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Amount and composition of faeces and urine

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Abstract

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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 in 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 and their products, i.e. as

$$\text{"nutrient input} - \text{nutrient uptake} = \text{nutrient excretion"}$$

The components included in the calculations are N, P, K, dry matter and organic matter. The excretion calculations of horses are conducted separately for different animal categories based on the horse's size and activity.

The critical factor of nutrient excretion calculations is to accurately estimate the amounts and nutrient concentrations of feeds consumed by the animals. This was obtained by calculating the energy requirement of the animals based on their maintenance requirements and level of activity. The diet composition was based on field data and expert assessments. The highest uncertainty is in estimating the intake of nutrients. The detailed steps of the calculations are described in the report.

Based on the results with year 2023 as an example, the annual N, P and K excretion of one adult horse working on moderate intensity activity level were 46.3, 8.0 and 47.7 kg, respectively. For ponies and small horses working on the corresponding activity level, the annual N, P and K excretions were 30.2; 5.1 and 30.4 kg, and for small ponies 20.2; 3.3 and 19.5 kg, respectively.

Keywords: faeces, input, horse, manure, nitrogen, output, phosphorus, potassium, pony, retention, urine

Tiivistelmä

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Luonnonvarakeskus (Luke)

Virallinen erityslaskenta tuottaa vuosittain eri kotieläinten sonnassa ja virtsassa eritetyn kuiva-aineen, orgaanisen aineen ja ravintoaineiden määrän. Luonnonvarakeskus (Luke) on vastuussa Suomen kansallisesta erityslaskennasta. 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 (ravinnetasot, kiertotalous). Eritettyjen ravinteiden määrä lasketaan rehuista saatujen ravintoaineiden ja eläimeen ja niistä saataviin tuotteisiin pidättyneiden ravintoaineiden erotuksena, eli

”ravintoaineiden saanti – ravintoaineiden pidättyminen = ravinteiden erittyminen”.

Laskennassa mukana olevat komponentit ovat N, P, K, kuiva-aine ja orgaaninen aine. Hevosten erityslaskenta suoritetaan erikseen eri eläinryhmille hevosten koon ja aktiivisuuden mukaan.

Eläimen syömän rehun koostumuksen arviointi on yksi erityslaskennan kriittisistä tekijöistä. Tässä laskennassa rehun koostumus arvioitiin laskemalla eläinten energiantarve ylläpidolle ja eri aktiivisuustasoille. Dieetin koostumus perustui kentältä kerättyyn tietoon ja asiantuntija-arvioihin. Laskennan suurin epävarmuustekijä on ravintoaineiden saannin arvioinnissa. Laskennan yksityiskohdat on kuvattu tässä raportissa.

Käyttäen vuotta 2023 esimerkkinä, yhden aikuisen, keskiverto aktiivisuudella työskentelevän hevosen vuosittainen N, P ja K erityys oli 46,3; 8,0 ja 47,7 kg. Ponien ja pienten hevosten vastaava vuosittainen erityys N, P ja K osalta oli 30,2; 5,1 ja 30,4 kg, ja pienille poneille 20,2; 3,3 ja 19,5 kg.

Avainsanat: erityys, fosfori, hevonen, kalium, lanta, pidättyminen, poni, sona, typpi, virtsa

Abbreviations

Abbreviation	Definition
CP	Crude protein
CPD	Crude protein digestibility, g/g
CP _{diet}	Concentration of crude protein of diet, g/kg DM
DM	Dry matter content, g/kg
DMD	Digestibility of dry matter, g/g
DMI	Intake of dry matter, kg/day
HR	Heart rate
K	Potassium
K _{diet}	Concentration of potassium of diet, g/kg DM
LW	Live weight, kg
ME	Metabolizable energy, expressed in MJ/kg
ME _{diet}	Concentration of metabolizable energy of diet, MJ/kg DM
ME _{req}	Total ME requirement, MJ/day
N	Nitrogen
OM	Organic matter content, g/kg DM
OMD	Digestibility of organic matter, g/g
OM _{diet}	Concentration of organic matter of diet, g/kg DM
OMI	Intake of organic matter, kg/day
P	Phosphorus
P _{diet}	Concentration of phosphorus of diet, g/kg DM

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1. Introduction

Natural Resources Institute Finland (Luke) is responsible for the national excretion calculations in Finland. Data on excretion of animals is needed for several purposes ranging from estimating emissions during manure management and use into air (greenhouse gases, ammonia) and waters [phosphorus (P) and nitrogen (N)], to estimating the quantity and quality of manure produced in Finland and in 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.

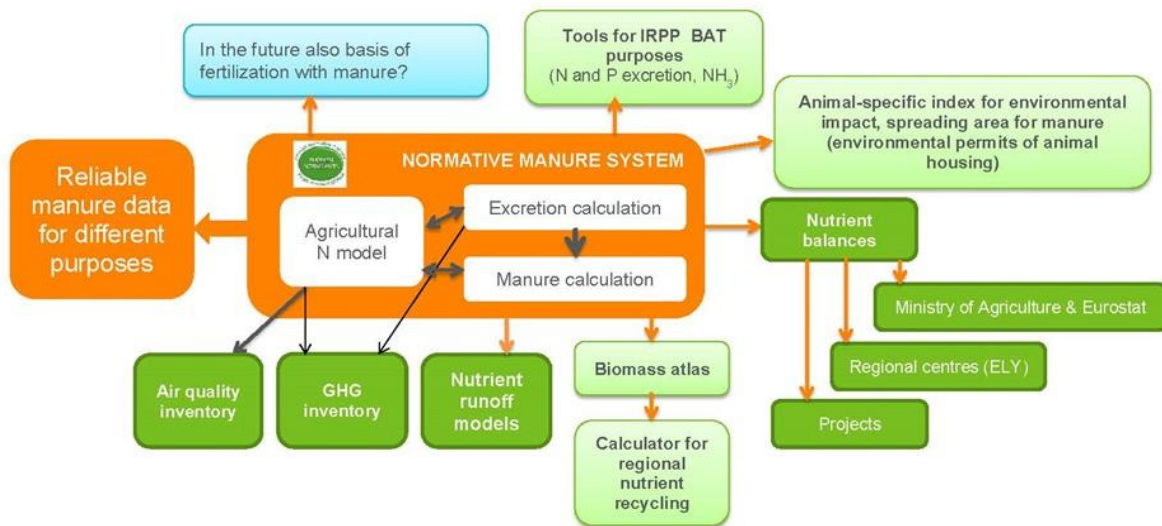


Figure 1. The nutrient excretion calculations form the basis of several other calculations (IRPP BAT = Intensive rearing of pigs and poultry Best available practises).

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 N, P, potassium (K), dry matter, and organic matter. The principles of the nutrient calculations are the same as previously published for cattle (Nousiainen et al. 2023).

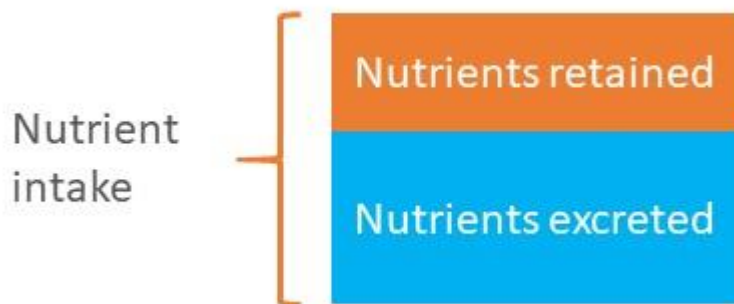


Figure 2. The principle of nutrient calculations: excretion is intake minus retention.

The excretion calculations of horses and ponies are conducted separately for different horse categories. Statistics on horses in Finland are done by breed. There are more than 200 horse and pony breeds in the stud book (horse register) kept by the breeding organization Suomen Hippos ry (central organisation for trotting and horse breeding of Finland). The horses are of different types, and the purpose of them varies from hobby horses to active riding school and athletic horses (riding horses, trotters). Horses are also used for example in equine tourism and horse-assisted therapy, and to a lesser extent in forest and farm work. Some thousand individuals are used in breeding, i.e. they are producing foals; four to five thousand foals are born each year dividing into tens of breeds of various sizes and purposes. As a conclusion, it is impossible to say how intense work each horse in the statistics perform, and how many are pregnant, growing, race-trained, or completely idle. Horses may also move quickly from one class to another, for example, when a racehorse is suddenly injured, or a foal dies under the dam. Horses do not have a specific "production age," but may move from one use to another or out of use at any time if they are no longer capable of operating in the task or operating at all.

