Nutrient intake, retention and excretion for adult does and bucks

Results shown in the appendices represent only that year the calculations are made from. Calculations are done separately each year with varying input data (animal numbers, slaughter data, milk yield, diet composition etc.). The equations used in calculations are updated, if necessary, for example, when new research information is available concerning the calculations in hand.

Results are reported per day and per year. Daily results were converted to annual ones by multiplying them with a factor of 365.

The calculations can be modified separately for meat and native breeds by changing the LW of sheep and goats in the calculations, or by the level of production by changing the annual milk, wool, lamb, or meat production. Similarly, the effects of changes in diet composition can be demonstrated. For official calculations, it is critical that correct national input data are used. In Appendices 1–7, the average Finnish values for the year 2025 have been used.

Appendices show the total excretion of faeces, urine, N, P and K. To evaluate the uncertainty of the calculation models, sensitivity analysis was conducted for the ewes (Chapter 4.4.). During the sensitivity analysis, only one variable at a time was changed and the results of these changes are shown in Figures 17–20.

4.2. Total excretion of N, P and K in different animal categories in 2025

Excretion for N, P, K, faeces and urine per animal per year are shown in Figures 3–7. Total excretions of N, P and K, faeces and urine for whole sheep and goat population in Finland are shown in Figures 8–12. Goats are on average smaller than sheep, and therefore also eat and

excrete less than sheep. Exception for this are does, who are used mainly for milk production and therefore also excrete more compared to sheep and other goats.

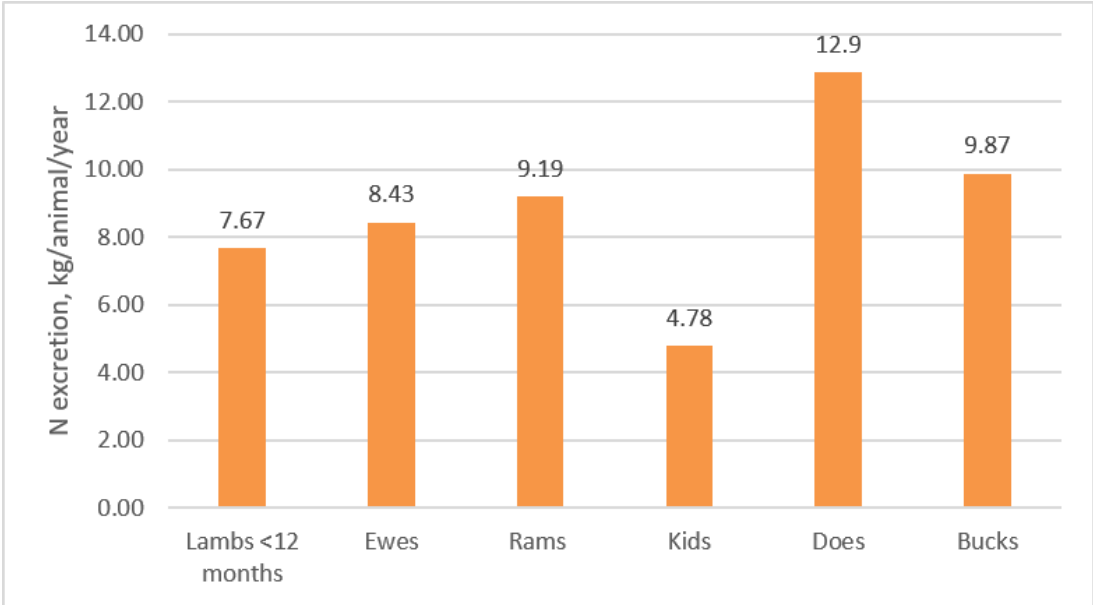


Figure 3. Nitrogen excretion per animal per year in 2025

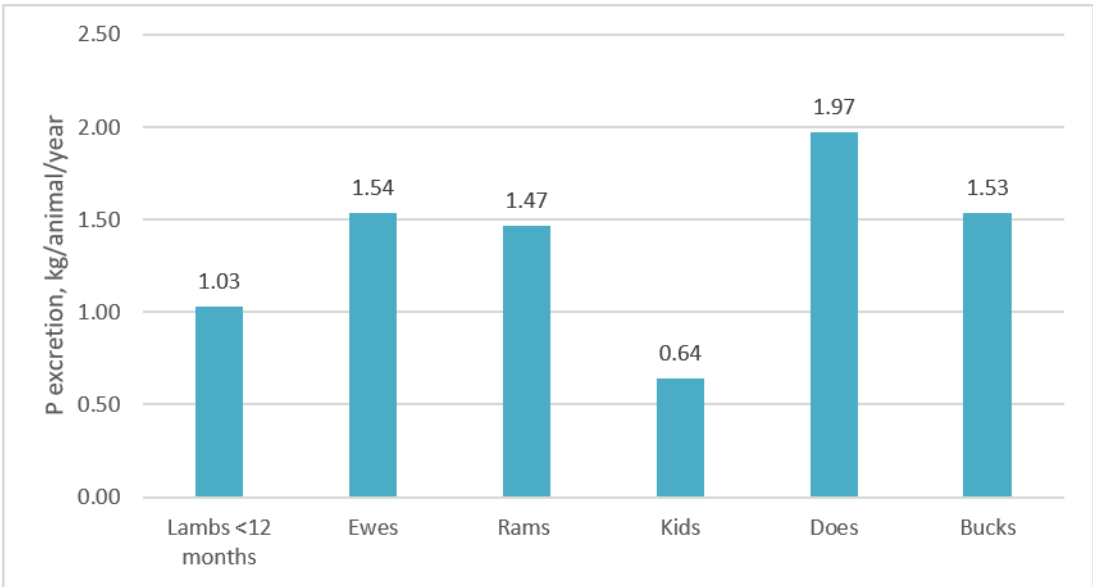


Figure 4. Phosphorus excretion per animal per year in 2025.

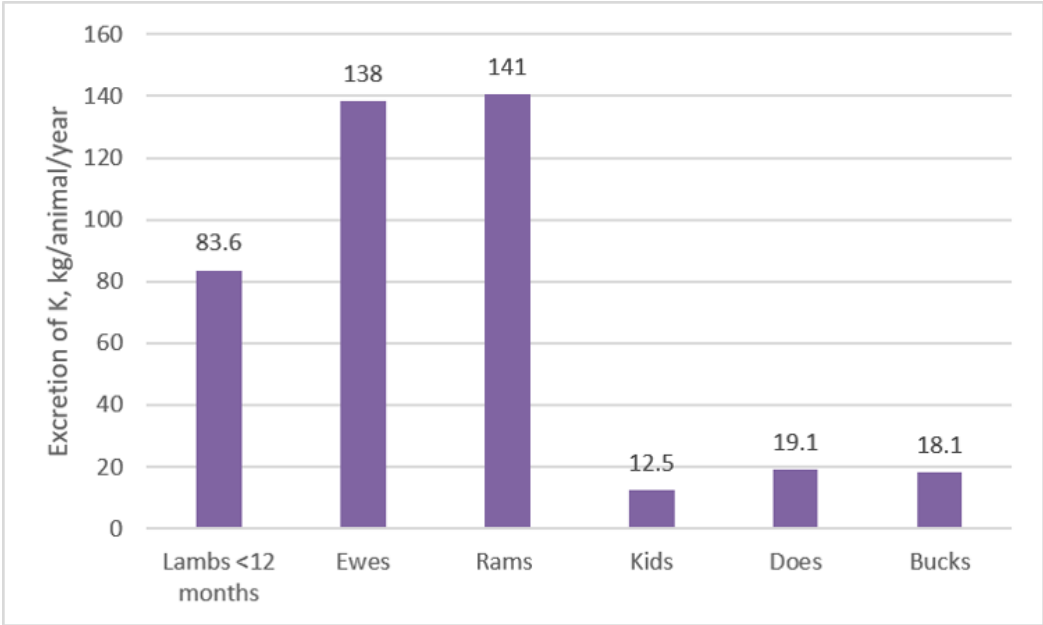


Figure 5. Potassium excretion per animal per year in 2025.

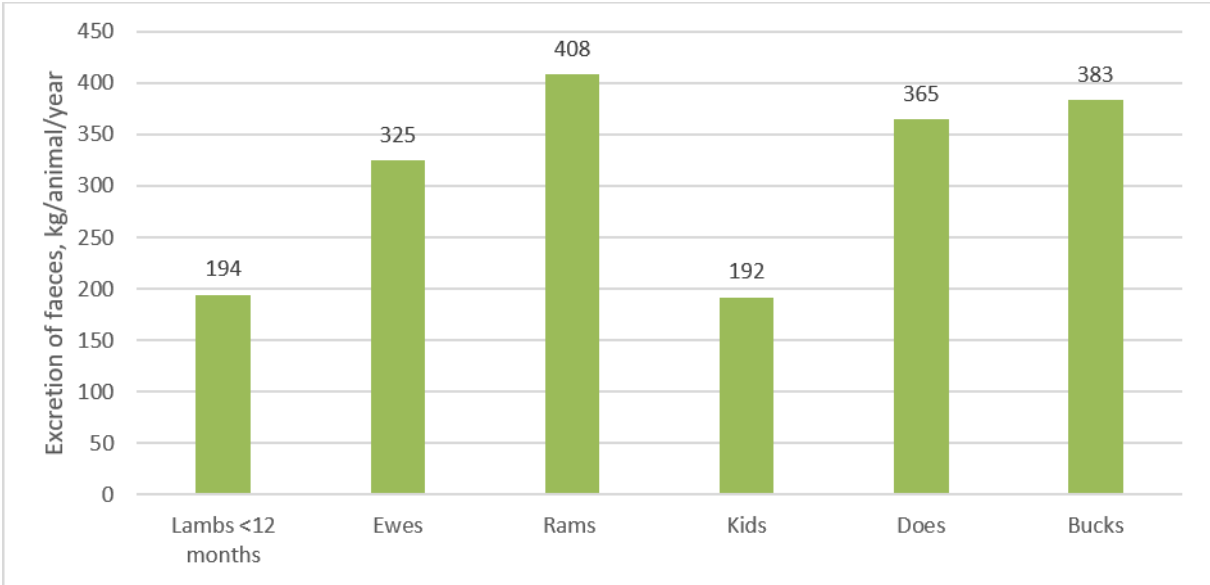


Figure 6. Excretion of faeces, kg/animal/year in 2025.

