Annual variations of roughage and its affect on coverage of Equine nutritional requirements

Sesongvariasjoner i grovfôrets næringsinnhold og hvordan dette påvirker dekning av hestens næringsbehov

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Master Thesis 30 credits 2013

Preface

Two years of living and studying equine science in Montana, USA, revealed to me how the horse is created to live and nourish off marginal grasslands highly unlike what would be considered feed for horses in Norway. I did find this diversity odd, as the animal itself is alike throughout the world. Therefore, I chose the topic of this thesis in order to view the roughage only diet in greater dept. As digestive problems and obesity are seen regularly among our horses, I wanted to focus on roughage only diets and suitability of the roughage for equines as this is an interesting field hiding potential preventions of these sufferings.

A lot of help have been given to me throughout the writing of this thesis. I would like to thank Eurofins, Moss for giving access to and assistance with their datasets covering all analysis of equine roughage in Norway. I would also thank my supervisors Dag Austbø and Jon Anders Næsset for indispensable help throughout the process of writing. If every horse owner in Norway were to acquire some of their knowledge in equine nutrition, I believe it would be a better place for many horses.

Also thank you to Anne Lise Bu, Merete Bekkevoll, Alena Standley and Emily Cornell for inputs and proofreading. Last but not least I am grateful for the patience and understanding given to me by Tarjei through all the years of studying; it has now finally come to an end!

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28.04.2013

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Abbreviations

AA – Amino Acids

ADG – Average daily gain

BW – Body weight

$BW^{0.75}$- Metabolic bodyweight

CP – Crude protein

DCP – Digestible crude protein

DE – Digestible energy

DM – Dry matter

FEh – «Fôrenhet hest» (Feed unit horse)

FEm - «Fôrenhet melk» (Feed unit milk)

ME – Metabolic energy

NDF – Neutral detergent fiber

NDS – Neutral detergent soluble

NE – Net energy

NRC- National Research Council

NSC – Non-structural carbohydrates

O_2 - Oxygen

OM – Organic matter

VDMI – Voluntary dry matter intake

VFA – Volatile fatty acids

WSCH – Water soluble carbohydrates

Sammendrag

Variasjon i grovfôrets næringsinnhold er vanskelig å unngå på grunn av de varierende dyrkingsforholdene i Norge gjennom ulike år. Dagens analysemetoder av grovfor til hest gjør at næringsinnholdet kan utnyttes fullt ut, og grovfôret kan i størst mulig grad bidra med ønskede næringsstoffer og fiber til hestens fordøyelsessystem.

Oppgaven består av to deler. Den første delen består av analyseresultater av grovfôr til hest, og ser på variasjoner innen og mellom ulike år. Det har blitt sett på næringsinnhold i alt analysert grovfôr til hest fra 2007 (uegnede forhold), 2008 (egnede forhold) og 2012 (nyeste produksjonsår). Analyseresultatene av energi, protein, Ca, P og Mg ble beregnet og sammenliknet. Oppgavens andre del dekker beregninger av hestens næringsbehov for å kunne vurdere hvordan grovfôret dekker næringsbehov dersom fôret kun med grovfôr.

Innhold av energi viser en tydelig variasjon mellom de ulike årene, hvor gjennomsnittlig verdi er H1 (0,63 FEh/kg TS), H2 (0,58 FEh/kg TS) og H3 (0,55 FEh/kg TS) fra henholdsvis 2008, 2007 and 2012. Allikevel er det ingen tydelig variasjon av fordøyelig råprotein (DCP) mellom de ulike årene, med gjennomsnittsverdier på 68,9 g DCP/kg TS (2007), 68,3 g DCP/kg TS (2008) and 62,3 g DCP/kg YS (2012) Generelt sett viser resultatene at innhold av DCP er klart høyere enn nødvendig for de fleste hester, med unntak av yngre unghester (< 18 mnd). Innholdet av mineraler i grovfôret fra de ulike årene tilfredsstiller generelt ikke behovet til hest.

Variasjonen i næringsinnhold som oppstår fra de ulike dyrkningssesonger må medberegnes og tas hensyn til i beregning av fôrrasjoner. Særlig gjelder dette til hester som fôres på ren grovfôrdiett. Muligheten for å kunne fastslå hvilket grovfôr som vil være egnet for ulike hester, avhenger i stor grad av hestenes maksimale opptak av tørrstoff (VDMI). Oppgaven konkluderer med at en ren grovfôrdiett vil tilføre den nødvendige mengde energi og DCP for de fleste hester til tross for variasjoner fra år til år. Underdekning av energi kan oppstå hos yngre unghester, samt ved høy treningsintensitet for unghest og voksne hester. Overskudd av energi og protein kan oppstå ved vedlikeholdsnivå og lettere trening av eldre unghester og de fleste voksne hester. Studier av det analyserte grovfôret bekrefter også at tilskudd av mineraler er nødvendig til alle hester fôret på ren grovfôr-diett.

Summary

Due to the various conditions during growth seasons in Norway, variation regarding nutritional content between years cannot be avoided. Because of the analysis methods used to determine the nutritional value of roughage for equines, utilization of this forage should be fully available in order to provide nutrients and fiber to the equine digestive tract.

The thesis consists of two sections. One is the roughage analysis results discovering variations between and within years of production. The nutritional content of roughage for equines are examined from 2007 (unfavorable growth season), 2008 (favorable growth season) and 2012 (current year of production). The analysis results of energy, protein, Ca, P and Mg are calculated and compared. The other section covers calculations of the nutritional requirements of the horse in order to outline the degree of coverage or abundance provided in roughage-only diets.

Content of energy is the factor varying the most, where the mean values did cover energy class H1, H2 and H3 in 2008, 2007 and 2012, respectively. The distribution of protein did not have a great variation between years, being 68.9 g DCP/kg DM (2007), 68.3 g DCP/kg DM (2008) and 62.3 g DCP/kg DM (2012). However, variations of DCP were evident within each separate year. Generally, the contents of DCP were at higher levels than desired to most horses, except younger growing horses (< 18 months). Mineral content of the chosen years rarely covered the calculated mineral requirements.

The annual variation of roughage productions must be considered and adjustments of forage rations must be carried out, especially regarding the horses fed roughage only diets. Determination of the suitable roughage to various horses highly depends on their voluntary dry matter intake (VDMI). This thesis concludes that a roughage only diet will provide adequate supply of energy and protein to most horses despite variations between years. Shortage will occur in younger growing horses and some with higher levels of exercise, while abundance of these nutrients is seen at maintenance and low levels of exercise as seen in older growing horses (> 18 months) as well as most adult horses. The study of roughage analysis does confirm the necessity of mineral supplement to all horses fed roughage only diets.