Because of this, it was summarized that for excretion calculation, it is relevant to classify the horses by their size and by their level of activity (Table 1). Size categorization was done utilizing the average height at withers as a classification criterion (Saastamoinen et al. 2017) as follows: 1. Adult horse (550 kg), 2. Pony and small horse > 120 cm (350 kg), and 3. Small pony < 120 cm (225 kg). For activity level categorization, the work intensity classes were used according to the Finnish feed tables (Kuoppala et al. 2024) separating maintenance, light work, moderate work, and heavy work (Table 1).

The above categories include both horse and pony breeds and individuals of different ages. Category 2 (Pony and small horse > 120 cm) also includes 1-year old horses (various warm-blooded horses and Finnhorses). Two-year old and older horses are included in category 1. Correspondingly, the young, still growing ponies and small horses belong to the groups corresponding their adult sizes (e.g. category 2 or 3). All sucking foals were handled within the same animal unit with their dams.

The critical factor of nutrient excretion calculations is to accurately estimate the amounts and nutrient concentrations of feeds consumed by the animals. In case of horses, as they are not a farmed animal in that sense that their feeding would be strictly determined by production phases, a lot of simplifying and many assumptions need to be made when estimating the nutrient intake of the animals in the different categories. The detailed steps in the calculations are described in the following chapters. Finally, an overview of the main results is presented in Chapter 6 and in the Appendices.

2. Energy requirements of horses

Feed intake and nutrient concentrations of the diets are key features in nutrient excretion calculations. Because of lacking measurements of actual feed intake of horses, it had to be estimated. Also, as stated earlier, the composition of the diets of horses differs at the individual level quite a lot. In this report, the estimation of feed intake was based on total energy requirements (ME_{req}) and the ME content (ME_{diet}) of the average diet.

Values from Finnish nutrient requirements for horses (Kuoppala et al. 2024) were used to determine the need for metabolizable energy (ME) (Table 1). The live weight (LW) class (adult weight) of 550 kg was used for the horse category 1. The weights of ponies and small horses (category 2) and small ponies (category 3) are those presented for various pony breeds in the book *Horse Feeding and Care* (Saastamoinen et al. 2017): for ponies and small horses, weight 350 kg, and for small ponies, weight 225 kg was used. For ponies and small horses, the LW 350 kg was used instead of 300 kg as the category includes also the 1-year-old horses. The energy requirements per LW kg were calculated and applied to all horse categories accordingly.

The work intensity level was categorized according to Finnish nutrient requirements (Kuoppala et al. 2024):

- **Maintenance (nonworking, nonbreeding):** includes horses and ponies which are not working or breeding, slowly growing young animals before training and those which are in very light recreational riding use.
- **Light work:** includes horses and ponies in recreational riding use; light training, walking or light trotting for 1 h, no sweating; average HR 80 beats/min for the whole training session.
- **Moderate work:** includes young trotters (horses and ponies) in training, breeding mares, and horses and ponies in active recreational riding or lessons use; brisk trotting, dressage or show jumping training, light sweating; average HR 90-100 beats/min for the whole training session.
- **Heavy work:** includes competing trotters (horses and ponies) and horses competing in national or international level in eventing, show jumping or carriage driving during the competition season; speed and strength training, work or exercise causing heavy sweating, daily exercise 6-10 hours/week; average HR 110-150 beats/min for the whole training session.

These work intensity classes were used to estimate the energy demands above maintenance requirements. For an adult horse in a LW category of 550 kg, the energy demand is estimated to increase 0–17% in light work, 17-42% in moderate work, and 42-67% in heavy work above maintenance. For the calculations, the energy requirement for different work intensity classes of different horse categories was calculated by calculating the energy requirement per LW kg using the average value calculated from the lower and upper limits given by the Finnish nutrient requirements [Eq. 1-4] (Table 2). The total energy requirement in different horse categories was calculated from these by multiplying the value (MJ/kg LW) by the total LW (225 kg, 350 kg, 550 g) (Table 1).

Table 1. The animal categories of horses and their energy requirements for nutrient excretion calculations in Finland.

Animal category	Size, kg	Work intensity level	ME _{req} , MJ/d
Adult horse	550 kg	Maintenance	70.0
		Light work	75.9
		Moderate work	90.8
		Heavy work	108.4
Pony and small horse ¹ , > 120 cm	350 kg	Maintenance	44.5
		Light work	48.3
		Moderate work	57.8
		Heavy work	69.0
Small pony, < 120 cm	225 kg	Maintenance	28.6
		Light work	31.1
		Moderate work	37.1
		Heavy work	44.3

ME_{req} = requirement of metabolizable energy; 1 Includes 1-year old horses

Table 2. Equations for calculating the energy requirements for different work intensity classes of different horse categories.

No	Equation
[1]	ME _{req} maintenance, MJ/kg LW = Mean((57.3/450);(70.2/550);(76/600))
[2]	ME _{req} light work, MJ/kg LW = Mean(Mean(57.3/450;66.7/450); Mean(70.2/550;81.9/550); Mean(76/600;88.9/600))
[3]	ME _{req} moderate work, MJ/kg LW = Mean(Mean(66.7/450;81.9/450); Mean(81.9/550;99.5/550); Mean(88.9/600;108.8/600))
[4]	ME _{req} heavy work, MJ/kg LW = Mean(Mean(81.9/450;95.9/450); Mean(99.5/550;117/550); Mean(108.8/600;127.5/600))

ME_{req} = requirement of metabolizable energy; LW = live weight, kg

3. Diet composition and nutrient intake of horses

There is quite a lot of variation in the feeding practices of horses: the number of different commercial compound feeds and supplements is large, and there are many types and qualities of roughages (Saastamoinen & Hellämäki 2012) that are fed with varied amounts. The diets are generally forage-dominated, the percentage of forages varying (on energy basis) from 40 to 100% (only-forage diets) in the daily feed portion. The largest concentrate portions (50-60%) are fed to horses in heavy work. The feeding is usually improperly planned, and feeding plans are missing from the majority of the horses (Uotila et al. 2012).

Therefore, the accuracy of the excretion calculation suffers from issues that cannot be affected or to be taken into account by the calculation method. The maintenance level intakes (Kuoppala et al. 2024) and excretion were calculated for each horse category assuming 100% roughage feeding (forage-only diet). Forage-only diets are reported to fulfil the energy and protein needs of horses working at different working intensities and in various disciplines (Ragnarsson 2009, Ringmark 2014, Connyson 2018). However, it is also appropriate to calculate the excretion applying a roughage-to-concentrate ratio of 80:20 on the light work intensity, 70:30 on the moderate work intensity and 60:40 on the heavy work intensity (Kuoppala et al. 2024), using some "consensus" grain-based concentrate/compound feed, or oats, which is the most popular grain fed to horses in Finland. In these calculations oats was used.

The average composition data of roughage were taken from the study of Saastamoinen and Hellämäki (2012) (Table 3) by calculating the weighted mean of hay and haylage samples. In addition to this, a few missing data were retrieved from feed tables (Kuoppala et al. 2024). The average composition of the oats was taken from the Finnish feed tables by calculating the mean from the values of three hectolitre weight classes of oats. The needs for calcium and phosphorus were met by roughage – thus, no additional minerals were included in the diets.

Table 3. Average composition of the feed materials.

	Roughage	Oats ²
Metabolizable energy (ME), MJ/kg DM	9.4 ¹	11.35
Dry matter (DM), g/kg	860 ²	860
In DM, g/kg		
Ash	80 ²	35
Crude protein (CP)	83 ¹	126
Organic matter (OM)	920 ²	965
Nitrogen (N) ³	13.3	20.2
Phosphorus (P)	2.2 ¹	3.5
Potassium (K)	18.1 ¹	5.0
Calcium (Ca)	3.1 ¹	0.5

1 Saastamoinen & Hellämäki, 2012; 2 Mean values calculated from different hectolitre weight oats, Finnish feed tables (Kuoppala et al. 2024); 3 Calculated from crude protein content (CP/6.25)

The average diets for maintenance and for different work intensity classes were calculated as ratio of roughage to oats: for maintenance the diet consisted of roughage only, and ratios of 0.8:0.2, 0.7:0.3 and 0.6:0.4 were used for light, moderate and for heavy work, respectively (Table 4).

Table 4. Average diet composition in different work intensity classes.