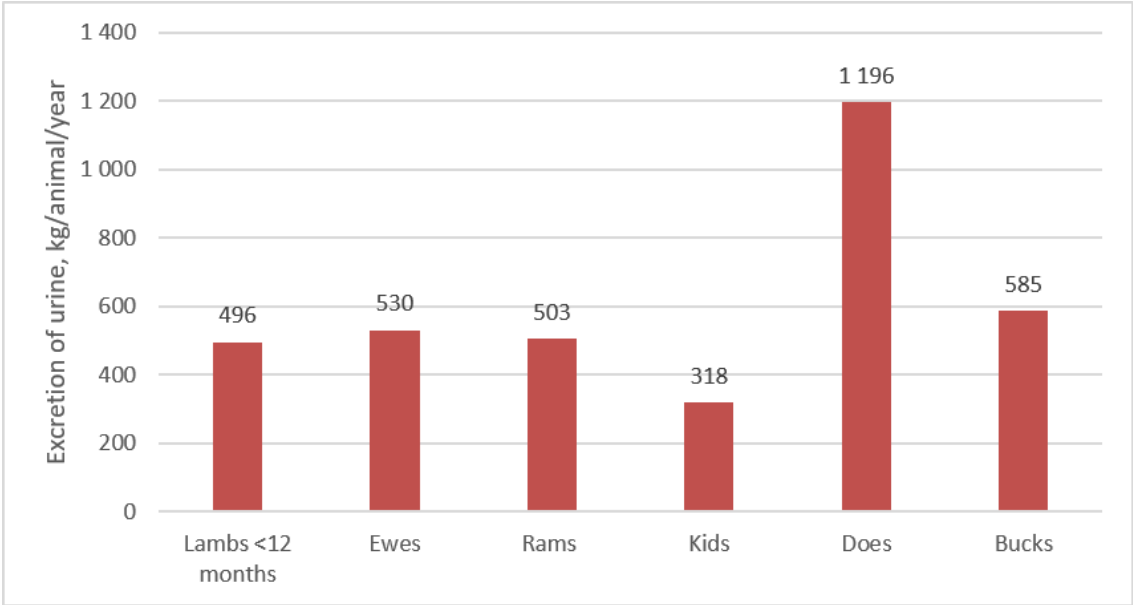


Figure 7. Excretion of urine, kg/animal/year in 2025.

In the total excretion for N, P, K, urine and faeces (Figures 8–12), whole excretion for the different sheep and goat categories are presented as 1000 kg per year. Smaller number of animals is the main reason for smaller excretion rates for all goats, but also the overall smaller excretion per animal explains the differences between sheep and goats.

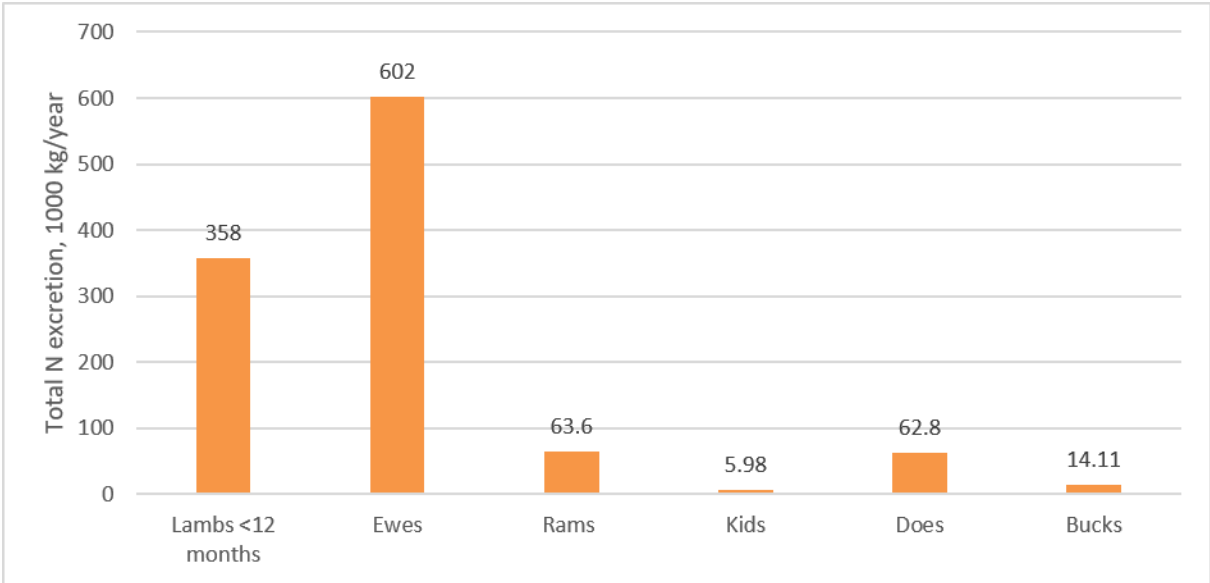


Figure 8. Total excretion of nitrogen in 2025, 1000 kg/year.

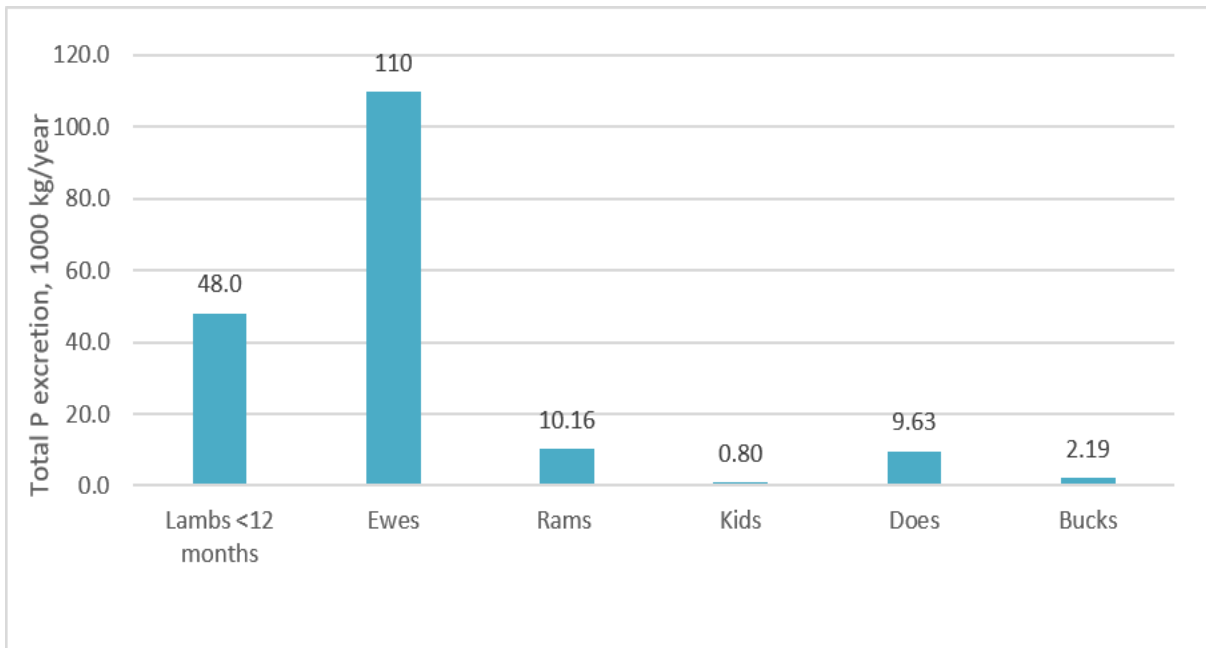


Figure 9. Total excretion of phosphorus in 2025, 1000 kilograms per year.