1. Introduction

From nature, the horse is a grass eater, whereas its intestinal tract is designed to process and utilize large fibrous roughage as a source of nourishment from the grass plains. The modern horse of today is deprived from its availability to graze the plains, and decades of altered use have resulted in a change of covering nutritional requirements. Today's horse is exposed to greater varieties of covering nutritional requirements, and use of cereals as source of needed energy is implemented.

The decreasing supply of roughage in exchange for cereals does result in several challenges to the horse, such as several digestive and metabolic disorders (Hoffman, 2009), as well as stereotypic behavior due to not fulfilling the nutritional need of fiber obtained from natural grazing and digestion (Lewis, 2005; Mc Greevy, 2004). There are several instances of gastric ulcerations in intensively managed horses, where lesions are found in 82% of racehorses (Vatistas et al., 1999).

Based on the roughage production in Norway, and the analysis methods to determine the nutritional value of the product, there is no reason why energy- , protein- and mineral content of roughage for equines should not be utilized to its full in order to provide nutrients, dual-purposed with covering the demand of fibrous material to the largest possible extent.

Due to the various conditions during growth seasons, variation regarding nutritional content between years cannot be avoided. This variation therefore must be taken into consideration when calculating the roughage provision of nutritional value to the horse. It's important to predict this variation to ensure a complete rationing of the roughage to cover an optimal diet.

The increase in horses suffering from being overweight affirms the fact that overload of energy is a challenge to many horses as well. This indicates that to some types of horses, providing less energy may be beneficial. To these horses, the energy and digestible crude protein (DCP) found solely in roughage may be adequate or even provide overcapacity.

In 2012, the national Centre for Rural Research; "Norsk senter for bygdeforskning" estimated the number of horses in Norway to be 125,000 (Norsk senter for bygdeforskning, 2012). In their report, it was stated that 69% of the horses were fed hay (< 80% DM), 56% fed haylage (50 – 80% DM) and 35% were fed silage (20 – 50% DM), as many use a combination of several types of roughage (Norsk senter for bygdeforskning, 2012).

If calculating with 125,000 horses throughout the country and supposing 1/3 of these are being ponies, a total voluntary dry matter intake (VDMI) of these horses would be 1,083,500 kg DM/day (maintenance level, intake 2% of bodyweight). If producing 675 kg DM/daa during two harvestings/year(www.grovfornett.no), this requirement of roughage to the horses of Norway will occupy 1,605 daa/year, equaling 14.6% of the total 11,000 daa being cultivated areas of the country (www.ssb.no).

1.2 Problem statement

The possible lack of focus on energy and DCP content of roughage as a replacement for some amounts of cereals fed to horses relies on knowledge of the nutritional content of roughage and its variation. If we exclude the minerals, comparing the roughage productions from various years to the nutritional requirements of the horse would be interesting in order to find coverage, shortage and excess of energy and DCP if fed only roughage in their diet. Based on this, this thesis has the following problem statement:

How do annual variations in Norway influence the potential coverage of nutritional requirements in horses?

In order to inquire into the problem statement listed above, the following sub theses are requested:

How does roughage produced during different growing seasons differ?
How does roughage cover nutritional requirements of horses if fed a roughage only diet?

1.3 Structure of thesis

In order to identify if roughage in a roughage only diet covers the nutritional requirements of a horse, a complete calculation of the nutritional requirements of the horse is required. This thesis therefore mainly consists of two components. One is the calculation of nutritional requirements of horses. These calculations are a completion of formulas in literature, and although being preliminary work they are not considered to be results. The calculations of nutritional requirements of the horse are therefore presented in section 4. The other component is covering the quantitative computing of analyzed samples of roughage for equines with production from the varying years of 2007, 2008 and 2012, presented as results during section 5.1 roughage analyses of 2007, 2008 and 2012. These two components are combined for evaluation and discussion.

Criticism and Assumptions

Because roughage analysis is performed voluntarily, and the analyses are placed under confidentiality, the research material may provide following weak points:

- Collected data from analysis of roughage does not be quantitatively representative for the total roughage for equines throughout the country.
- The roughage analyzed does not specify what area it has been produced in; furthermore it doesn´t specify what quantity the sample represents.

This thesis does assume that the collected data represents production of roughage throughout the country, and that the majority of producers and customers analyzing their samples behave consistently over the years, meaning that the variation seen in the results from analysis are mirroring the distribution and availability in the market.

This thesis also assumes that the amount (kg) roughage represented by each sample is somewhat even, giving roughly the same distribution in (kg) available at the market as the distribution of energy content displayed in the respective year of production.

Delimitations

The total nutritional requirement of the horse covers a broad spectrum of substances. However, this thesis is limited to the main categories of nutrients: energy, DCP, calcium (Ca), phosphorus (P) and magnesium (Mg). Therefore, these are the substances covered when referring to “nutritional requirements” throughout the thesis.

This thesis looks at the nutritional requirements of growing horses at set ages, but does not cover growing horses within the racing industry (undergoing intensive growth management). It also looks at adult horses at all levels of exercise. It does not cover pregnancy or lactating mares. It also does not cover any requirement of stallions, breeding or non-breeding.

The selection of roughage production is limited to three years of various conditions for production. These years are chosen in attempt to obtain an overview of variation, yet still managing to cover a dataset within limitations set for master thesis in general.

Reasoning for selected years

The three years chosen to represent various roughage productions are selected on the basis of a general opinion among producers and customers for being in particular unfavorable or favorable, yet still being among the latest growth seasons.

2012 is used to include the latest results on roughage for horses in Norway.
2008 is remembered as having a favorable growth season.
2007 is recalled to be an unfavorable and rainy growth season.

2. Literature review

2.1 Production of roughage for equines

Roughage is relatively low in energy and crude protein (CP) and high in fiber content. Roughage for equines may be conserved either as hay or as ensiled in wrapped bales with varying dry matter (DM) content. Roughage with DM above 84% is defined as hay. Ensiled roughage with DM content ranging between 50 – 84% is defined as haylage, whereas ensiled roughage with DM content below 50% is defined as silage.

Morphological development and harvesting

Harvesting grass at an early stage will result in higher energy and CP content, and lower fiber (Mo, 2005).

The first harvest has a uniform development, resulting in the nutritional content and morphological development to change at the same rate. Rapid changes can be seen in the maturation, and early or delayed time of harvesting may result in major changes in the total product. Second harvest does not develop with the same equality, and rapid changes are not experienced the same way as for the first harvest. Therefore, the second harvest can be cut at a later morphological stage without major loss of energy and CP content. The fiber content of second harvest is somewhat lower (Mo, 2005).

Hay

A common way to conserve forage is as hay. In order to prevent molding and fermentation, hay need to have a DM content of 80 – 85% (Nedrebø & Nome, 1972). 84 % DM is used as the borderline for storage stability of hay, and as defining hay for calculations throughout this thesis. The high DM content required for storing hay involves great losses of nutrients through loss of foliage in the field and during mechanical handling (Mo, 2005). Total loss during production is typically 20 – 30% of initial crop for hay being stored indoor (Barnes et al., 2007). Due to the required drying prior to storage, production of hay is more dependent on weather conditions than that of ensiled roughage.