	Maintenance	Light work	Moderate work	Heavy work
Metabolizable energy (ME), MJ ME/kg DM	9.4	9.8	10.0	10.2
In DM, g/kg				
Ash	80.0	71.0	66.5	62.0
Crude protein (CP)	83	91.6	95.9	100.2
Organic matter (OM)	920	929	934	938
Phosphorus (P)	2.2	2.5	2.6	2.7
Potassium (K)	18.1	15.5	14.2	12.9

DM = dry matter

Dry matter intake (DMI, kg/d) was calculated as the ME requirement (ME_{req} , MJ/d) divided by ME concentration of the diet (ME_{diet} , MJ/kg DM) [Eq.5] (Table 5). Organic matter intake (OMI, kg/d) was calculated by multiplying the organic matter content of the diet (OM_{diet} , g/kg DM) with the DMI [Eq.6] (Table 5). The intake of ash (kg/d) was calculated as the difference of DMI and OMI [Eq.7] (Table 5). Intake of nutrients was calculated by multiplying the nutrient concentrations in feed DM by DMI [Eq.8-11] (Table 5).

Table 5. Equations for calculating the intake of DM, OM, ash, CP, N, P and K.

No	Equation
[5]	$DMI, \text{ kg/d} = ME_{req}, \text{ MJ/d} / ME_{diet}, \text{ MJ/kg DM}$
[6]	$OMI, \text{ kg/d} = DMI \times (OM_{diet}/1000)$
[7]	$\text{Intake of ash, kg/d} = DMI, \text{ kg/d} - OMI, \text{ kg/d}$
[8]	$\text{Intake of CP, g/d} = CP_{diet}, \text{ g/kg DM} \times DMI, \text{ kg/d}$
[9]	$\text{Intake of N, g/d} = (CP_{diet}, \text{ g/kg DM} / 6.25) \times DMI, \text{ kg/d}$
[10]	$\text{Intake of P, g/d} = P_{diet}, \text{ g/kg DM} \times DMI, \text{ kg/d}$
[11]	$\text{Intake of K, g/d} = K_{diet}, \text{ g/kg DM} \times DMI, \text{ kg/d}$

DMI = dry matter intake; ME_{req} = requirement of metabolizable energy; ME_{diet} = diet ME concentration; DM = dry matter; OMI = organic matter intake; OM_{diet} = diet OM concentration; CP = crude protein; CP_{diet} = diet CP concentration; N = nitrogen; P = phosphorus; P_{diet} = diet P concentration; K = potassium; K_{diet} = diet K concentration

4. Retention of nutrients

Retention of nutrients to the animals was not included in these calculations. Most of the animals in different categories are adult animals and only a small number of foals and young animals still growing are included in different categories. Also, the number of mares in foal was assumed to be insignificant in this context. However, retention of nutrients is a process continuously occurring.

The highest level of retention of nutrients is occurring during the first 12 months of age when a foal is growing fast; 58–67% of adult body weight and 87–90% of adult withers height are reached at this age (Fradinho et al. 2019). From 1-year old onwards the growth is slower, although still occurring. The rate of growth strongly depends on the breed of the horse and horses of different breeds reach their maturity at different ages (Łuszczynski et al. 2011). In young horses in addition to growth, the start of training increases the retention level.

In adult horses the rate of retention is dependent on diet, activity level, breed, age, and physiological state of the animal. The start of training or an increase in activity cause an increase in retention especially in the first months after the change in the activity and training status.

5. Excretion

The mass balance calculations for DM, OM, N, K and P are based on the data about animals, feed composition and digestibility. The source data for the national calculations was obtained from the registries of the Natural Resources Institute Finland (Finnish feed tables, Kuoppala et al. 2024) and Suomen Hippos ry (number of animals).

To be able to estimate the amount of faeces, the digestibility of DM needs to be calculated. Dry matter intake was calculated so that the ME requirement was filled with a diet consisting of roughage only (maintenance) or roughage and oats (other work intensity classes). Other nutrient intakes were then calculated accordingly: The digestibility of the organic matter (OMD) [Eq.12] (Table 6) was translated into the digestibility of the dry matter (DMD) based on the [Eq. 13] (Table 6) (Jensen et al. 2014, Palmgren Karlsson et al. 2000). The digestibility of crude protein (CPD) was determined by the [Eq. 14] (Table 6) (Ragnarsson & Lindberg 2008). With this data, it was possible to calculate the amount of indigested dry matter and organic matter and indigested crude protein [Eq.15-17] (Table 6). An estimate of 21% was used for the dry matter content of the faeces (Särkijärvi & Saastamoinen, 2019). The amount of faeces was calculated based on this [Eq.18] (Table 6). The values from the German feed table (DLG 1998) were used as digestibility values for the organic matter of the roughage. For the OMD of the OM in oats, the mean of Finnish feed table values (Kuoppala et al. 2024) for oats was used. For the work intensity classes with diets containing roughage and oats in different ratios, the OMD was calculated as the weighted mean of the digestibility values of roughage and oats. According to studies, the OMD improves in the mixed diets containing roughage and concentrates (cereal grains) in different ratios (e.g. Martin-Rosset & Dulphy 1987, Palmgren Karlsson et al. 2000). Thus, the use of the weighted mean in the calculations was reasonable despite slightly underestimating the digestibility value. The output of urine was calculated based on the amount of urine excreted in one hour per 100 LW kg (95.7 ml) (Saastamoinen et al. 2020 & 2021) and the relative density of urine (Movet, 2024: 1.0425 kg/l). [Eq.19–20] (Table 6).

Table 6. Equations for calculating the digestibility of OM, DM and CP, the amount of excreted OM, DM and CP, and the amount of faeces and urine.

No	Equation
[12]	Digestibility of OM (OMD), g/g = $\text{OMD (roughage)} \times \text{content in diet, \%} / 100 + \text{OMD (oats)} \times \text{content in diet, \%} / 100$
[13]	Digestibility of DM (DMD), g/g = $0.9548 \times \text{OMD (\%)} + 1.6082$ (Jensen et al. 2014 and Palmgren Karlsson et al. 2000)
[14]	$\text{CPD} = 1.0164 \times \text{CP} - 36.684$ (Ragnarsson & Lindberg 2008)
[15]	Indigestible OM excreted, kg/d = $\text{OMI} \times (1 - \text{OMD})$
[16]	Indigestible DM excreted, kg/d = $\text{DMI, kg/d} \times (1 - \text{DMD})$
[17]	Indigestible CP excreted, kg/d = $\text{CP intake} \times (1 - \text{CPD})$
[18]	Output of faeces, kg/d = $\text{Indigestible DM, kg/d} / \text{DM content of the faeces, g/kg} \times 1000$
[19]	Output of urine, l/d = $(\text{LW} \times 0.0957 \times 24) / 100$
[20]	Output of urine, kg/d = $(\text{LW} \times 0.0957 \times 24) / 100 \times 1.0425$ (Saastamoinen et al. 2020 & 2021, Movet 2024)

OM = organic matter; OMD = organic matter digestibility; DM = dry matter; DMD = dry matter digestibility; CPD = crude protein digestibility; CP = crude protein; OMI = organic matter intake; DMI = dry matter intake; LW = live weight

The fate of the nutrients is either to be used for the maintenance of the body, be retained in the body of the horse or her foal or be excreted in faeces or urine. The concentration of ash in faeces was calculated as the difference of the amount of digestible DM and digestible OM intake [Eq.21] (Table 7), and the concentration in urine as the difference of ash intake and ash in faeces [Eq.22] (Table 7). The equation for calculating the DM content in urine was based on the measurements published earlier by Almsgård & Persson (2011) [Eq.23] (Table 7). The OM excreted in urine was calculated as the difference of DM and ash excretion in urine [Eq.24] (Table 7). The amount of N in faeces was calculated from the amount of indigestible CP excreted [Eq.25] (Table 7) and the amount in urine was calculated using [Eq.26] (Table 7) (Ragnarsson 2009). The concentration of P in faeces was calculated based on apparent digestibility of phosphorus (8.9%) using [Eq.27] (Table 7). The P concentration in urine was calculated using [Eq.28] (Table 7). The concentration of potassium (K) in faeces was calculated using [Eq.29] (Table 7) based on apparent digestibility of K (75%). The K concentration in urine was calculated using [Eq.30] (Table 7).

Table 7. Equations for calculating the amount of nutrients excreted in faeces or in urine.