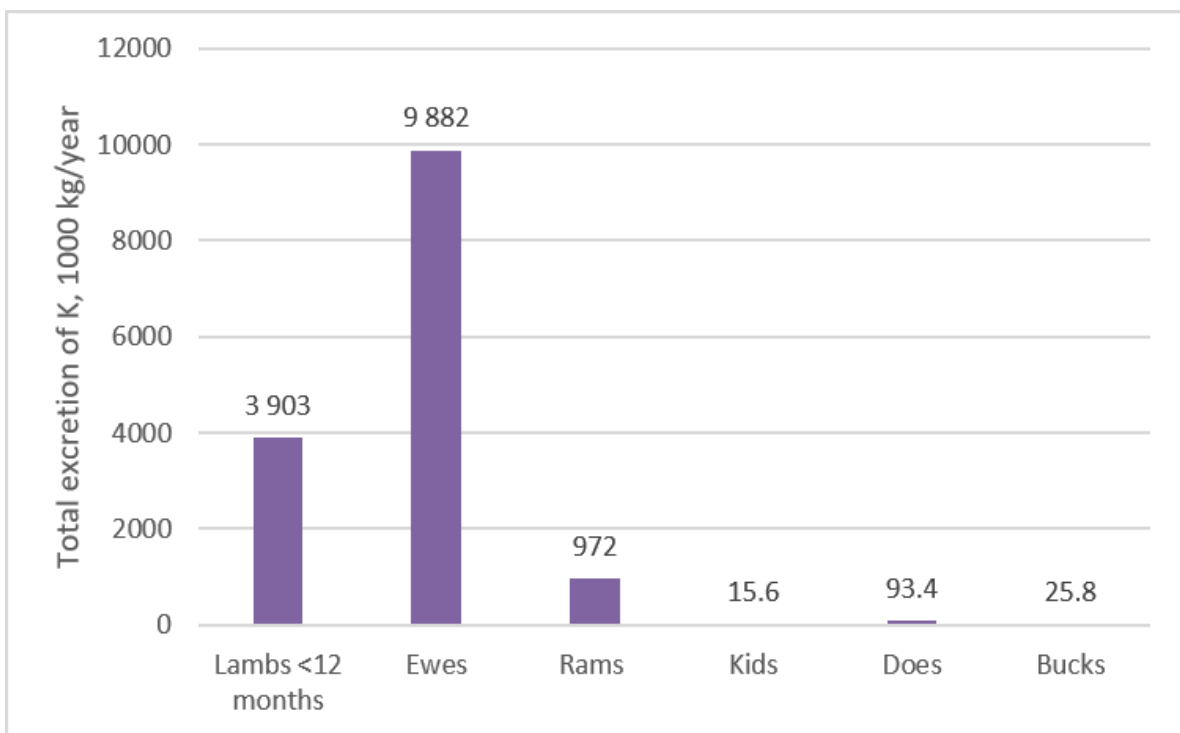


Figure 10. Total excretion of potassium in 2025, 1000 kilograms per year.

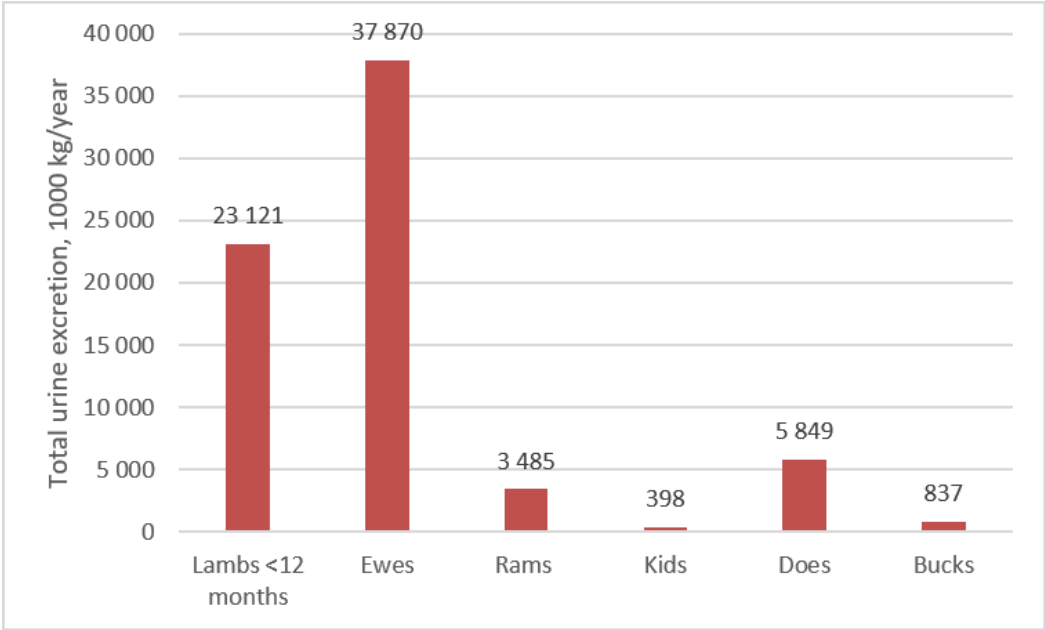


Figure 11. Total excretion of urine in 2025, 1000 kilograms per year.

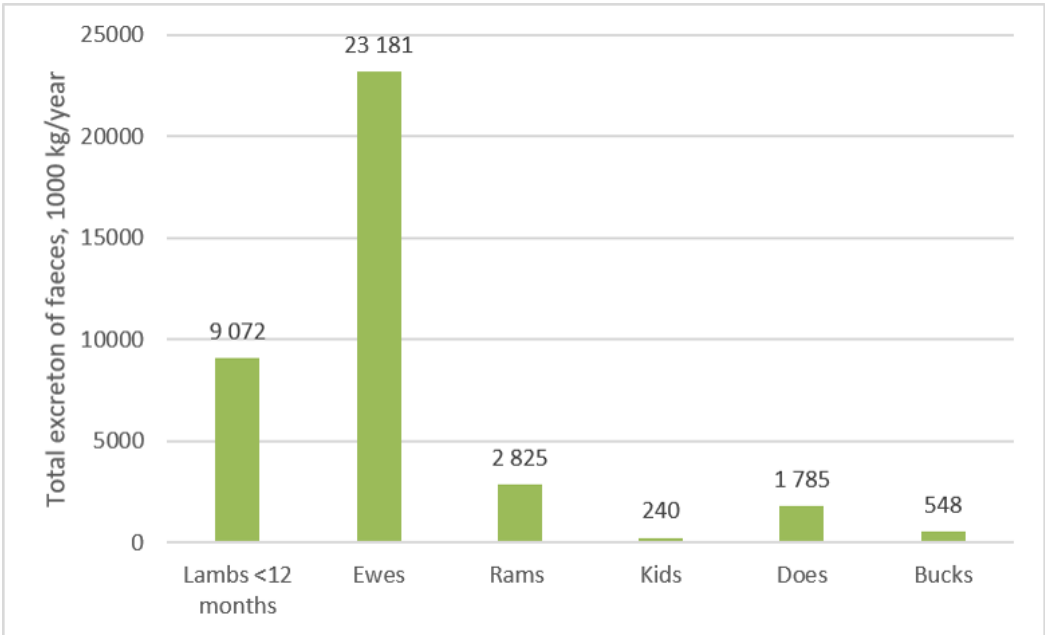


Figure 12. Total excretion of faeces in 2025, 1000 of kilograms per year.

4.3. Time series for sheep and goats 1990–2025

The official excretion calculations are the base for many purposes and offer valuable information about the animal production. Calculations over time form time series, in which the starting point is the year 1990.

The time series of sheep’s N excretion is shown in Figure 13 and the time series for P excretion in Figure 14. The time series of goats N and P excretion are presented in Figures 15 and 16.

To form a time series, a lot of data is needed from the production and feeding of the animals. Since the actual feed intakes of sheep and goats are not recorded, and there are lot of

uncertainties regarding the actual feeds consumed by the animals, the time series reflects more the number of animals and the change in the population size. The sharp variations between some years, as e.g. 2003–2004 in sheep, reflect the changes in the number of animals.

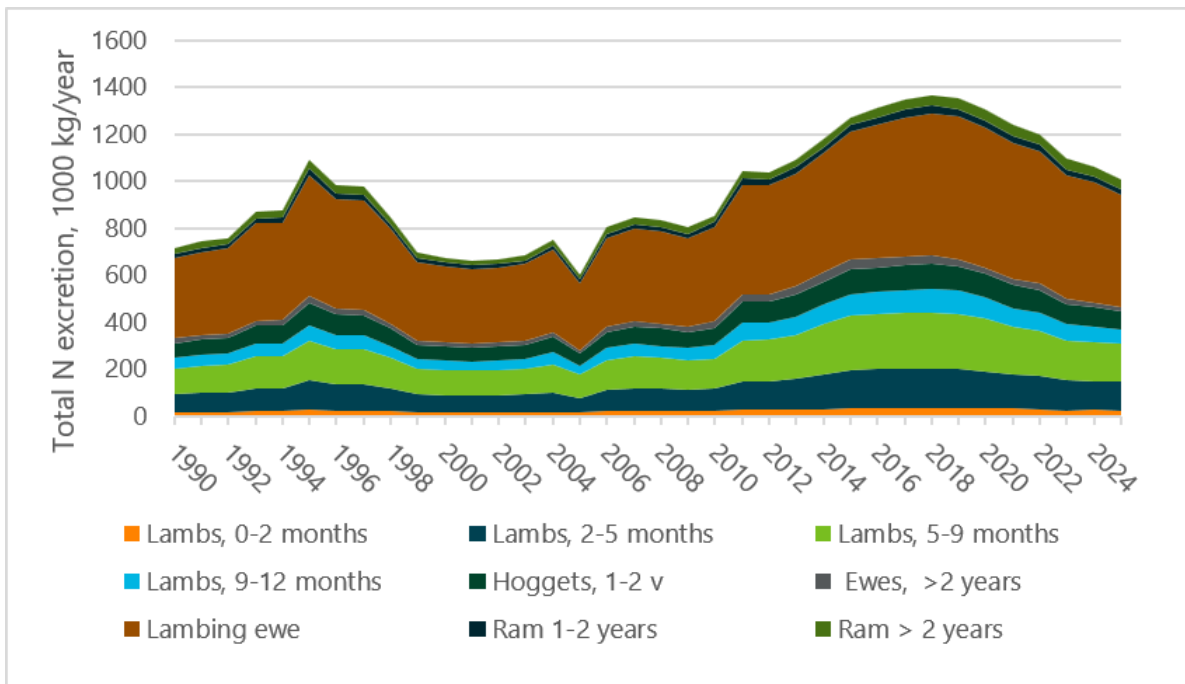


Figure 13. Time series for nitrogen excretion of sheep in 1990–2025.