Haylage and Silage

Ensiled roughage is defined as conserving plant material with relatively low DM content, without oxygen (O_2), in the silo or as wrapped forage. Silage often has a low DM content (20 – 30%) and pH towards 4.2 (Mo, 2005). Haylage often have a DM content of 50% and higher (Müller et al., 2011).

Average morphological development at harvesting is at the stage of heading and the two following weeks (www.sorost.no). Although ensiled roughage for horses is preferred with a higher DM content than for ruminants, the production does not require the same drying time in the field (Mo, 2005). It can therefore be harvested at a more desired stage than hay in regard of energy and CP content, and is easier to achieve with preferred energy- and CP content in enisled roughage than hay.

Producing haylage involves less fermentation due to the lack of water to the lactic acid producing bacteria, as this production decrease in DM above 35% (Barnes et al., 2007). The reduced fermentation leads to a slight lowering of pH and reduced production of organic acids. Unwanted microorganisms require a humid environment, and are not found in great numbers when DM is above 30%. However, pH lowering additives may be beneficial even when producing haylage (Mo, 2005). DM above 70 – 80% inhibits bacterial growth, while DM below 30% stimulates the growth of both lactic acid bacteria and several undesirable bacteria such as *Clostridia* (Barnes et al., 2007; Mo, 2005).

Hay, haylage or silage to horses?

Horse owners often have a preference for ensilage having 70% DM or higher, possibly due to a background of feeding hay (Müller & Lingvall, 2001). Different feeding management strategies related to hay, haylage and silage may benefit one ahead of another in terms of practical use, but these conditions are not further discussed in the thesis.

A study of forage analyses through ten years displayed that haylage did have 2.3% -units higher content of neutral detergent fiber (NDF) than hay, resulting in the haylage having better digestibility and nutritional value (Saastamoinen & Hellämäki, 2012). The difference seen were addressed to possible be due to loss of leaves during harvesting of hay. Austbø

(1990) studied nutritional content and digestibility of silage, haylage and hay from the same crop. Horses were fed rations of 5.2 kg DM of hay (85.7% DM), 5.6 kg DM of haylage (54.1% DM) or 5.3 kg DM of silage (24% DM). The organic matter (OM) content was equal among the different roughages, while CP was lower in hay (17.0%) than haylage (19.0%) and silage (19.7%). The results showed that the digestibility of OM was best in silage (67.8%), while lower in haylage (64.5%) and lowest in hay (63.5%).

The fermentation process is different at different DM contents, shifting noticeably at 50% DM (Mo, 2005). Therefore, the DM content of the analysis used in this thesis is divided into following groups: below 50% DM (silage) and 50 – 83% DM (haylage). The risk of poor fermentation leading to depreciation of quality and production of toxins has been assigned through several studies (Müller et al., 2011; Müller & Lingvall, 2001; Müller & Udén, 2007). This is highly related to the discussion of feeding ensilage to horses, but will not be covered further in this thesis.

Species commonly found in roughage for equines

Harstad (2011) states that there are minor differences between grass species in regard to nutritional value when harvested at the same morphological stage. However, the difference between legumes and grasses is major, as legumes have higher CP content when harvested at the same time as grasses. In addition, legumes also show higher values of Ca and Mg and less NDF compared to grasses (Harstad, 2011).

The composition of species used for roughage production has a long history. In order to be productive through several years, the species must complement each other, and the morphological development must correlate with one another. The species commonly used for production of roughage in Norway are Timothy, (*Phleum pratense)* at 100%, or Timothy in mixture with Meadow Fescue (*Schedonorus pratensis*) at 80% Timothy and 20% Meadow Fescue. Some producers additionally include Red Clover (*Trifolium pratense*) in this mixture, resulting in a mixture containing 70 – 75% Timothy, 20% Meadow Fescue and 10 – 15% Red Clover. (Austbø, 2013; www.sorost.no). Approximately 10% Rye-Grass (*Lolium perenne*) may be included if capable of surviving the winter, as this specie increases the quantity of the harvested forage. Bluegrass (*Poa pratensis*) may be included in mixtures designed for pastures and roughage production, as this is a more hardy specie (www.felleskjøpet.no; www.norgesfor.no; www.sorost.no).

Timothy (Phleum pratense)

Timothy is classified as a cool-season grass suitable for humid areas. Various species of *Phleum* are native to northern Europe. It has a shallow root system, which makes it spread non-aggressively (Barnes et al., 2007). However, it does not withstand rotational grazing very well. Flowering and development of Timothy require a period of long daytime, and is affected by temperature (Barnes et al., 2007). The plants are capable of handling extended ice encasement and low temperatures during winter. Because Timothy is suited for the Norwegian growth conditions, and its palatability is preferred by horses, this specie is commonly used in production of roughage for horses in Norway (www.grovfornett.no).

The national references of nutritional content in forages, "Fôrtabellen" (UMB & Mattilsynet, 2008) defines the energy content of timothy to be 0.61 feed unit horse (FEh)/kg DM at heading and 0.52 FEh/kg DM at flowering, while protein is 89.2 g DCP/kg DM and 61.0 g DCP/kg DM, respectively. When compared to other cool-climate grasses, Timothy matures slower and has a higher digestibility, and cultivars must be chosen in consideration to this.

Meadow Fescue (Festuca pratensis)

Meadow Fescue prefers humid soils and a rainy climate. It has a more rapid growth than what is seen in Timothy after first harvesting, and it therefore will do well on several harvesting grasslands where it provides a larger second harvest (Nedrebø & Nome, 1972). Because Meadow Fescue withstands grazing and multiple harvestings well, it is well suited in combination with Timothy and Red Clover to provide a hardier and richer roughage production over several years (Nedrebø & Nome, 1972).

Meadow Fescue is defined in the "Fôrtabellen" as having nutritional content of 0.69 FEh/kg DM and 114 g DCP/kg DM at heading, and 0.47 FEh/kg DM and 66.4 g DCP/kg DM at flowering (UMB & Mattilsynet, 2008).

Red clover (Trifolium pretense)

Red clover is a cool-season legume for humid areas, and is adapted to moderately cool temperatures in summer and sufficient moisture (Barnes et al., 2007). There are three types of Red Clover. The “medium type” is the one used in roughage production, and has early flowering and is able to produce two or three crops every year. Red Clover is high in moisture and can be difficult to dry as hay (Barnes et al., 2007). Clover causes higher OM losses from the mechanical treatment, as it is prone to loss of leaves during harvesting. Legumes do provide an elevated CP content to the roughage, seen by the nutritional values listed in “Fôrtabellen” being 0.74 FEh/kg DM and 204.7 g DCP/kg DM at early development stage, as well as 0.59 FEh/kg DM and 142.6 g DCP/kg DM at late development stage (UMB & Mattilsynet, 2008).