No	Equation
[21]	Ash in faeces, g/d = DMI, kg ka/d × DMD, g/g - OMI, kg ka/d × OMD, g/g
[22]	Ash in urine, g/d = Ash intake, g/d - ash in faeces, g/d
[23]	DM in urine, g/d = (0.3312 × digestibility of DM - 0.1145) × DMI (Nousiainen, based on Almsgård & Persson, 2011)
[24]	OM in urine, g/d = DM in urine - ash in urine, g/d
[25]	N in faeces, g/d = indigestible CP excreted / 6.25
[26]	N in urine, g/d = 0.5035 × intake of N, g/pv + 5.6546 (Ragnarsson 2009)
[27]	P in faeces, g/d = 0.911 × intake of P, g/d (Pagan 1998)
[28]	P in urine, g/d = 0.025 × intake of P, g/d (Schryver 1971)
[29]	K in faeces, g/d = 0.25 × intake of K, g/d (Pagan 1998, Pagan et al 1998, Crozier et al. 1997)
[30]	K in urine, g/d = 7.8 g/l × output of urine, l/d

DMI = dry matter intake; DMD = dry matter digestibility; OMI = organic matter intake; OMD = organic matter digestibility; DM = dry matter; OM = organic matter; N = nitrogen; CP = crude protein; P = phosphorus; K= potassium

6. Summary of calculated results for all horse categories

Detailed excretion calculation results for different horse categories using input data from year 2023 are presented in Appendices 1–3.

- Appendix 1: Adult horse
- Appendix 2: Pony and small horse
- Appendix 3: Small pony

Results are reported per year. Daily results can be calculated from annual ones by dividing them with a factor of 365. The calculations can be modified separately, and the effects of diet composition can be demonstrated. For official calculations, it is critical that correct national input data are used.

6.1. Total excretion of N and P in different animal categories

The number of horses in each category were taken from the studbook registers of various breeds kept by Suomen Hippos ry, both representing the current situation (year 2023) (Table 8) and the time series (1990–2023). The horses were then divided into different work intensity classes: The numbers of racing trotters (horses, ponies) and competing riding horses were taken from the annual statistics of Suomen Hippos and Suomen Ratsastajainliitto (The Finnish Equestrian Federation), respectively. The numbers of covered and foaling mares (active breeding mares) as well as the number of young horses were adapted from the statistics of Suomen Hippos. Then, horses and ponies of various breeds in the other classes (young horses in training, riding school horses, hobby/recreational horses, work horses and others) were estimated based on statistics of numbers of e.g. horse-related entrepreneurs, trainers, riders etc.

Since adult horses comprise the largest group of horses in Finland, they also account for the biggest amount of excretion annually (Figures 3–7).

Table 8. Number of animals in different horse categories and work intensity classes in Finland in 2023.

Animal category	Size, kg	Work intensity	Number of animals
Adult horse	550 kg	Total	56 510
		Maintenance	9 080
		Light work	13 740
		Moderate work	26 130
		Heavy work	7 560
Pony and small horse, > 120 cm	350 kg	Total	7 310
		Maintenance	570
		Light work	2 930
		Moderate work	3 690
		Heavy work	120
Small pony, < 120 cm	225 kg	Total	3 800
		Maintenance	2 700
		Light work	-
		Moderate work	700
		Heavy work	400

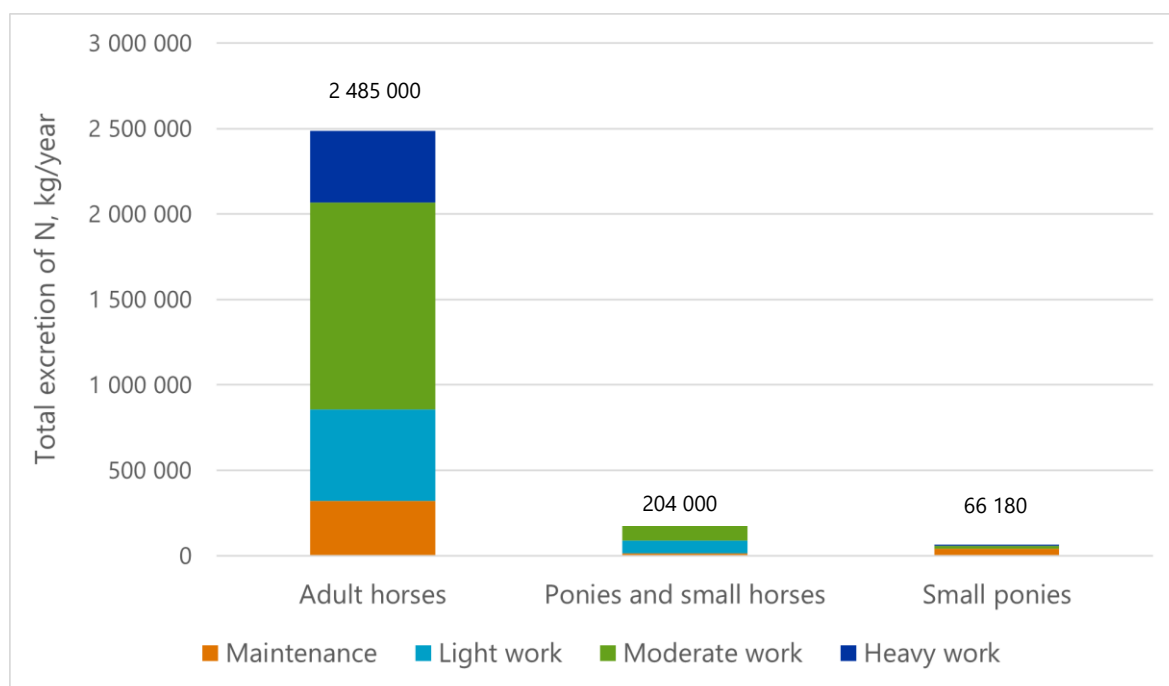


Figure 3. Total excretion of nitrogen (N) of different horse categories, shown as kilograms per year in 2023.

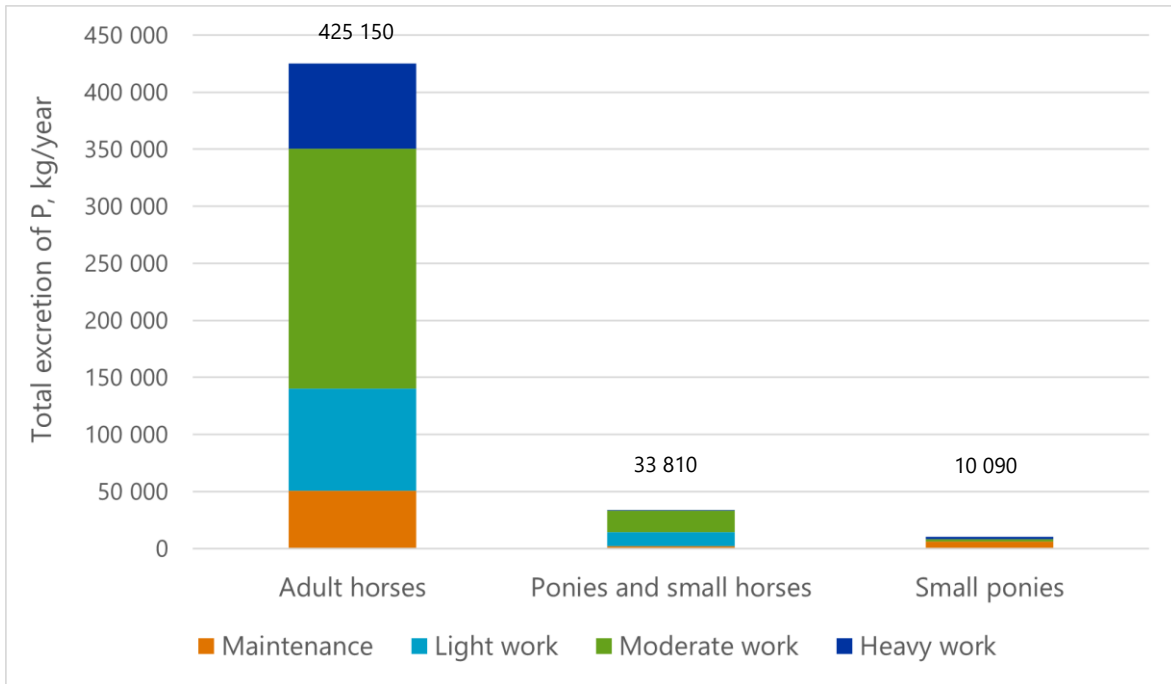


Figure 4. Total excretion of phosphorus (P) of different horse categories, shown as kilograms per year in 2023.