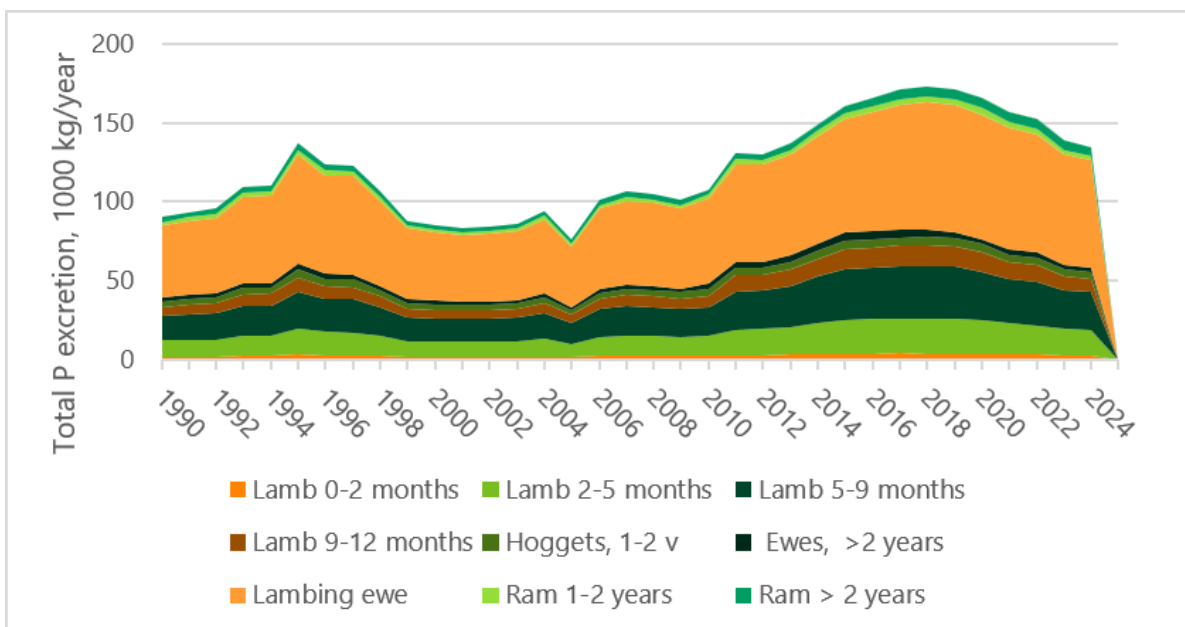


Figure 14. Time series for phosphorus excretion of sheep in 1990–2025.

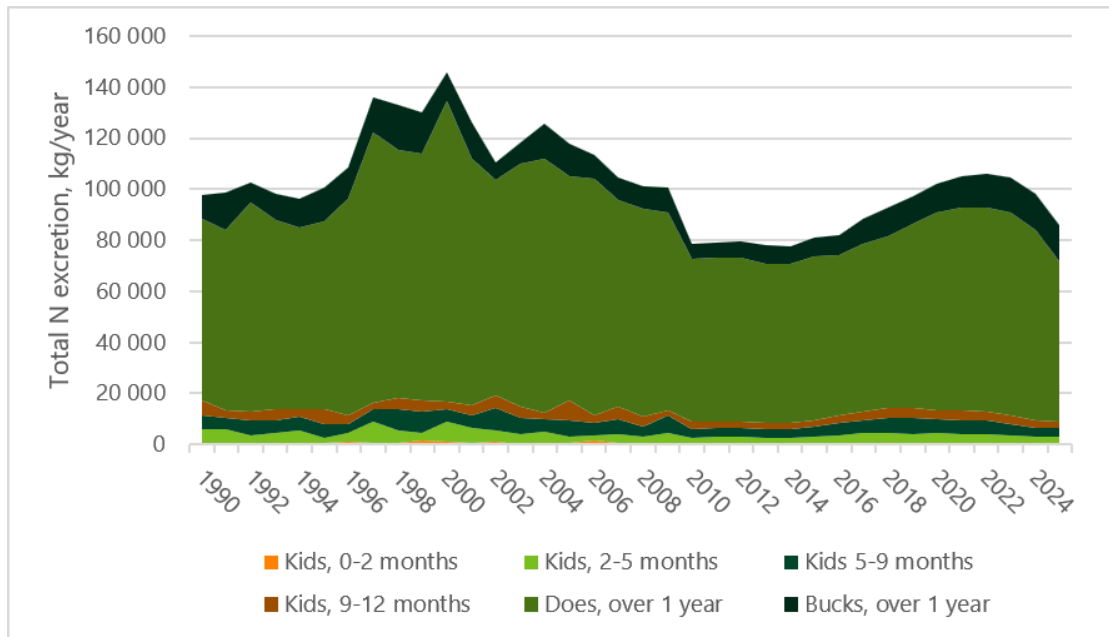


Figure 15. Time series for nitrogen excretion of goats in 1990–2025.

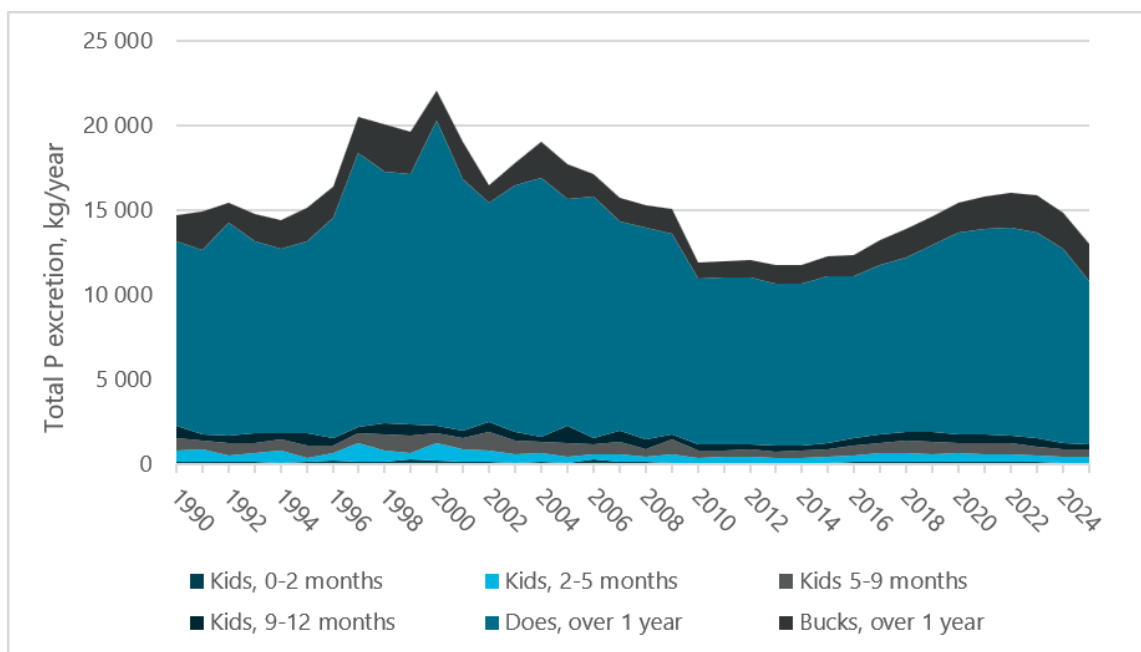


Figure 16. Time series for phosphorus excretion of goats in 1990–2025.

To form a time series, a total number of animals from 1990 to the present day was needed. Since the statistical methods have changed few times during this time, there was no similar ways in which goats and sheep were calculated throughout the timeseries. The more constant excretion rates from 2010 onwards reflect the number of animals obtained from Finnish Food Authority. Before that, the number of animals was obtained from Official Statistics (Luke 2026a) and was adjusted to reflect the differences in animal numbers between OFS and Finnish Food Authority from the years 2010–2025. Therefore, the rapid changes in animal population size and in the excretion might reflect more the statistical error than the actual change in overall excretion.

4.4. Sensitivity analysis for ewe’s excretion

Sensitivity analyses the excretion of adult ewes were conducted so that only one variable at a time was changed (Figures 17–20). Live weight (LW), diet CP, P or K concentration or dry matter intake (DMI) were increased or decreased 10% from the average values used in the calculations to see how much these factors attribute to the calculations. In reality, LW and DMI are strongly correlated and if one factor changes, often so does the other. The same principle applies for the nutrient content of the feeds. However, sensitivity analysis shows valuable information about the critical points of calculations and offers some insights on how the excretion rates could be decreased.