Red Clover is adapted to a variety of soil types and tolerates a pH down to 5.5, but does not favor areas prone to excess moisture or drought. Animal performance on Red Clover pasture is similar to results seen from Alfalfa. Harvesting at about 20% bloom will give the best compromise in regard to forage quality and quantity (Barnes et al., 2007).

Nutritional value of roughage for equines

Harstad (2011) defines the nutritional value as the capacity to promote or maintain the activity within the body. The term normally covers energy and DCP, but also includes vitamins and minerals. The digestibility of the feedstuff is the number one factor of determining the nutritional value. The dry matter digestibility is highest as young grass and decreases rapidly as the plant matures, being dependent on leaf: stem ratio and plant anatomy (McDonald et al., 2002).

Apart from digestibility, nutritional value in regard of nutritional content is dependent on numerous factors, with fertilizing (nitrogen (N) in particular), morphological development at harvesting, and botanical composition being greatest (Harstad, 2011).

Energy content of roughage

The energy content of forages for horses in Norway is calculated as net energy (NE) and given as FEh (Feed unit horse). 1FEh = 9.414 MJ (NE).

Carbohydrates are the major source of energy found in roughage, and this potential energy is categorized into soluble and insoluble carbohydrates or structural and non-structural roles (Barnes et al., 2007). Although being a monogastric animal, the horse is capable of utilizing the energy provided from both structural and non-structural carbohydrates, due to the microbial fermentation in the hindgut.

Structural carbohydrates

The structural carbohydrates are components of the cell wall (polysaccharides), referred to as neutral detergent fiber (NDF). NDF is called plant fiber and consists of cellulose, hemicellulose and lignin. Cellulose is the most abundant polysaccharide in forage cell walls, and all plant cell walls contain cellulose (Barnes et al., 2007). In the horse, the structural carbohydrates are fermented in the hindgut by microorganisms that produce volatile fatty acids (VFA) that are absorbed and utilized mainly for energy (Pagan, 1996). Some of the NDF is not fermented, this being referred to as insoluble NDF (iNDF). NDF provides the main fraction of energy supplied to the horse, and the NDF content also provides favorable structure to the digestive tract.. Hay usually holds 600 g NDF/kg DM (www.eurofins.no). The digestibility of the non-structural carbohydrate fraction decreases as the plant matures (Mo, 2005), partially causing the decrease in nutritional value in more mature grass. In the early stage of development, the carbohydrates of the plant are approximately 35% NDF fraction, while being 60% at flowering (Mo, 2005).

Non-structural carbohydrates

The non- structural carbohydrates (NSC) are all other carbohydrates than those being structural (Barnes et al., 2007), also referred to as neutral detergent solubles (NDS). As a group, NSC includes starch and water soluble carbohydrates (WSCH), which also include pectin and fructans (Pagan, 1996). The NSC is found inside the cells. Applying N-fertilizer depresses the level of NSC in temperate grasses (McDonald et al., 2002). The NSC in roughages are glucose, fructose, sucrose and fructans (Barnes et al., 2007).

Among the species commonly used for roughage production, Timothy has a slightly higher content of WSCH (110 g /kg DM) than Meadow Fescue (96 g/kg DM) (Mo, 2005). Levels of WSCH found in Norwegian roughages are approximately 100 – 120 g/kg DM (www.eurofins.no). The WSCH are approximately 100 % soluble independent of morphological development of the plant (Mo, 2005).

Factors influencing the energy content of roughage

The morphological state at harvesting is the main factor influencing the energy content of roughage(Barnes et al., 2007; Mo, 2005). Roughage harvested at earlier morphological stages have higher energy content (Gramstad et al., 2011; Harstad, 2011), and the level of energy reaches highest value about one week after heading (Mo, 2005). The morphological development is dependent on temperature, light, and specie. The energy content of Timothy decreases rapidly as the plant matures during the two weeks after heading. In the period following this, the decrease of energy declines (www.sorost.no).

Digestible crude protein (DCP) in roughage

Due to the digestibility of protein, the total CP content of forage is not available to the animal. Analyses of roughage give the CP, whereas the DCP is the apparent amount of CP available to the animal. Excess DCP can be regarded as unfavorable, especially for adult competition horses as excess may negatively influence their athletic performance (Austbø, 2013). Alterations in fluid and acid balance of trotters have been found when fed roughage only diet with roughage high in CP content (160% of requirement) (Saastamoinen & Hellämäki, 2012). Saastamoinen and Hellämäki (2012) also states that feeding high protein rations may cause lowering of Ca deposition or recruitment of Ca from the bones.

Protein is present in all plant cell walls, although at low concentrations. Legume cell walls have a higher CP content than that of grass species, typically containing 15 – 25% CP, whereas grasses contain 10 – 20% CP (Barnes et al., 2007).

Factors influencing the protein content of roughage

As the CP content is calculated as N x 6.25, the amount N-fertilizer applied certainly influences the CP values. The CP content may vary from 30 g CP/kg DM in very mature roughage to 300 g CP/kg DM in heavily fertilized roughage (McDonald et al., 2002).

The CP content of roughage also relies on the morphological stage at time of harvesting (Harstad, 2011). The highest level being at the stage of heading (Mo, 2005). The CP content of plants is inversely related to the morphological state, and environmental conditions during growth also strongly influences the amount of CP (Barnes et al., 2007). The relative proportions of amino acids (AA) varies little among species (McDonald et al., 2002).

Mineral content of roughage

The type of soil has a large influence on the mineral content of the plant, where deficiency often leads to reduced growth or –concentration in the plant. Ca, P, Mg, copper (Cu) and cobalt (Co) are the minerals most commonly found deficient, although major variations are seen due to variations in soil among regions and continents (McDonald et al., 2002). Fertilizing of P does of course influence the P content of the plant, but does not influence other nutritional aspects of the plant. Fertilizing potassium (K), however, may decrease the level of Ca and Mg (Harstad, 2011).

Total ash (non-organic matter) represents the mineral content of the feed, with minerals being specified at chemical analysis of the roughage. The mineral values of roughage for equines are normally within the range of 3 – 5 g/kg DM of Ca, 2 – 3 g/kg DM of P and 1.2-2.2 g/kg DM of Mg (www.eurofins.no). Total ash content of roughage for equines should be below 100 g/kg DM, as a higher value found at mineral analysis of roughage may indicate soil contamination of the product (www.eurofins.no). The total ash content of the plant decreases as the plant matures (McDonald et al., 2002). Weather conditions prior and after harvesting also influences the total ash content.

Mineral content varies among species, depending on chemical composition. Also, fertilization affects the mineral content as N-fertilizers secondly cause the amide and nitrate contents in the plant (McDonald et al., 2002).