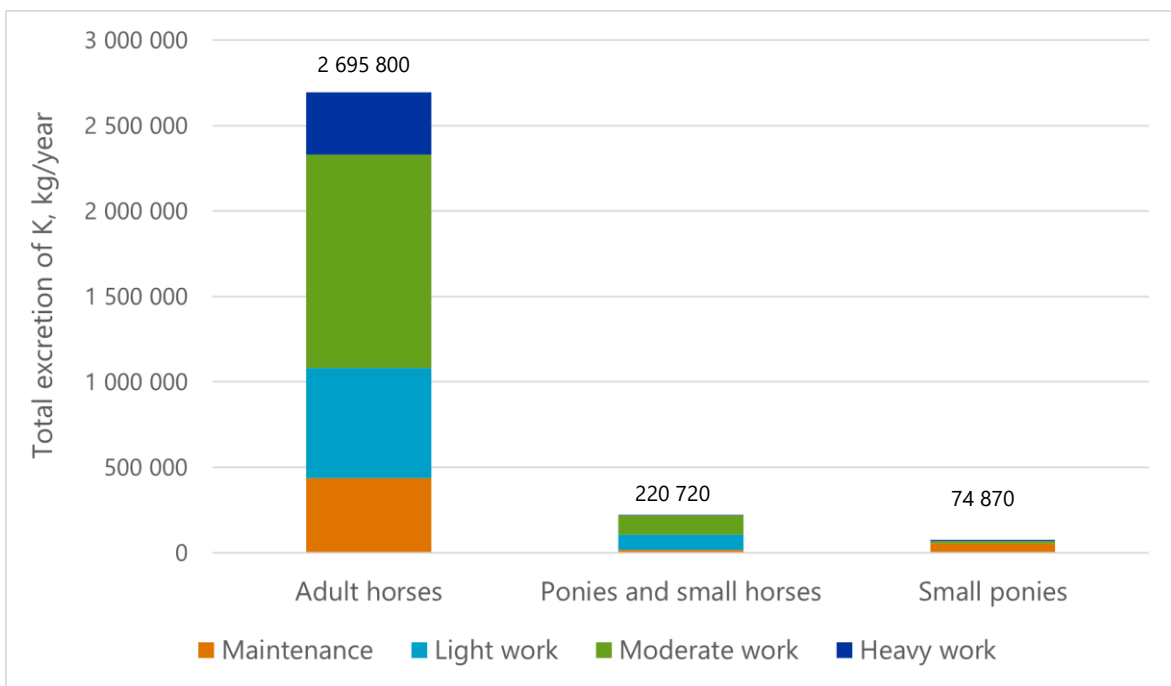


Figure 5. Total excretion of potassium (K) of different horse categories, shown as kilograms per year in 2023.

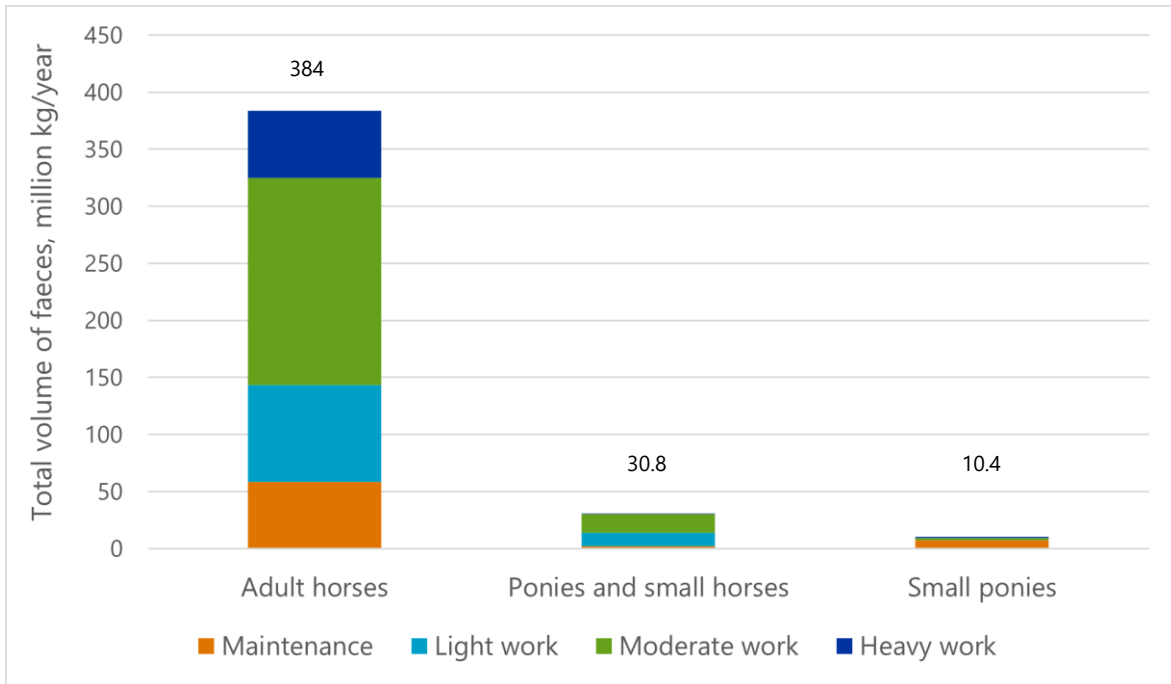


Figure 6. Total volume of faeces of different horse categories, shown as million kilograms per year in 2023.

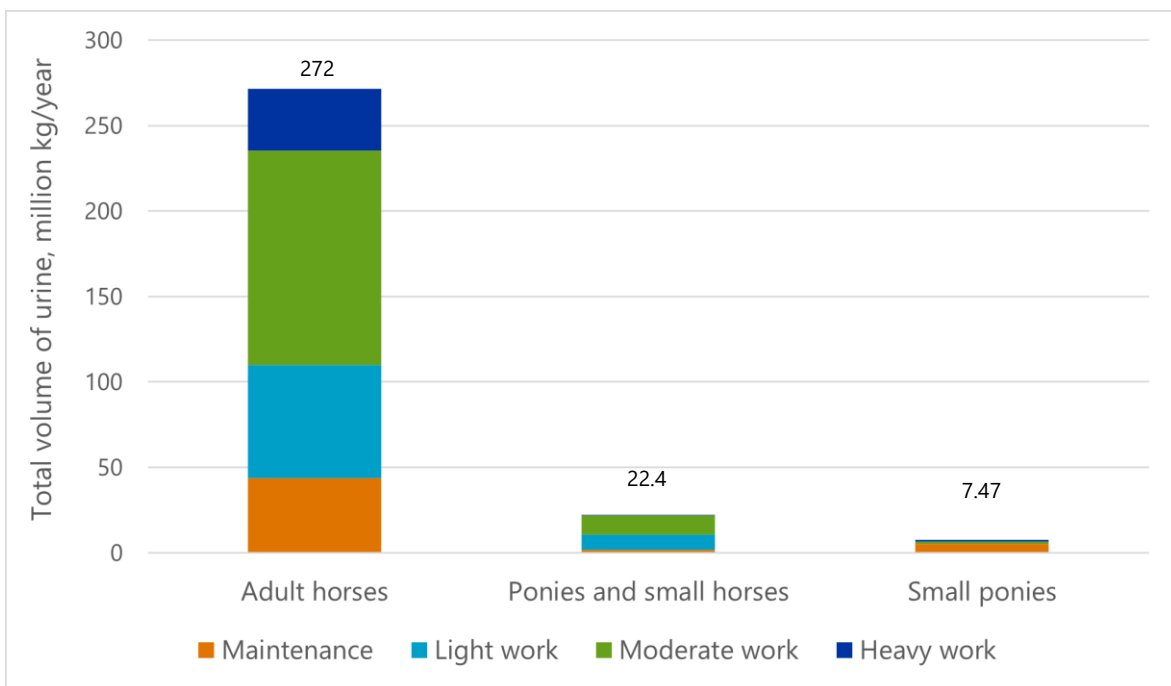


Figure 7. Total volume of urine of different horse categories, shown as million kilograms per year in 2023.

6.2. Sensitivity analysis of adult horses' excretion

Sensitivity analyses were conducted so that only one variable at a time was changed. Live weight (LW), diet crude protein (CP), phosphorus (P) or potassium (K) concentration, dry matter intake (DMI) or dry matter content of the faeces (Faeces DM%) were increased or decreased 10% from the average values used in the calculations. As adult horses in moderate work comprise the largest group of horses in Finland, the sensitivity analysis was conducted using the excretion values of this group.