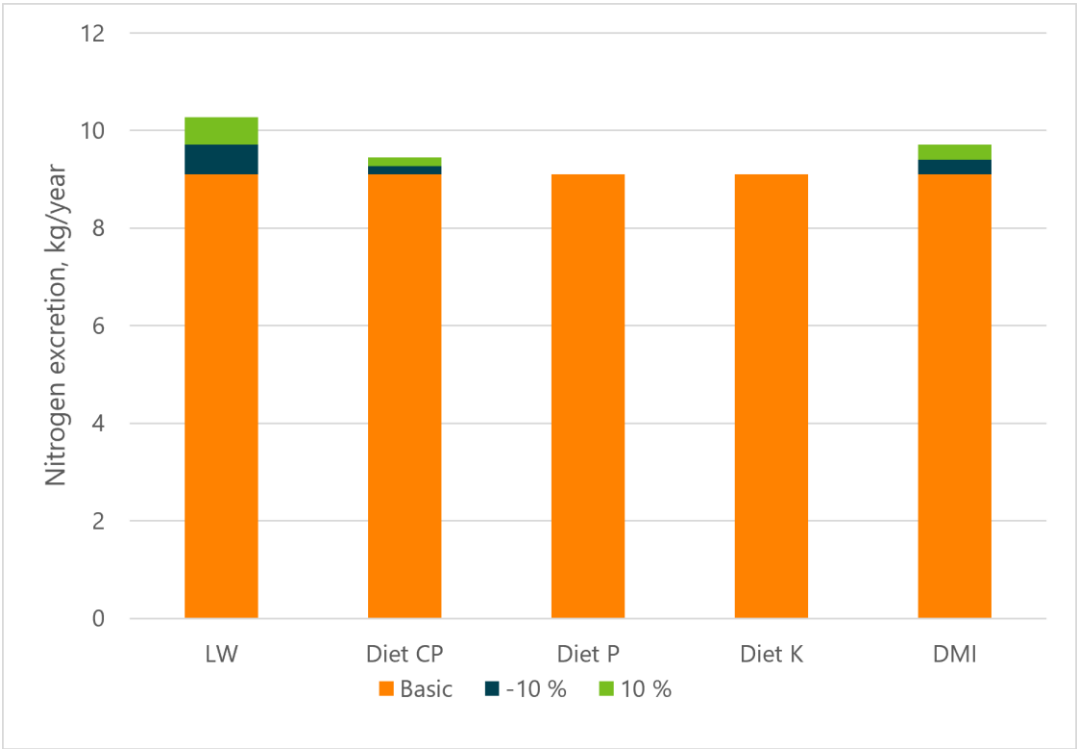


Figure 17. Sensitivity analysis for nitrogen excretion.

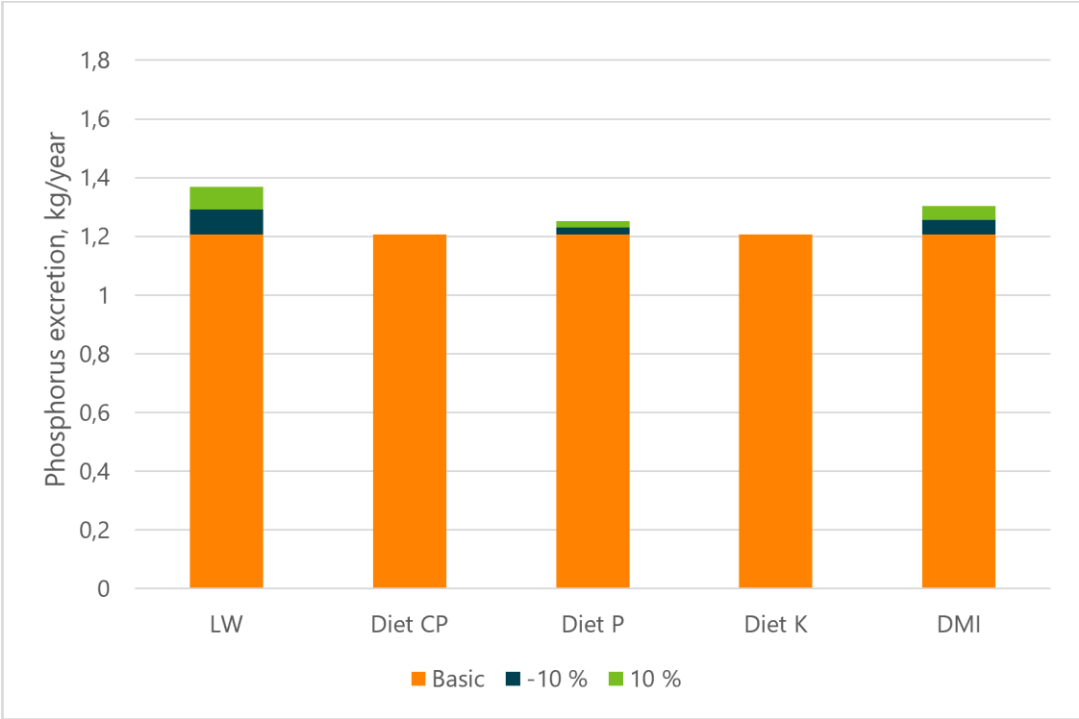


Figure 18. Sensitivity analysis for phosphorus excretion.

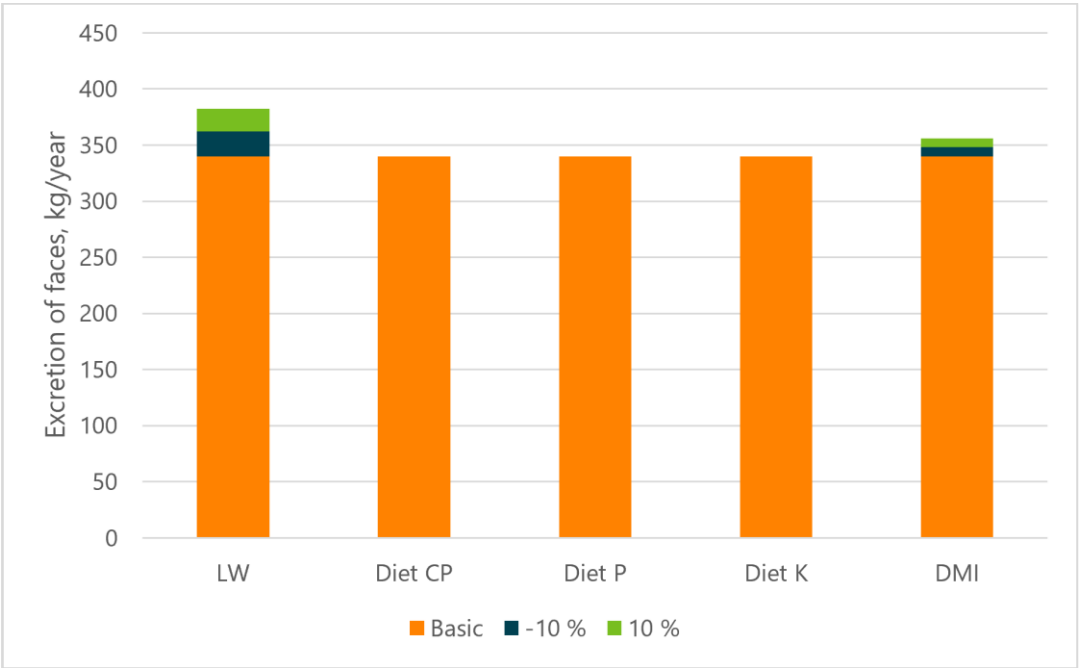


Figure 19. Sensitivity analysis for excretion of faeces.

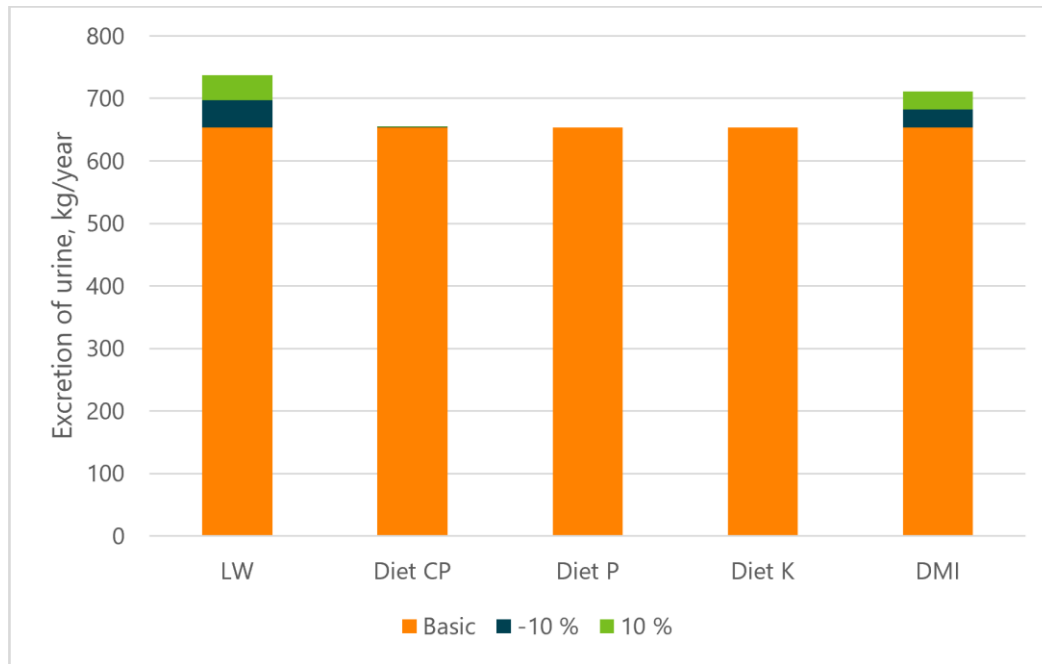


Figure 20. Sensitivity analysis for excretion of urine.

Baseline in the sensitivity analysis is the border line between the blue and green bars. Green bar represents the 10% increase from the base level, and blue bar 10% decrease.

Changes in the LW and DMI affect the excretion rates the most. Increase in LW also increases DMI, which then increases excretion. The same principle applies if LW or DMI decreases. Naturally, the CP or P content of the diet also affects nutrient excretion, since only certain proportion of nutrients are retained in the animal itself. CP content of the diet affects the urine excretion, since the excess CP is turned into ammonia, which is then excreted as urea via urine. The effect of dietary CP increase to excretion of urine in these calculations is still somewhat small.

Changes in LW affect all the excretion parameters the most. To get the most accurate results from the excretion calculations, these parameters should be as precise as possible even in the future. To get the calculations more precise, more information would also be needed from the actual diet composition and DMI of the animals.