Studies of roughage for equines in Sweden

Müller (2012) performed a study from 2009 to 2012 to investigate the effects of feeding roughage only diets to growing trotters undergoing exercise and regular competition at ages two and three years. The study was performed by feeding roughage only diets as a source of energy and DCP. The study used 13 warm-blooded trotter geldings (born 2009), fed roughage only diets *ad libitum*, including a mineral supplement. The roughage produced for the study had a DM ranging from 47 -73%, with a nutritional content of 10.2 – 11.7 MJ ME/kg DM (71 – 113 g DCP/kg DM). To obtain the preferred nutritional content, early harvesting was performed, but both first and second harvestings were used.

During exercise, the horses were divided into two groups; one undergoing regular workload according to industry standards, and the other undergoing 70% of the regular workload. Growth rates, development and health were also examined for study over the three year period. The results were compared to related studies of traditional management of trotters.

The study concluded that roughage only diets were superior in promoting a healthy digestive tract and physiological health in the growing trotters. Müller (2012) also concluded that horses fed roughage only diets are able to get energy- and DCP requirements covered when fed suitable roughage based on roughage analysis. The study also states that more information is needed regarding the potential of roughage as feed for horses, as well as specifying roughage to different groups of horses.

2.2 Calculating nutritional requirements of growing horses

Background and premises for calculations

Age groups of growing horses

Growing horses were divided into the following groups by age:
6 months (weaning), 12 months, 18 months, 24 months and 36 months.

Although there are reasons to believe that corrections should be made regarding different types of growing horses, this is not applied to this group like it is to adult horses.

Exercise of the growing horse

The categories for exercise of the growing horse differ from those of the adult horse. The exercise load increases with increased age of the horse, yet no exercise is performed until the age of > 12 months (NRC, 2007). The increased nutritional requirements due to exercise is divided into four activity levels independent of age. The amount of exercise required for the adult horse is given as a factor from maintenance requirements:

Light exercise: maintenance + 20%

Moderate exercise: maintenance + 40%

Heavy exercise: maintenance + 60%

Very heavy exercise: maintenance + 90%

(NRC, 2007).

The category of growing horses undergoing intensive growth is not included in this thesis; therefore, the level of "very heavy exercise" is not included in requirement calculations for the growing horse.

Weight and gain of the growing horse

Horses were calculated at several classes based on expected mature bodyweight (BW).

Average daily gain (ADG) for growing horses is calculated for each age-group based on Table 1, showing actual BW given in percent of mature BW. ADG is given in kg and calculated by $\frac{gain}{period} = \frac{average\ gain}{day\ in\ given\ period}$. The mean value of the two up to periods of ADG was used at each chosen age.

Table 1 – The current weight of a growing horse, being in % of expected mature BW

Age (months)	**0**	**6**	**9**	**12**	**18**	**24**	**36**
% of adult BW	10	47	58	67	82	89	97

(NRC, 2007)

Rodriguez et al. (2007) performed a study on finding a formula for BW estimation of foals. By using 80 thoroughbred foals ranging in 2- 180 days of age, they found that a weight estimate based on girth measurements can be performed with the following formula:

Weight estimate (kg) = girth measurement^3 (m) x 90.

Outdoor housing of the growing horse

Growing horses are often stalled in groups, in outdoor housing. These horses are given an additional 10% of daily energy requirement (Austbø, 2013) due to active living and outdoor temperatures.

Intensive growth

Within the horseracing industry, horses are bred and raised to compete at competitions starting at two years of age. In order to accomplish the needed qualities for this, the management of these horses through their growth period is intensified regarding feeding and exercise. This model of management is defined as "intensive management".

Horses undergoing intensive management have an energy requirement of regular energy requirement plus 25%. DCP requirement is also increased by 25% (Austbø, 2013). Mineral requirements are at the same level and ratio as for the rest of growing horses.

The additional nutritional requirement for exercise follow regular levels of light exercise (+ 20%), moderate exercise (+ 40%) and heavy exercise (+ 60%) in relation to maintenance requirement. However, at intensive management, these additions are made to the elevated maintenance requirement described above.

Intensive management does not apply to growing horses intended for recreational use or sports, and is therefore not further discussed through the thesis.

Energy requirements of the growing horse

Energy requirements for maintenance and growth for growing horses are calculated according to the French and Dutch systems (Vemorel et al., 1984).

Energy requirement for maintenance:

7-12 months: 0.044 FEh /kg $BW^{0.75}$/day.

13 – 36 months: 0.042 FEh/ kg $BW^{0.75}$/ day.

Energy requirement for growth: $FEh = ADG \times \frac{1{,}350 + 67.94 \text{ x age } - 1.093 \text{ x age}\hat{}2}{1{,}000}$

Age = age in months   ADG = given in kg

Protein requirements of the growing horse

Daily DCP requirements for maintenance and growth is listed as DCP (Austbø, 2013; Hove Software A/S, 2013), given in relation to total FEh requirement of the growing horse:

6 months: 130 g DCP /FEh

12 months: 95 g DCP/FE

18 months: 85 g DGP/FEh

≥ 24 months: 80 g DCP/FEh (same as adult).

Mineral requirements of the growing horse

Minimum requirements of minerals are given by the National Research Council (NRC, 2007). An additional 20% has been added to the minimum mineral requirements to ensure mineral coverage. Ca and P requirements do not change due to an increase in exercise.

Minimum mineral requirements of growing horses

Ca: (0.072 x BW) + (32 x ADG)

P: (0.04 x BW) + (17.8 x ADG)

Mg (no exercise): (0.015 x BW) + (1.25 x ADG)

Mg (exercise, all levels): (0.03 x BW)

ADG = given in kg

2.3 Calculating nutritional requirements in adult horses

Background and premises for calculations

Types of adult horses

Adult horses were divided into three categories:

- Coldblooded: including all coldblooded and heavy set horses.
- Warm-blooded: including all warm-blooded horses and coldblooded trotters (maintenance requirement of coldblooded horse + 5%)
- Thoroughbred (maintenance requirement of coldblooded horse + 10%)

The definition of a pony is based on height, and in regard to nutritional requirement, will be based on BW. The above-mentioned categories are therefore also applied to ponies, although breeds of ponies are often categorized as coldblooded.

Exercise of the adult horse

A variety of tests has been performed to determine the energy requirements of different workloads. Most of these tests have shown that exercise causes energy requirements to increase up to 200% of maintenance requirements (NJF-arbeidsgruppen, 1996). Because it may be hard to determine the requirement of energy at different activities performed with horses, the NJF-report (1996) states the energy required for exercise as a factor from maintenance requirements. Values used are based on NJF report (NJF-arbeidsgruppen, 1996) of workload:

Light exercise: maintenance requirements + 25%
Moderate exercise: maintenance requirements + 50%
Heavy exercise: maintenance requirements + 75%
Intense exercise: maintenance requirements + 100%

Horses used for recreational use are estimated with workload of light exercise.
Sport horses are estimated with workload of moderate exercise.