The change in LW had an effect on excretion of all nutrients studied and also on volume of faeces and urine (Figures 8–11). For potassium and volume of faeces and urine the change in LW caused the biggest change of all the variables tested (Figures 10 and 11), and for nitrogen (N) excretion the change was as big as when DMI was changed (Figure 8). The smallest change in N excretion was observed when the diet CP was changed (Figure 8), in K excretion when the DMI or Diet K was changed (Figure 10), and in volume of faeces and urine when the DMI was changed (Figure 11). The change in variables LW, DMI and diet P concentration all had a same magnitude effect on P excretion (Figure 9).

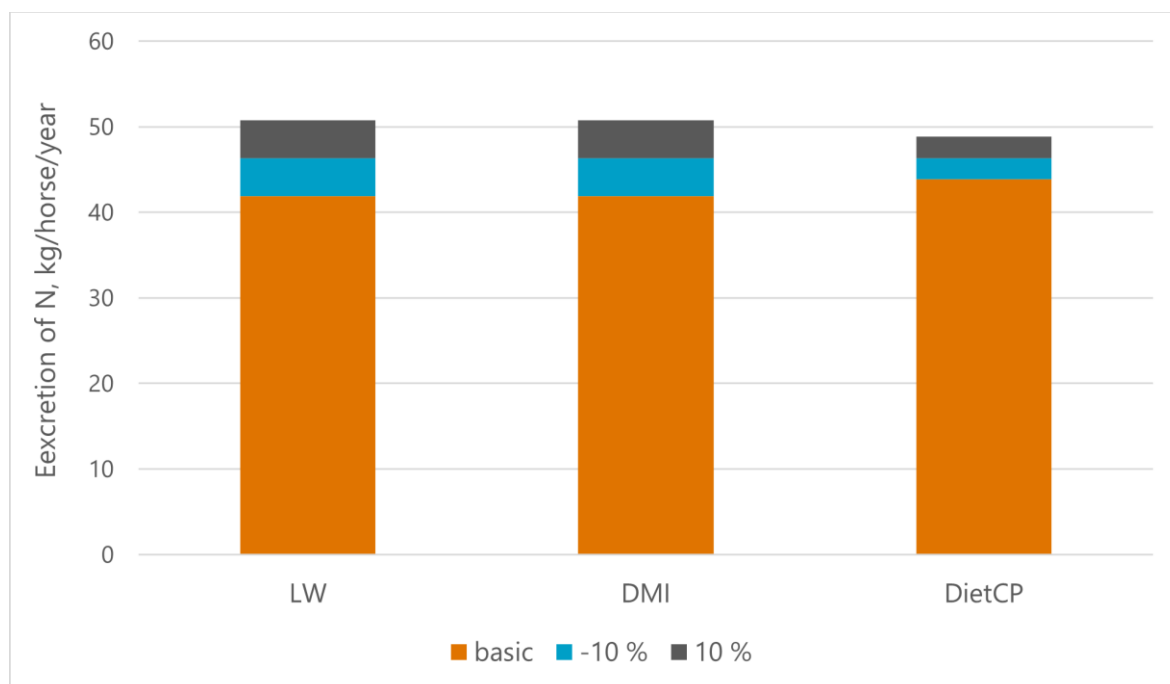


Figure 8. Total nitrogen (N) excretion of an adult horse in moderate work when live weight (LW), dry matter intake (DMI) or diet crude protein concentration (DietCP, g/kg DM) was changed in the calculation. Grey colour represents 10% increase and blue 10% decrease from the original level. The border between the blue and grey is the average excretion level for adult horse in moderate work in 2023.

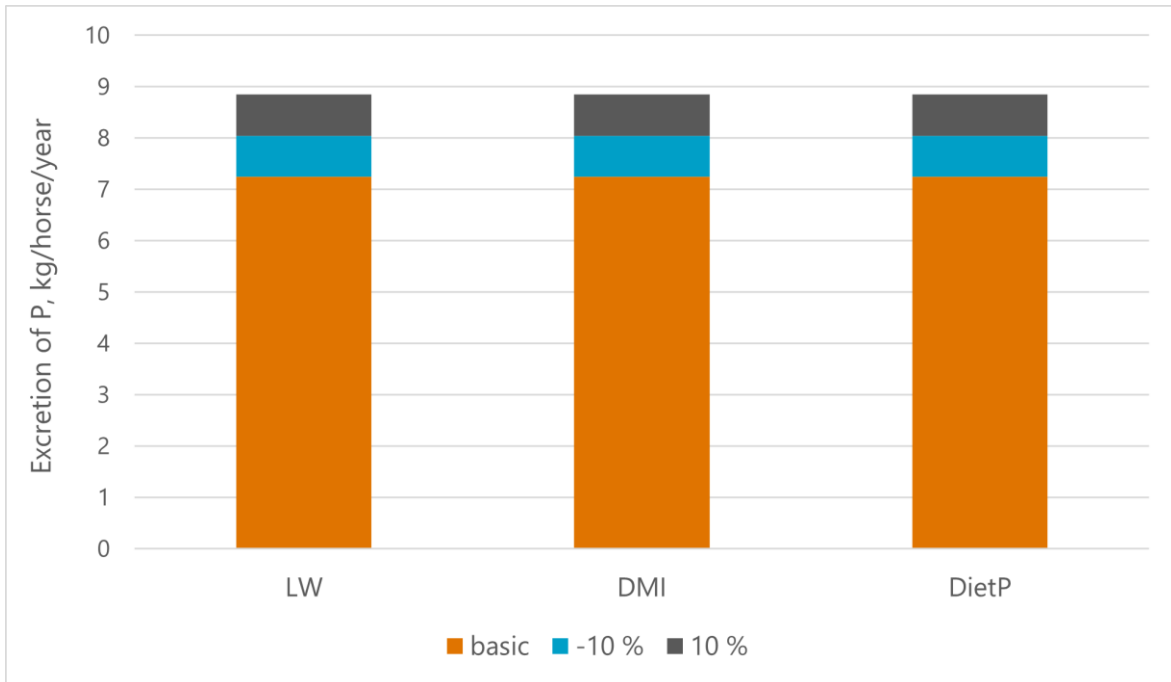


Figure 9. Total phosphorus (P) excretion of an adult horse in moderate work when live weight (LW), dry matter intake (DMI) or diet phosphorus concentration (DietP, g/kg DM) was changed in the calculation. Grey colour represents 10% increase and blue 10% decrease from the original level. The border between the blue and grey is the average excretion level for adult horse in moderate work in 2023.

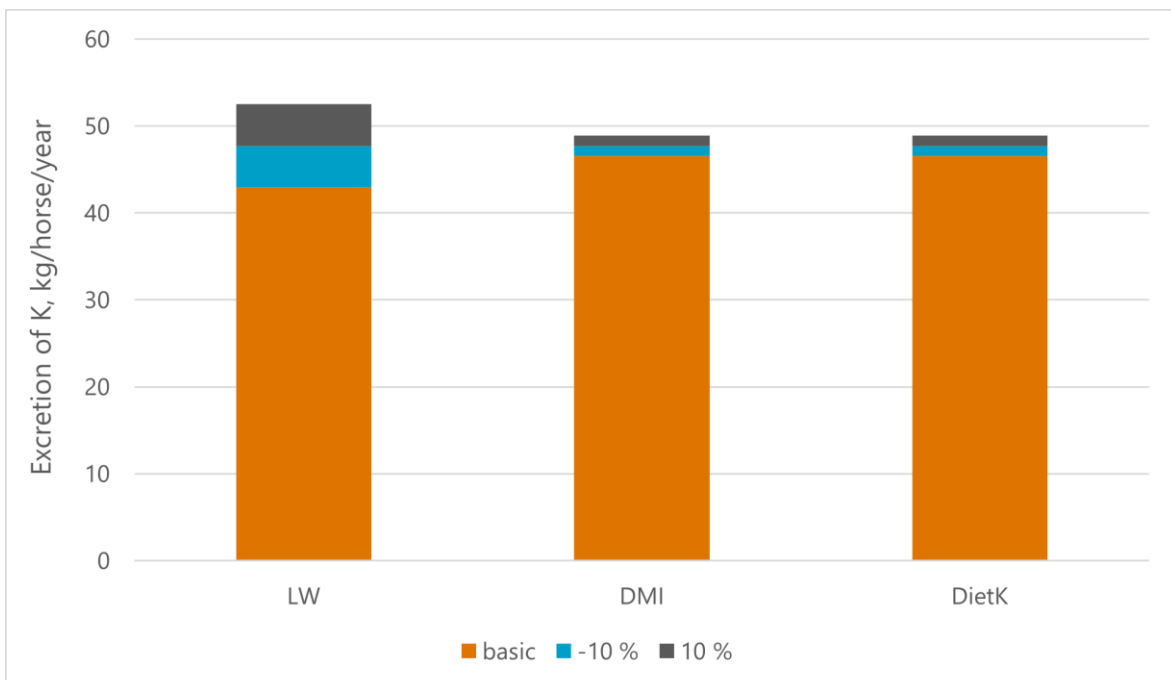


Figure 10. Total potassium (K) excretion of an adult horse in moderate work when live weight (LW), dry matter intake (DMI) or diet potassium concentration (DietK, g/kg DM) was changed in the calculation. Grey colour represents 10% increase and blue 10% decrease from the original level. The border between the blue and grey is the average excretion level for adult horse in moderate work in 2023.