5. References

- Amoah, E., Gelaye, S., Guthrie, P. & Rexroad, C. 1996. Breeding Season and Aspects of Reproduction of Female Goats. *Journal of animal science*. 74(4): 723–8. <https://10.2527/1996.744723x>
- Appuhamy, J.A.D.R.N., Wagner-Riddle, C., Casper, D.P., France, J. & Kebreab, E. 2014. Quantifying body water kinetics and fecal and urinary water output from lactating ruminants. *Journal of Dairy Science* 97: 6177–6195. <https://doi.org/10.3168/jds.2013-7755>
- AFRC. 1993. Energy and Protein Requirements of Ruminants. CAB International, Wallingford, UK.
- ARC. 1965. The Nutrient Requirements of Ruminant Livestock. Agricultural Research Council. London. ARC. 1980. The Nutrient Requirement of Ruminant Livestock. CAB, Farnham Royal.
- Burns, R.H., Johnston, A., Hamilton, J.W., McColloch, R.J., Duncan, W.E. & Fisk, H.G. 1964. Minerals in domestic wools. *Journal of Animal Science*. 23: 5–11. <https://doi.org/10.2527/jas1964.2315>
- Bravo, D., Sauvant, D., Bogaert, C. & Meschy, F. 2003. Quantitative aspects of phosphorus excretion in ruminants. *Reproduction, nutrition, development*, 43: 285–300. <https://doi.org/10.1051/rnd:2003021>
- Brown, J.E., Brown, C.J. & Butts, W.T. 1972. A Discussion of the Genetic Aspects of Weight, Mature Weight and Rate of Maturing in Hereford and Angus Cattle. *Journal of Animal Science* 34: 525–537. <https://doi.org/10.2527/jas1972.344525x>
- Cannas, A., Pellegrini, M. & Tedeschi, L.O. 2004. Energy and protein requirements of dairy sheep. *Small Ruminant Research* 55: 185–194. <https://10.5555/20043188306>
- Chizzotti, M.L., Tedeschi, L.O., Valadares Filho, S.C., Paulino, P.V.R., Valadares, R.F.D., Lage, C.F.A. & Fonseca, M.A. 2007. Nutrient requirements of Nellore cattle and small ruminants. *Revista Brasileira de Zootecnia* 36 (supplement): 287–298. <https://10.2527/jas.2006-632>
- Degen, A.A. & Young, B.A. 1981. Effect of air temperature and feed intake on live weight and water balance in sheep. *The Journal of Agricultural Science, Cambridge*. 96: 493–496. <https://10.1017/S0021859600066302>
- Field, A.C. & Suttle, N.F. 1967. Retention of minerals by the developing sheep foetus. *Journal of Agricultural Science* 69: 417–427. <https://10.1017/S0021859600019109>
- Finnish Food Authority 2026. Slaughter data of sheep and goats 2025.
- Finnsheep ry 2026. Wool. Cited 29.5.2026. Available at: <https://finnsheep.fi/en/wool-the-renewable-natural-recourse/>
- Gaines, W.L. & Davidson, F.A. 1923. Relation between percentage fat content and yield of milk: Correction of milk yield for fat content. University of Illinois Agricultural Experiment Station, Bulletin No. 245

- Greene, L.W, Fontenot, J.P. & Webb, K.E. Jr. 1983. Effect of Dietary Potassium on Absorption of Magnesium and other Macroelements in Sheep Fed Different Levels of Magnesium. *Journal of Animal Science*. 56:1208–1213. <https://doi.org/10.2527/jas1983.5651208x>
- INRAE. 2023. INRA feeding system for ruminants. Leiden, The Netherlands: Wageningen Academic. <https://doi.org/10.3920/978-90-8686-292-4>
- Jagusch, K.T., Duganzich D.M. & Kidd G.T. 1983. Efficiency of goat milk utilisation by milk-fed kids. *New Zealand Journal of Agricultural Research*. 26: 443–445. <https://doi.org/10.1080/00288233.1983.10427019>
- Johnson, I.R., France, J., Thornley, J.H.M. & Bell, M.J. 2012. A generic model of growth, energy metabolism, and body composition for cattle and sheep. *Journal of Animal Science* 90: 4741–4751. <https://doi.org/10.2527/jas.2011-5053>
- Kapadiya, D.B., Prajapati, D.B., Jain, A.K., Mehta, B.M. & Darji, V.B. 2016. Comparison of Surti goat milk with cow and buffalo milk for gross composition, nitrogen distribution and selected minerals. *Veterinary World* 9: 710–716. <https://doi.org/10.14202/vetworld.2016.710-716>
- Kellaway, R.C. 1973. The effects of plane of nutrition, genotype and sex on growth, body composition and wool production in grazing sheep. *The Journal of Agricultural Science, Cambridge*. 80: 17–27. <https://doi.org/10.1017/S0021859600057014>
- Kuoppala, K., Vattulainen, J., Perttilä, S., Saastamoinen, M. & Rinne, M. 2024. Finnish Feed Tables and Nutrient Requirements: Ruminants, pigs, poultry, horses. *Natural Resources and Bioeconomy Studies* 70/2024. Natural Resources Institute Finland. Helsinki. 97 p.
- Laki ruoka- ja luonnonvaratilastoista (562/2014), ajantasaisesti säädös. Referred 1 June 2026. Available at: <https://www.finlex.fi/fi/lainsaadanto/2014/562>
- Luke 2026a. Number of livestock. Natural Resources Institute Finland (Luke). Referred 1 June 2026. Available at: https://statdb.luke.fi/PxWeb/pxweb/fi/LUKE/LUKE__maa/
- Luke 2026b. Meat production. Natural Resources Institute Finland (Luke). Referred 1 June 2026. Available at: https://statdb.luke.fi/PxWeb/pxweb/fi/LUKE/LUKE__maa/
- MTT 2006. Rehutaulukot ja ruokintasuositukset. MTT Agrifood Research Finland. Available at: <https://urn.fi/URN:ISBN:952-487-001-0>
- More, T., Howard, B., & Siebert, B.D. 1983. Effect of level of water intake on water, energy and nitrogen balance and thyroxine secretion in sheep and goats. *Australian Journal of Agricultural Research*. 34: 441–446. <https://doi.org/10.1071/AR9830441>
- Muir, P.D., Thomson, B.C. & Askin, D.C. 2008. A review of dressing out percentage in New Zealand livestock. Ministry of Agriculture and Forestry, New Zealand. Saatavilla: <https://www.mpi.govt.nz/dmsdocument/2963-A-review-of-dressing-out-percentage-in-New-Zealand-livestock>
- Nehring, K., Beyer, M., Hoffmann, L. & Schiemann, R. 1965. Futterbewertung und Futtermittelverwertung in der Tierproduktion. Berlin: VEB Deutscher Landwirtschaftsverlag.
- NRC. 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. National Academies Press, Washington, DC.

- Nousiainen, J., Kuoppala, K., Vattulainen, J., Sairanen, A., Palmio, A., Joki-Tokola, E., Luostari-
nen, S. & Rinne, M. 2023. Excretion calculations of cattle in Finland - amount and com-
position of faeces and urine. Natural resources and bioeconomy studies 68/2023. Nat-
ural Resources Institute Finland. Helsinki. 62 p.
- Ogejo, J.A., Wildeus, S., Knight, P. & Wilke, R.B. 2010. Technical note: Estimating goat and
sheep manure production and their nutrient contribution in the Chesapeake Bay wa-
tershed. Applied Engineering in Agriculture. 26: 1061–1065. [https://
10.13031/2013.35912](https://doi.org/10.13031/2013.35912)
- Park, Y.W., Juárez, M., Ramos, M. & Haenlein, G.F.W. 2007. Physico-chemical characteristics of
goat and sheep milk. Small Ruminant Research 68: 88–113.
<https://doi.org/10.1016/j.smallrumres.2006.09.013>
- Peart, J.N. 1968. The yield and composition of the milk of Finnish Landrace × Blackface ewes.
Journal of Agricultural Science 70: 231–237.
- Peart, J.N. 1970. The effects of live weight and body condition on milk production of ewes.
Journal of Agricultural Science 75: 459–469.
- Perttilä, S., Högel, H., Vattulainen, J., Nousiainen, J., Sevón-Aimonen, M-L., Kuoppala, K., Rinne,
M., Grönroos, J. & Luostarinen, S. 2025. Excretion calculation of pigs in Finland : ER-
ITYSproject report. Natural Resources and Bioeconomy Studies 72/2025. Natural Re-
sources Institute Finland. Helsinki. 42 p.
- ProAgria 2026. Lammastuotosseurannan vuosiyhteenveto 2025. Referred 1 June 2026. Availa-
ble at: [https://proagría-website.files.svdcdn.com/production/Ladattavat-oppaat/Lam-
mastuotosseurannan-vuosiyhteenveto-2025.pdf?dm=1781504209](https://proagría-website.files.svdcdn.com/production/Ladattavat-oppaat/Lam-
mastuotosseurannan-vuosiyhteenveto-2025.pdf?dm=1781504209)
- Ramin, M. & Huhtanen, P. 2013. Development of equations for predicting methane emissions
from ruminants. Journal of Dairy Science 96: 2476–2493.
<https://doi.org/10.3168/jds.2012-6095>
- Ratray, P.V., Garrett, W.N., Meyer, H.H., Bradford, G.E., East, N.E. & Hinman, N. 1973. Body
and carcass composition of Targhee and Finn- Targhee lambs. Journal of Animal Sci-
ence. 37: 892–897. <https://doi.org/10.2527/jas1973.374892x>
- Ratray, P.V., Garrett, W.N., Hinman, N. & East, N.E. 1974. Effects of level of nutrition, preg-
nancy and age on the composition of the wool-free ingesta-free body and carcass of
sheep. Journal of Animal Science. 39: 687–693.
<https://doi.org/10.2527/jas1974.394687x>
- Richards, F.J. 1959. A flexible growth function for empirical use. Journal of Experimental
Botany 10: 290–301. <https://doi.org/10.1093/jxb/10.2.290>
- Saastamoinen, M., Särkijärvi, S., Högel, H., Vattulainen, J. & Nousiainen, J. 2024. Excretion cal-
culation of horses in Finland. Natural Resources and Bioeconomy Studies 67/2024.
Natural Resources Institute Finland. Helsinki. 30 p.
- Sahlu, T., Goetsch, A.L., Luo, J., Nsahlai, I.V., Moore, J.E., Galyean, M.L., Owens, F.N., Ferrell, C.L.
& Johnson, Z.B. 2004. Nutrient requirements of goats : developed equations, other
considerations and future research to improve them. Small Ruminant Research 53:
191–219. <https://doi.org/10.1016/j.smallrumres.2004.04.001>.