Outdoor housing of the adult horse

Horses defined to be in outdoor housing, are given an additional 10% of maintenance requirements (Austbø, 2013).

Energy requirements of the adult horse

The energy calculations are based on the French and Dutch calculation system (Veevoederbureau, 2004; Vemorel et al., 1984):

Maintenance: FEh = 0.0373 FEh x $BW^{0.75}$ (+ potential corrections for type and sex).

Protein requirement in the adult horse

Requirements of protein are listed as DCP. DCP requirements are calculated to be 80 g/FEh both during maintenance and loads of exercise (Austbø, 2013).

Mineral requirement of the adult horse

The minimum requirement of each mineral given by NRC (2007) listed below are increased by 20% to ensure coverage; making the actual requirements. Mineral requirements of adult horses increase as the intensity of exercise increases.

Minimum mineral requirements of adult horses

Table 2 – Formulas for calculating minimum mineral requirement of adult horses (g /day)

Mineral	Maintenance	Exercise			
		Intensity Light	Moderate	Heavy	Intense
Ca	0.040 x BW	0.060 x BW	0.070 x BW	0.080 x BW	0.080 x BW
P	0.028 x BW	0.036 x BW	0.042 x BW	0.058 x BW	0.058 x BW
Mg	0.015 x BW	0.019 x BW	0.023 x BW	0.030 x BW	0.030 x BW

(NRC, 2007)

2.4 Apportioning of feed and feed intake

The amount of feed eaten by the horse can be grouped based on stable management; amount of roughage fed in rations and voluntary intake (*ad libitum*).

Apportioning roughage

Restricted feeding with rations is commonly used for barn management with individual stalls, where horses are kept separate at most feedings and have individual feeding. In the Scandinavian countries, suggestions are stated that minimum ration of roughage should represent at least 1.5% of BW/day when fed as hay. The thesis defines regular hay to hold a DM of 84%, which will result in an intake of 1.26 kg DM/100 kg BW.

Voluntary intake

The majority of horses kept in outdoor housing are grouped and fed *ad libitum*. Studies have showed that VDMI of legumes is higher than that of grass hay (Edouard et al., 2008). These studies conclude that the influence of forage quality (digestibility, fiber content, DCP) has not yet been determined through scientific research, and must be viewed as an open question. However, it is a common observation showing through the results of several studies of intake, that individual horses differ greatly in their ability to consume forages (Edouard et al., 2008).

Several studies have been performed to detect preference of roughage among horses. Müller (2005) did a study on preference for DM content, by offering hay and ensiled roughage of different DM content (35%, 55% and 70%) at the same time. The roughage was harvested simultaneously. Results showed that the horses smelled several feeds before choosing another feed to eat. The horses preferred 35% DM forage the most, 55% DM next, and hay last.

Müller and Udén (2007) also did an experiment to determine how different methods of forage conservation influenced the horses preference for conserved roughage. Hay (88.4% DM), haylage with high DM (68.4% DM), haylage with low DM (57.7% DM) and silage (23.9% DM) containing the same grass crops, conserved with minor variation in energy and NDF were fed four times a day (1 kg DM/forage/meal). Results from their study showed that hay was never completely consumed, while silage was never left in favor to another roughage, as silage was the number one choice 72 out of 84 times. Silage had the highest forage consumption and eating time, while hay had shortest for both. The reasons for the results remain unclear (Müller & Udén, 2007).

Estimated maximum feed intake is given as VDMI and listed as DM in percent of BW /day (NRC, 2007), represents the assumed daily intake in horses fed *ad libitum.*

Growing horses

Daily assumed VDMI for growing horses up to 24 months is 2.5% of BW, while estimated average maximum intake > 24 months is 2- 3% (Austbø, 2013; NRC, 2007). When calculating the nutritional requirement of the feed, 2.5% VDMI is being applied to all ages of growing horses.

Adult horses

Daily assumed VDMI for maintenance and light exercise is 2% of BW (NRC, 2007).

Daily assumed VDMI for moderate exercise is 2.25% of BW, whereas VDMI for heavy and intense exercise is stated to be 2.5% (NRC, 2007).

Factors affecting voluntary intake

When attempting to cover the nutritional needs of the horse with roughage, the most suitable roughage in order to obtain longer eating time is highly dependent on the voluntary intake of the horse, which is variable among individuals and forage.

Management of grouped horses most often includes *ad libitum* feeding. Variation in nutritional requirements among the individuals in the group combined with varying VDMI in these individuals may bring challenges to feeding such groups. When aiming to cover nutritional needs by feeding the correct amount of roughage according to the standard requirements at voluntary intake, the variation of VDMI is of great importance. The individual VDMI will be the element possibly causing individuals in such groups to suffer malnutrition, as roughage provided may have the suitable restricted nutrient content.

Animal factors and individual preferences affecting voluntary intake in horses

Regulation of feed intake in grouped horses is highly affected by the herd social order and access to feed, whereas age and residency time is deemed to be the main factors for social rank (NRC, 2007). Aggressive interactions become evident when feed is limited (Arnold & Grassia, 1982), and related or resided horses are more likely to tolerate closer proximity to each other within the feeding area.

Horses appeared to be stimulated to eat when having visual contact of companion horses (Sweeting et al., 1985). Houpt and Houpt (1988) found that horses isolated from visual contact of others were more active and spent 51.5% less time eating..

Environmental effects affecting voluntary intake in horses

As for the horses fed outdoors, intake may be affected by weather. Studies have been performed on grazing horses, presumably applying also to horses fed outside during outdoor housing management. Rainfall and wind results in less time spent grazing, as did temperature where horses spent more time eating during colder temperature than in warmer temperatures (NRC, 2007). The change due to weather was seen as higher bite rate, higher step rate and increased step distance, but fewer bites per step.

Throughout the year, time spent grazing is at its highest during spring and fall, as the horses increased time spent standing in the summer, due to warm weather and external parasites, s well as it was dependent on length of day (Dulphy et al., 1997a; NRC, 2007).

Feed effects affecting voluntary intake in horses

Horses prefer certain feeds, but also appear to like variety in their diet, as seen in feral horses (Salter & Hudson, 1979). Mechanisms that control VDMI of hay are assumed to be influenced by energy requirements, DM digestibility and NDF content (NRC, 2007). Little relation has been found through studies of VDMI and energy requirements, and VDMI and DM digestibility. A correlation have been found between VDMI and NDF content (Aiken et al., 1989), but VDMI of hay is possibly controlled by a number of several factors interacting with one another.