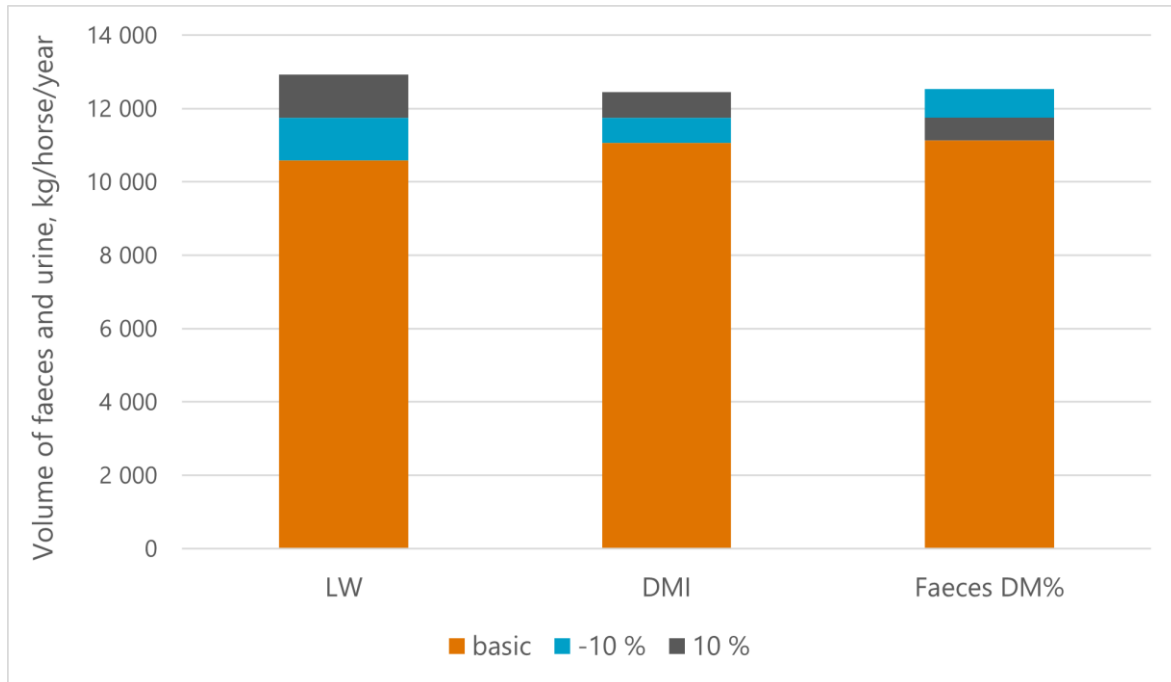


Figure 11. Total faeces and urine excretion of an adult horse in moderate work when live weight (LW), dry matter intake (DMI) or dry matter content of faeces (Faeces DM%) was changed in the calculation. Grey colour represents 10% increase and blue 10% decrease from the original level. The border between the blue and grey is the average excretion level for adult horse in moderate work in 2023.

Since DMI and intake of nutrients is calculated based on ME requirements, which in turn is based on LW of horses, it is reasonable that changes in LW have the biggest effect on the excretion. Dry matter intake has an effect on the intake of nutrients and also on the excretion. In case of CP the increase in intake affects the digestibility of CP which in turn has an effect on the excretion.

To get more accurate results from the calculations in the future, it would be beneficial to estimate more precise DMI of each horse group, and, to some extent, the actual average LW of horses, since they are the variables affecting most on the excretion. This would be, however, very difficult to execute in practise.

7. Time series for the excretion of horses in Finland

Excretion calculations form a continuous time series, which can show a trend in the excretion of the whole horse population in Finland. The time series is also required for the emission inventories of greenhouse gas and ammonia emissions from manure. The starting point for the time series is year 1990, and the time series is updated with a new annual data point every year when the calculations are completed or completely if the calculation method is changed.

Figure 12 shows the time series for the N excretion and Figure 13 for the P excretion of Finnish horses from year 1990 to 2023. Excretion is presented as thousands of kilograms per year. Different horse categories are shown in different colours.

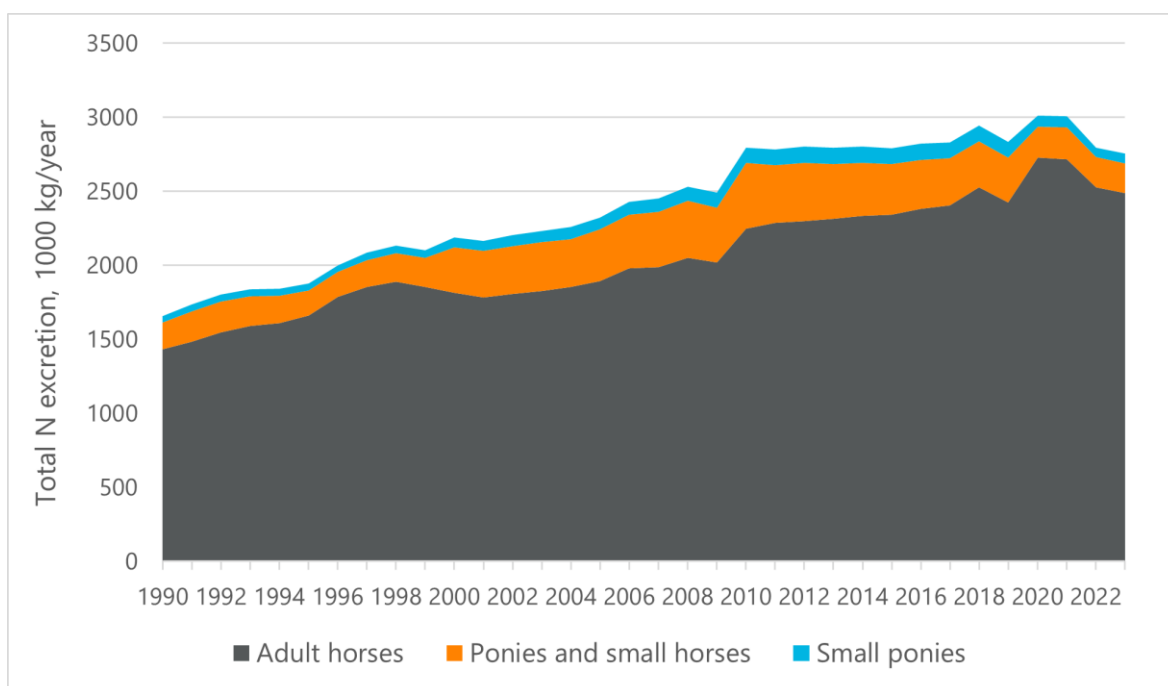


Figure 12. Total nitrogen (N) excretion of different horse categories from 1990 to 2023, shown as thousands of kilograms per year.