- SAS Institute Inc. 2013. SAS® 9.4 Language Reference: Concepts, Sixth Edition. Cary, NC, USA.
- Souza A.P., St-Pierre N.R., Fernandes M.H.R.M., Almeida A.K., Vargas J.A.C., Resende K.T. & Teixeira I.A.M.A. 2017. Energy requirements for growth of male and female Saanen goat kids. *Journal of Dairy Science* 100: 4574–4586. <https://doi.org/10.3168/jds.2016-11983>
- Theron, P.G., Brand, T.S., Cloete, S.W.P. & van Zyl, J.H.C. 2024. Wool production and quality traits of pure- and crossbred Merino-type sheep. *Tropical Animal Health and Production* 56: 47. <https://10.1007/s11250-023-03870-3>.
- Virtanen, T., Sahlström, L. & Lyytikäinen, T. 2013. Sheep and goat production in Finland from an epidemiological standpoint. *Eviran tutkimuksia 1/2013*, Helsinki, Finland. ISBN: 978-952-225-125-1.
- Wallace, J.D & Denham, A.H. 1970. Digestion of range forage by sheep collected by esophageal fistulated cattle. *Journal of Animal Science*. 30: 605–608.
- Wallace, J.D., Hyder, D.N. & Knox, K.L. 1972. Water metabolism in sheep fed forage rations differing in digestibility. *American Journal of Veterinary Research*. 33: 921–927. <https://doi.org/10.2460/ajvr.1972.33.05.921>
- Wan Zahari, M., Thompson, J.K., Scott, D., Topps, J. H., Buchan, W. & Pennie, K. 1989. Effect of growth rate on mineral retention and body composition of growing lambs. *Animal Production*. 49: 443–450. <https://10.1017/S0003356100032645>

6. Appendices

Appendix 1. Energy requirements for different sheep and goat categories shown as metabolizable energy, MJ/day and MJ/year.

Metabolizable energy requirements	MJ/day	MJ/year
Lambs 0-2 months	6.18	2256
Lambs 2-5 months	11.3	4125
Lambs 5-9 months	12.2	4453
Lambs 9-12 months	14.1	5147
Hogget, idle	10.0	3650
Hogget, gestation	13.4	4891
Hogget, gestation 1-2 weeks	17.2	6278
Hogget, gestation 3-6 weeks	14.2	5183
Ewe, lactation	24.4	8906
Ewe, gestation	13.1	4782
Ewe, gestation 1-2 weeks	18.5	6753
Ewe, gestation 3-6 weeks	14.9	5439
Barren ewe	9.65	3522
Ram 1-2 years, idle	11.7	4271
Ram, 1-2 years, breeding	18.0	6570
Ram, >2 years, idle	11.4	4161
Ram, >2 years, breeding	17.7	6461
Doe Kid 0-2 months	2.94	1073
Buck Kid 0-2 months	3.57	1303
Doe Kid 2-5 months	6.31	2303
Buck Kid 2-5 months	7.87	2873
Doe Kid 5-9 months	8.17	2982
Buck Kid 5-9 months	10.5	3833
Doe Kid 9-12 months	9.26	3380
Buck Kid 9-12 months	12.2	4453
Doe	21.2	7738
Buck	14.2	5183

Appendix 2. Summary of intake and excretion of nutrients of lambs of 0–12 months and the amount of faeces and urine expressed as kg per sheep per day and per year in 2025.

Lambs	Per day				Per year			
	0–2	2–5	5–9	9–12	0–2	2–5	5–9	9–12
Age, months	0–2	2–5	5–9	9–12	0–2	2–5	5–9	9–12
Intake of nutrients								
Dry matter, kg	0.34	1.11	1.16	1.28	125	404	425	469
Organic matter, kg	0.32	1.01	1.06	1.18	115	369	388	429
Nitrogen, g	0.01	0.03	0.030	0.031	5.15	10.4	10.8	11.5
Phosphorus, g	0.002	0.004	0.004	0.004	0.78	1.45	1.50	1.56
Potassium, g	0.02	0.29	0.31	0.33	8.70	105	111	119
Retained								
Nitrogen, g	0.006	0.006	0.004	0.004	2.19	2.18	1.46	1.31
Phosphorus, g	0.001	0.001	0.001	0.0005	0.44	0.36	0.20	0.18
Potassium, g	0.0004	0.0005	0.0001	0.0004	0.13	0.17	0.05	0.13
Faecal output, kg								
Fresh matter, kg	0.07	0.75	0.78	0.91	27.2	272	284	331
Dry matter, kg	0.01	0.10	0.10	0.12	3.54	35.4	36.9	43.0
Organic matter, kg	0.005	0.06	0.06	0.07	1.81	20.3	21.0	25.4
Nitrogen, kg	0.001	0.01	0.01	0.01	0.27	2.83	2.96	3.28
Phosphorus, kg	0.0009	0.0029	0.0034	0.0036	0.33	1.06	1.25	1.31
Potassium, kg	0.005	0.06	0.07	0.07	1.96	32.7	25.1	26.8
Urinary output								
Urine, kg	0.99	1.38	1.48	1.58	361	504	538	576
Dry matter, kg	0.05	0.12	0.14	0.15	17.3	43.0	49.7	53.0
Organic matter, kg	0.03	0.07	0.08	0.09	12.6	25.3	29.9	32.3
Nitrogen, kg	0.007	0.015	0.017	0.019	2.68	5.39	6.37	6.89
Phosphorus, kg	0.00004	0.0001	0.0001	0.0002	0.01	0.03	0.05	0.07
Potassium, kg	0.002	0.22	0.24	0.25	6.59	81.5	86.3	91.9
Total excretion								
Nitrogen, kg	0.0009	0.025	0.027	0.029	2.92	9.13	9.86	10.6
Phosphorus, kg	0.001	0.003	0.004	0.004	0.34	1.09	1.30	1.38
Potassium, kg	0.007	0.28	0.31	0.32	2.56	102	113	117
Faeces + urine, kg	1.06	2.13	2.26	2.49	387	777	825	909

Appendix 3. Summary of intake and excretion of nutrients for ewes and the amount of faeces and urine, expressed as kg per sheep per day and per year in 2025.

Ewes	Per day			Per year		
	Idle	Gestation	Lactation	Idle	Gestation	Lactation
Production stage						
Intake of nutrients						
Dry matter, kg	0.96	1.29	2.17	352	472	793
Organic matter, kg	0.88	1.18	1.98	323	432	722
Nitrogen, kg	0.02	0.03	0.05	7.89	10.8	20.0
Phosphorus, kg	0.003	0.004	0.01	0.95	1.34	3.14
Potassium, kg	0.26	0.34	0.54	96.12	125	196
Retained						
Nitrogen, kg	0.0015	0.0015	0.016	0.55	0.55	5.94
Phosphorus, kg	0.000012	0.00001	0.002	0.004	0.004	0.83
Potassium, kg	0.000003	0.000003	0.002	0.001	0.001	0.87
Faecal output, kg						
Fresh matter, kg	0.79	1.04	1.43	288	378	523
Dry matter, kg	0.10	0.13	0.19	37.4	49.2	68.0
Organic matter, kg	0.06	0.08	0.11	23.2	30.0	38.5
Nitrogen, kg	0.01	0.01	0.02	2.97	4.04	5.53
Phosphorus, kg	0.002	0.003	0.006	0.87	1.26	2.24
Potassium, kg	0.06	0.08	0.12	21.6	28.1	44.1
Urinary output						
Urine, kg	1.09	1.49	3.71	399	544	1353
Dry matter, kg	0.10	0.14	0.20	35.6	50.2	71.5
Organic matter, kg	0.06	0.08	0.11	20.5	29.1	40.2
Nitrogen, kg	0.01	0.02	0.02	4.37	6.21	8.57
Phosphorus, kg	0.0002	0.0002	0.0002	0.08	0.08	0.08
Potassium, kg	0.20	0.27	0.41	74.5	96.9	151
Total excretion						
Nitrogen, kg	0.02	0.03	0.04	7.34	10.3	14.1
Phosphorus, kg	0.003	0.004	0.01	0.95	1.34	2.32
Potassium, kg	0.26	0.34	0.53	96.1	125	195
Faeces + urine, kg	1.88	2.53	5.14	687	922	1876

Appendix 4. Summary of intake and excretion of nutrients for rams and the amount of faeces and urine expressed as kg per sheep per day and per year in 2025.