The effect of particle size and processing on voluntary intake

Coarseness and brittleness are textures that can negatively affect feed intake in horses. Feed intake may therefore be very different depending on feed processing (Haenlein et al., 1966). Pelleted or cubed forage have shown to increase VDMI (NRC, 2007).

Voluntary intake influenced by digestibility and physical control in the horse

Edouard and Fleurance (2008) showed through their study with twenty one saddle horse geldings that were fed hay, that individual horses can increase VDMI as a response to a decline in nutritional content and digestibility. Their study showed that this did not appear in all individuals, and that most individuals implemented the increased intake when fed forage with declined digestibility.

Another study performed on VDMI concluded that the horses displayed very diverse behavior in regard to VDMI (Dulphy et al., 1997a). This study found that there seemed to be some degree of physical control of appetite in horses. It also stated that horses do not increase their intake as a respond to decreased energy concentration, but the decrease was less than observed as a response in ruminants.

DM content and ensiling influencing voluntary intake

Ensiling has been reported to reduce the voluntary intake of forages in horses. The same is seen in sheep and cows (NRC, 2007). When this has been studied more in depth, it was found that hay, haylage and silage showed a difference in NDF content in addition to having different nutritive values (Müller, 2007). Based on these findings, it may be difficult to determine whether it is the conservation method and DM content that causes the difference in intake, or if it is due to the nutrient composition.

Grasses with generally high DM content have been shown to be well accepted by ponies, eating 1.4-2.2% DM of BW, while grasses with generally low DM have shown to not be as palatable, with VDMI of 0.92% of BW (NRC, 2007). Other studies reviewed by NRC looking at the difference in VDMI in regard to DM content showed that intake of low DM silage were less than 50% of intake of hay. DM content is not the only factor influencing VDMI of ensilaged forage and composition of species have shown to influence intake in both ensilaged forage and hay (NRC, 2007).

Voluntary intake at pasture

Not much information has been collected regarding VDMI of fresh forages, due to the challenges of measuring grazing animals. However, the estimates done on grazing non-pregnant and non-lactating horses were on average1.8 – 2.0% of BW (Dulphy et al., 1997b).

2.5 BW versus metabolic BW

The Norwegian calculation of energy and protein requirements are based on the French calculation system use metabolic BW ($BW^{0.75}$) as base when calculating maintenance requirements of the horse (Vemorel et al., 1984). By using this, the calculations estimate a higher energy requirement/kg BW at a decreasing BW. This may not be correct due to the changes in breed and type of horse related to a change in BW (Austbø, 2013), which is seen in horses but may not apply to other livestock. NRC uses actual BW when calculating nutritional requirements in the horse (NRC, 2007). Figure 1 does illustrate how the two calculations do differ in relation to increase of BW, as a metabolic BW calculation does show a steeper increase.

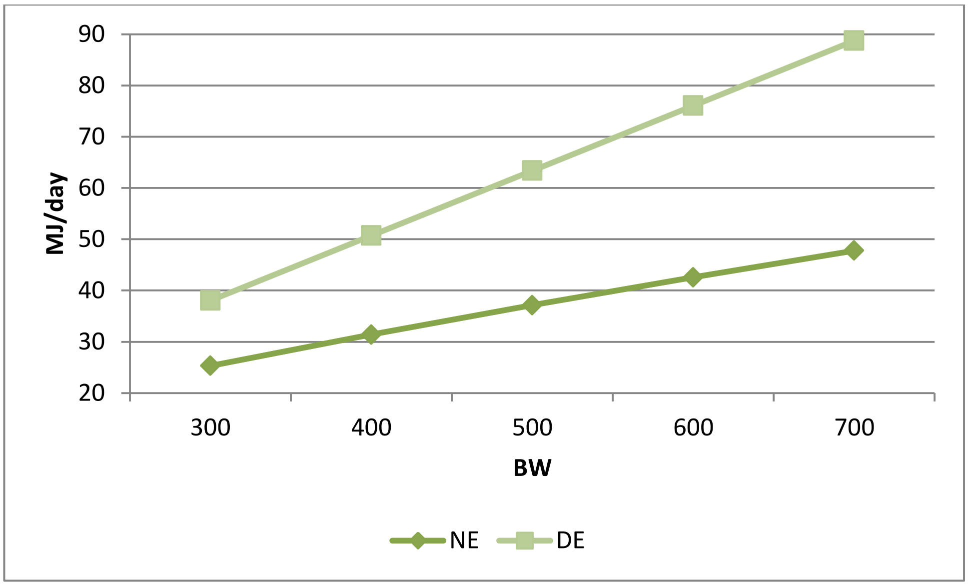

Figure 1 – Daily energy requirement in DE and NE, with calculations based on metabolic BW (NE) and actual BW (DE) as illustration of how the two calculations differ in relation to increase of BW.

This thesis follows the national standards, and therefore uses $BW^{0.75}$ as a basis for calculations of energy requirements, whereas mineral requirements are based on actual BW. The term BW is used for the actual bodyweight of both adult and growing horses. The mature BW of a growing horse is referred to as "mature BW".

2.6 Viewing the economic aspects to the horse owner

Increased utilization of the nutritional content of the roughage may lead to a decrease in distribution of concentrates to the horse. Exchanging concentrates with roughage may increase the demand for roughage containing higher energy content, resulting in a higher price/FEh and/or higher price/kg DM.

If limiting or eliminating grain mixtures fed to the horse, a mineral supplement must be provided in order to cover the required vitamins and minerals, and therefore the price of this must be included in the cost of possible roughage only rations.

The cost of all-round equine mineral supplements were 20.2 NOK/kg "Champion Multitilskudd", granulated (Felleskjøpet, 2013), required 100 g/day at 500 kg BW, resulting in a cost of 2.02 NOK/day. The "Vitafôr Solid", pelleted (Norgesfôr, 2013) has a retail price of 31.8 NOK/kg and is required at +/- 175 g/day at 500 kg BW, resulting in a cost of 5.56 NOK/day.

Retail price of roughage for equines

The retail price of roughage for equines varies between regions and production years. However, one of the leading distributors of roughage for equines had the following retail prices in march 2013 (Gjesti-Furasje, 2013), including VAT (value added tax):
Hay: 5.64 NOK/kg DM
Haylage (65 – 70% DM), small bales (20 – 25 kg): 7.3 – 8.0 NOK/kg DM
Haylage (65 – 70% DM), large bales (approx. 300 kg): 4.6 – 5.3 NOK/kg DM

Retail price of concentrates

The equine feed market is stocked with numerous of dealers who provide concentrates of many types and from a variety of producers to the equine feed market. Among the national contributors, Felleskjøpet and Norgesfôr are the main producers providing a variety of mixtures to all livestock throughout the country. Prices are from February 2013 (Felleskjøpet, 2013; Norgesfôr, 2013), and are calculated based on the purchase of single bags, whereas nutritional content is listed from PC-horse (Hove Software A/S, 2013).