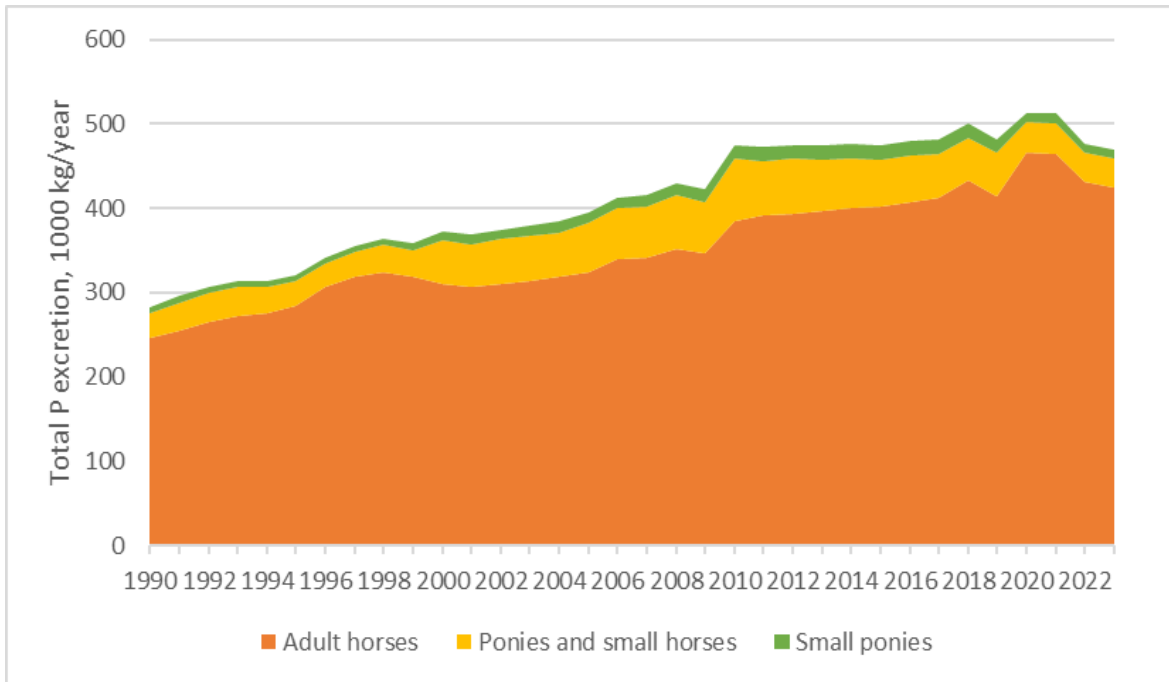


Figure 13. Total phosphorus (P) excretion from different horse categories from 1990 to 2023, shown as thousands of kilograms per year.

The feeding practises and proportions stay the same throughout the time series, although the nutritional quality of roughage has improved during the timeline (1990-2023), due to improvements in production systems. The increase of both N and P excretion during the 1990-2023 is due to the increase in the number of horses in Finland during this time, being 41 170 horses in 1990 and 67 620 horses in 2023. The number of horses in the registries was revised in 2021, which caused a drop in the excretion time series. During the timeline, the division of horses into different work intensity categories has changed, and the number of horses used in leisure activities has increased compared to horses used in competition activities, especially in trotting.

8. Conclusions

In contrast to other production animals, there is a wide variation in the feeds and feeding practices between horses. Most horses are fed with rather low concentrate levels, and the variation in the feed values of forages is large (Saastamoinen & Hellämäki 2012). Applying diets containing 20, 35 and 0% concentrates, Saastamoinen et al. (2020) reported that the P excretion increased slightly with increasing concentrate and P intakes. In addition, practical diets are often supplemented with mineral mixtures, probably influencing the excretion, as well (Saastamoinen et al. 2020). Correspondingly, the N excretion was decreased with increasing oats and high-quality protein supplement proportions in the diets compared to forage-only diets (Saastamoinen et al. 2021).

In the future, there is most likely minor need to update the excretion calculation methodology for horses. The annual data points can be calculated with the presented method just by applying the latest statistics of the number of horses in each category. To improve the accuracy of the calculations, more information about the composition of the actual diets of the horses and the feed intake in practice would be needed. The collection of such data is acknowledged as challenging due to the high variation in practices. Most of the horses used in light work are located in smaller leisure activity stables, partly kept by private persons, whereas horses used in heavy work, such as eventers or trotters, are living in professional stables and their use of feeds might vary from each other drastically. Also, the utilization of roughage analysis as the basis of feeding plans varies between different stables and has an effect on the final excretions.

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Appendices

Appendix 1. Summary of intake and excretion of nutrients of an adult horse (550 kg) of different work intensity classes and the amount of faeces and urine, expressed as kg per horse per year in 2023.

	Maintenance	Light work	Moderate work	Heavy work
Intake				
Total DM intake, kg	2 712	2 830	3 317	3 885
Total OM intake, kg	2 395	2 629	3 097	3 644
Total ash intake, kg	217	201	221	241
Total N intake, kg	36.0	41.5	50.9	62.3
Total P intake, kg	6.0	7.0	8.6	10.6
Total K intake, kg	49.1	43.8	47.0	50.0
Total output				
DM, kg	1 489	1 481	1 694	1 935
OM, kg	1 239	1 251	1 440	1 655
Ash, kg	217	201	221	241
Nitrogen, kg	35.5	38.9	46.3	55.2
Phosphorus, kg	5.6	6.5	8.0	9.9
Potassium, kg	48.2	46.9	47.7	48.5
Faecal output				
Volume, kg	6 419	6 182	6 946	7 781
DM, kg	1 348	1 298	1 459	1 634
OM, kg	1 223	1 183	1 332	1 494
Ash, kg	92	86	94	101
Nitrogen, kg	15.3	15.9	18.6	21.8
Phosphorus, kg	5.4	6.3	7.8	9.6
Potassium, kg	12.3	11.0	11.8	12.5
Urinary output				
Volume, kg	4 807	4 807	4 807	4 807
DM, kg	141	183	236	301
OM, kg	16.1	68.0	109	161
Ash, kg	125	115	127	140
Nitrogen, g	20.2	23.0	27.7	33.4
Phosphorus, g	0.15	0.17	0.21	0.26
Potassium, kg	36.0	36.0	36.0	36.0

Appendix 2. Summary of intake and excretion of nutrients of a pony or small horse (350 kg) in different work intensity classes and the amount of faeces and urine, expressed as kg per horse/pony per year in 2023.

	Maintenance	Light work	Moderate work	Heavy work
Intake				
Total DM intake, kg	1 726	1 801	2 111	2 472
Total OM intake, kg	1 588	1 673	1 971	2 319
Total ash intake, kg	138	128	140	153
Total N intake, kg	22.9	26.4	32.4	39.6
Total P intake, kg	3.8	4.4	5.5	6.7
Total K intake, kg	31.2	27.9	29.9	31.8
Total output				
DM, kg	948	943	1 078	1 231
OM, kg	788	796	917	1 053
Ash, kg	138	128	140	153
Nitrogen, kg	23.4	25.5	30.2	35.9
Phosphorus, kg	3.6	4.1	5.1	6.3
Potassium, kg	30.7	29.9	30.4	30.8
Faecal output				
Volume, kg	4 085	3 934	4 420	4 951
DM, kg	858	826	928	1 040
OM, kg	778	753	847	951
Ash, kg	58	55	60	64
Nitrogen, kg	9.8	10.1	11.9	13.9
Phosphorus, kg	3.5	4.0	5.0	6.1
Potassium, kg	7.8	7.0	7.5	7.9
Urinary output				
Volume, kg	3 059	3 059	3 059	3 059
DM, kg	89.9	117	150	194
OM, kg	10.2	43.2	69.2	102
Ash, kg	79.7	73.4	80.8	89.1
Nitrogen, g	13.6	15.4	18.4	22.0
Phosphorus, g	0.09	0.11	0.14	0.17
Potassium, kg	22.9	22.9	22.9	22.9

Appendix 3. Summary of intake and excretion of nutrients of a small pony (225 kg) in different work intensity classes and the amount of faeces and urine, expressed as kg per pony per year in 2023.

	Maintenance	Light work	Moderate work	Heavy work
Intake				
Total DM intake, kg	1 110	1 158	1 357	1 589
Total OM intake, kg	1 021	1 075	1 267	1 491
Total ash intake, kg	88.8	82.2	90.3	98.6
Total N intake, kg	14.7	17.0	20.8	25.5
Total P intake, kg	2.4	2.8	3.5	4.3
Total K intake, kg	20.1	17.9	19.2	20.4
Total output				
DM, kg	609	606	693	791
OM, kg	507	512	589	677
Ash, kg	89	82	90	99
Nitrogen, kg	15.8	17.1	20.2	23.8
Phosphorus, kg	2.3	2.7	3.3	4.0
Potassium, kg	19.7	19.2	19.5	19.8
Faecal output				
Volume, kg	2 626	2 529	2 841	3 183
DM, kg	551	531	597	668
OM, kg	500	484	545	611
Ash, kg	38	35	38	41
Nitrogen, kg	6.3	6.5	7.6	8.9
Phosphorus, kg	2.2	2.6	3.2	3.9
Potassium, kg	5.0	4.5	4.8	5.1
Urinary output				
Volume, kg	1 966	1 966	1 966	1 966
DM, kg	57.8	75.0	96.5	123
OM, kg	6.6	27.8	44.5	65.8
Ash, kg	51.2	47.2	52.0	57.2
Nitrogen, g	9.5	10.6	12.6	14.9
Phosphorus, g	0.06	0.07	0.09	0.11
Potassium, kg	14.7	14.7	14.7	14.7



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