Rams	Per day				Per year			
	1-2y, idle	1-2 y, breeding	>2y, idle	>2y, breeding	1-2y, idle	1-2 y, breeding	>2y, idle	>2y, breeding
Age and production phase								
Intake of nutrients								
Dry matter, kg	1.23	1.74	1.20	1.63	449	635	438	595
Organic matter, kg	1.13	1.60	1.10	1.49	413	582	402	545
Nitrogen, kg	0.03	0.04	0.02	0.04	9.18	15.8	8.9	14.8
Phosphorus, kg	0.003	0.01	0.003	0.01	1.11	1.98	1.09	1.85
Potassium, kg	0.32	0.47	0.31	0.44	116	172	113	161
Retained								
Nitrogen, kg	0.003	0.003	0.002	0.002	0.98	0.98	0.72	0.72
Phosphorus, kg	0.0002	0.0002	0.00003	0.00003	0.07	0.07	0.01	0.01
Potassium, kg	0.0001	0.0001	0.00001	0.00001	0.03	0.03	0.01	0.01
Faecal output, kg								
Fresh matter, kg	1.08	1.24	1.06	1.17	395	454	385	425
Dry matter, kg	0.14	0.16	0.14	0.15	51.4	59.0	50.1	55.3
Organic matter, kg	0.09	0.10	0.09	0.09	32.8	35.0	32.0	32.8
Nitrogen, kg	0.01	0.01	0.01	0.01	4.16	4.50	4.05	4.22
Phosphorus, kg	0.003	0.005	0.003	0.005	0.95	1.82	0.98	1.75
Potassium, kg	0.07	0.11	0.07	0.10	26.1	38.7	25.4	36.3
Urinary output								
Urine, kg	1.31	2.14	1.28	2.01	478	783	467	735
Dry matter, kg	0.10	0.21	0.10	0.20	36.3	77.0	37.0	74.3
Organic matter, kg	0.05	0.13	0.05	0.13	19.0	48.6	19.6	46.4
Nitrogen, kg	0.01	0.03	0.01	0.03	4.04	10.4	4.18	9.90
Phosphorus, kg	0.0002	0.0002	0.0003	0.0003	0.09	0.09	0.10	0.10
Potassium, kg	0.25	0.37	0.24	0.34	89.7	133	87.5	125
Total excretion								
Nitrogen, kg	0.02	0.04	0.02	0.04	8.20	14.9	8.23	14.1
Phosphorus, kg	0.003	0.005	0.003	0.005	1.04	1.91	1.08	1.84
Potassium, kg	0.32	0.47	0.31	0.44	116	172	113	161
Faeces + urine, kg	2.39	3.39	2.34	3.18	873	1237	852	1161

Appendix 5. Summary of intake and excretion of nutrients for doe kids, and the amount of faeces and urine, expressed as kg per kid per day and per year in 2025.

Doe kids	Per day				Per year			
Age, months	0–2	2–5	5–9	9–12	0–2	2–5	5–9	9–12
Intake of nutrients								
Dry matter, kg	0.17	0.55	0.78	0.96	63.0	201	286	349
Organic matter, kg	0.16	0.50	0.72	0.89	59.5	183	264	325
Nitrogen, kg	0.01	0.01	0.02	0.02	2.08	5.33	6.29	6.22
Phosphorus, kg	0.001	0.002	0.002	0.002	0.39	0.77	0.83	0.89
Potassium, kg	0.002	0.014	0.019	0.021	0.90	5.16	6.87	7.61
Retained								
Nitrogen, kg	0.0024	0.0023	0.0024	0.0018	0.86	0.84	0.87	0.66
Phosphorus, kg	0.0005	0.0005	0.0004	0.0004	0.17	0.16	0.16	0.13
Potassium, kg	0.0002	0.0002	0.0002	0.0001	0.07	0.06	0.07	0.05
Faecal output, kg								
Fresh matter, kg	0.06	0.34	0.61	0.83	21.5	124	223	302
Dry matter, kg	0.02	0.13	0.24	0.33	6.75	46.3	88.4	121
Organic matter, kg	0.02	0.11	0.21	0.30	5.65	39.1	77.6	109
Nitrogen, kg	0.001	0.004	0.005	0.006	0.27	1.49	1.93	2.14
Phosphorus, kg	0.001	0.002	0.002	0.002	0.22	0.59	0.64	0.72
Potassium, kg	0.001	0.003	0.004	0.005	0.20	1.16	1.55	1.71
Urinary output								
Urine, kg	0.42	0.72	0.91	1.02	152	262	331	374
Dry matter, kg	0.02	0.06	0.07	0.07	5.74	23.7	26.5	26.1
Organic matter, kg	0.01	0.04	0.04	0.04	4.49	14.1	16.4	16.1
Nitrogen, kg	0.003	0.008	0.010	0.01	0.96	3.00	3.49	3.43
Phosphorus, kg	0.0000	0.0000	0.0001	0.0001	0.01	0.01	0.03	0.04
Potassium, kg	0.002	0.011	0.014	0.02	0.63	3.93	5.26	5.85
Total excretion								
Nitrogen, kg	0.003	0.01	0.01	0.02	1.22	4.49	5.42	5.56
Phosphorus, kg	0.001	0.002	0.002	0.002	0.22	0.60	0.67	0.76
Potassium, kg	0.002	0.01	0.02	0.02	0.83	5.09	6.80	7.56
Faeces + urine, kg	0.48	1.06	1.52	1.85	174	385	554	676

Appendix 6. Summary of intake and excretion of nutrients for buck kids, and the amount of faeces and urine, expressed as kg per kid per day and per year in 2025.

Buck Kids	Per day				Per year			
	0–2	2–5	5–9	9–12	0–2	2–5	5–9	9–12
Age, months								
Intake of nutrients								
Dry matter, kg	0.21	0.69	1.01	1.26	76.4	250	369	459
Organic matter, kg	0.20	0.62	0.93	1.17	72.2	228	340	428
Nitrogen, kg	0.007	0.018	0.022	0.022	2.53	6.64	8.10	8.18
Phosphorus, kg	0.001	0.003	0.003	0.003	0.48	0.96	1.07	1.17
Potassium, kg	0.003	0.018	0.024	0.027	1.09	6.42	8.84	10.0
Retained								
Nitrogen, kg	0.003	0.003	0.003	0.002	0.97	1.02	1.05	0.82
Phosphorus, kg	0.0006	0.0006	0.0006	0.0005	0.20	0.21	0.21	0.18
Potassium, kg	0.0002	0.0002	0.0002	0.0002	0.07	0.08	0.08	0.06
Faecal output, kg								
Fresh matter, kg	0.07	0.42	0.79	1.09	26.1	154	287	397
Dry matter, kg	0.02	0.16	0.31	0.44	8.18	57.7	114	160
Organic matter, kg	0.02	0.13	0.27	0.39	6.85	48.7	100	143
Nitrogen, kg	0.001	0.005	0.007	0.008	0.32	1.86	2.48	2.81
Phosphorus, kg	0.001	0.002	0.002	0.003	0.27	0.73	0.82	0.95
Potassium, kg	0.001	0.004	0.005	0.006	0.24	1.45	1.99	2.25
Urinary output								
Urine, kg	0.51	0.89	1.17	1.35	185	326	426	492
Dry matter, kg	0.02	0.08	0.09	0.09	7.32	29.6	34.5	34.5
Organic matter, kg	0.02	0.05	0.06	0.06	5.77	17.6	21.4	21.3
Nitrogen, kg	0.003	0.010	0.012	0.012	1.23	3.76	4.56	4.55
Phosphorus, kg	0.00002	0.00005	0.0001	0.0001	0.01	0.02	0.03	0.04
Potassium, kg	0.002	0.013	0.019	0.021	0.77	4.90	6.77	7.70
Total excretion								
Nitrogen, kg	0.004	0.02	0.02	0.02	1.55	5.62	7.04	7.36
Phosphorus, kg	0.001	0.002	0.002	0.003	0.27	0.74	0.86	1.00
Potassium, kg	0.003	0.017	0.024	0.027	1.01	6.35	8.76	9.95
Faeces + urine, kg	0.58	1.32	1.95	2.44	211	480	713	889

Appendix 7. Summary of intake and excretion of nutrients for adult does and bucks, and the amount of faeces and urine, expressed as kg per goat per day and per year in 2025.

Does and bucks	Per day		Per year	
	Does	Bucks	Does	Bucks
Intake of nutrients				
Dry matter, kg	1.81	1.43	661	521
Organic matter, kg	1.66	1.33	607	484
Nitrogen, kg	0.05	0.03	16.5	10.0
Phosphorus, kg	0.01	0.004	2.69	1.57
Potassium, kg	0.04	0.03	14.2	11.2
Retained				
Nitrogen, kg	0.01	0.0005	3.60	0.17
Phosphorus, kg	0.002	0.0001	0.72	0.04
Potassium kg	0.004	0.00004	1.51	0.01
Faecal output, kg				
Fresh matter, kg	1.09	1.17	398	428
Dry matter, kg	0.41	0.47	148	171
Organic matter, kg	0.35	0.42	126	152
Nitrogen, kg	0.01	0.01	4.57	3.27
Phosphorus, kg	0.01	0.004	1.91	1.47
Potassium, kg	0.01	0.01	3.19	2.52
Urinary output				
Urine, kg	3.28	1.60	1196	585
Dry matter, kg	0.18	0.13	65.1	48.8
Organic matter, kg	0.11	0.08	38.9	31.0
Nitrogen, kg	0.02	0.02	8.28	6.60
Phosphorus, kg	0.0002	0.0002	0.06	0.07
Potassium, kg	0.03	0.02	9.47	8.68
Total excretion				
Nitrogen, kg	0.04	0.03	12.9	9.87
Phosphorus, kg	0.01	0.004	1.97	1.53
Potassium, kg	0.03	0.03	12.7	11.2
Faeces + urine, kg	4.37	2.78	1594	1014



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