Felleskjøpet markets seven grain mixtures (Champion) in addition to several variations of separately bagged oats, corn, soy, sugar beet-pulp, barley and mineral mixtures. **Norgesfôr** markets four grain mixtures (Pionér) in addition to several variations of separately bagged oats, sugar beet-pulp, Lucerne and mineral mixtures.

Table 3 – Retail price and nutritional content of commonly used equine grain mixtures in Norway

	Mixture	FEh/kg	g DCP/kg	NOK/kg	NOK/FEh
Growing horses	Champion Føll	1.0	150	8.14	8.14
	Champion Oppdrett	0.88	135	4.80	5.45
	Pionér Oppdrett	0.92	140	5.95	6.46
Adult horses	Champion Komplett	0.90	75	4.45	4.94
	Champion Energi	1.0	75	4.65	4.65
	Pionér Standard	0.90	85	5.50	6.10
	Pionér Sport	1.0	140	5.75	5.75
	Oats (whole)	0.79	69	4.30* 5.50**	5.44* 6.96**

* Felleskjøpet

** Norgesfôr

(Felleskjøpet, 2013; Norgesfôr, 2013)

3. Methodology

3.1 Analysis of roughage

The analysis of forage fed to livestock in Norway is mainly performed by Eurofins Scientific, department of Eurofins Food and Agro Testing Norway A/S, located in Moss. They present the analysis results by id-numbers in Microsoft Excel. Eurofins implement the following techniques.

Analysis of dry matter

The DM analysis is performed through two steps:

Factor 1: The sample is dried at 60 °C for 24 hours, and DM is calculated from the formula: $\frac{Weight\ out - tare}{Weight\ in - tare}$. The samples are then being cooled for 4 hours during which it absorbs moisture and receives a stable weight at room temperature. The sample is then ground to 0.75 mm. for the analysis of nutritional content.

Factor 2: The remaining moisture in the sample is found by drying the sample at 60 °C for 18 hours prior to being analyzed using NIR (described below).

The DM content is then found by the formula: (Factor 1 x factor 2) x 100 = percent DM.

Analysis of energy and protein

The near-infrared (NIR)-technique is applied for analysis of energy, CP, NDF and sugar. NIR is a spectroscopic analysis at 1,100 – 2,500 nm, that uses a reflection from close-up infrared radiation to perform quantitative and qualitative measurements (Eurofins, 2012). The NIR-technique measures how much light is being absorbed by the sample, and uses this to calculate the nutritional content based on calibration and chemical scores.

Instrument: NIRs 6500

Analysis of minerals

When analyzing the content of minerals, a chemical analysis is performed. The sample is decomposed in hydrochloric acid (HCl) in a heat unit containing test-tubes. The solution is then heated from 60°C to 120°C in 8 minutes. The minerals analyzed by this technique are Ca, P, Mg, iron (Fe), copper (Cu), potassium (K), manganese (Mn), sodium (Na), zinc (Zn) and sulphur (S).

Reference method: NMKL No 161, model 1998.

Instrument: ICP-MS

3.2 Data processing

The data collected from the analysis is processed in Microsoft Excel 2010. Analysis results were sorted in respective years, where errors and duplicates were removed. The results from each sample were assembled with id-numbers with FEh, CP, DM, Ca, P and Mg.

Statistical analysis of the datasets has not been performed. Results from analysis are presented and compared through tables and figures, where possible statistical analysis output is considered to be of no supplemental value.

Energy was classified according to national standards (www.eurofins.no).

H1: > 0.62 FEh/kg DM

H2: 0.58-0.62 FEh/kg DM

H3: 0.52-0.57 FEh/kg DM

H4: 0.46-0.51 FEh/kg DM

H5: < 0.46 FEh/kg DM

DCP was calculated based on CP, with the equation: - 36.69 + (0.955 x CP) (Austbø, 2013). DCP was then divided into classes based on Eurofins grouping of DCP (www.eurofins.no).

Very high: > 115 g DCP/kg DM

High: 91-115 g DCP/kg DM

Medium: 66-90 g DCP/kg DM

Low: 40-65 g DCP/kg DM

Very low: < 40 g DCP /kg DM

DM was divided into three classes:

Higher than 84 (hay): > 84% DM

50-84 (haylage) : the range between 50% and 84% DM

Lower than 50 (silage): < 50% DM

Every year, the 20% outermost regarding energy value + each energy-class (H-class) were looked at separately. Mean, maximum and minimum value, typical value and standard deviations (SD) of these groups were calculated in Microsoft Excel 2010.

4. Calculation of nutritional requirements

By using the previous given equations, the following requirements are computed:

4.1 Nutritional requirements of growing horses

The premises of calculations

The background for calculating nutritional requirements of growing horses is given in the following tables.

Actual weight of growing horses

Based on table 1, the BW is calculated for growing horses at different classes of mature BW.

Table 4 - BW (kg) of growing horses at various ages in several groups of expected mature BW

Age (months)	% of mature BW	BW (kg) at given age				
		BW* 300	400	500	600	700
6	**47**	141	188	235	282	329
9	**58**	174	232	290	348	406
12	**67**	201	268	335	402	469
18	**82**	246	328	410	492	574
24	**89**	267	356	445	534	623
36	**97**	291	388	485	582	679

*Expected mature BW (kg)

Average daily gain (ADG) of growing horses

Based on the calculations on page 23 for calculating ADG, the following table has been made.

Table 5 - Average daily gain (ADG) in growing horses at various ages in several groups of expected mature BW (kg/day)

Age	Average daily gain (kg/day)					
(months)	BW*	300	400	500	600	700
6		0.48	0.64	0.81	0.97	1.13
9		0.33	0.44	0.55	0.66	0.77
12		0.27	0.36	0.45	0.54	0.63
18		0.18	0.24	0.30	0.36	0.42
24		0.09	0.11	0.14	0.17	0.20
36		0.06	0.07	0.09	0.11	0.13

* Expected mature BW (kg)

Intake and apportioning of feed for growing horses

DM intake per day is calculated for feeding restricted apportioned roughage and *ad libitum*.

Voluntary intake for growing horses

VDMI for the growing animal is calculated to be as follows, based on guidance from page 28.

Table 6- Estimated VDMI for growing horses at various ages in several groups expected mature BW when fed ad libitum (kg DM/day)

Age	Intake/day	Average daily intake fed *ad libitum* (kg DM/day)					
(months)	% of BW	BW*	300	400	500	600	700
6	2.5		3.5	4.7	5.9	7.1	8.2
9	2.5		4.4	5.8	7.3	8.7	10.2
12	2.5		5.0	6.7	8.4	10.1	11.7
18	2.5		6.2	8.2	10.3	12.3	14.4
24	2.5		6.7	8.9	11.1	13.4	15.6
36	2.0		5.8	7.8	9.7	11.6	13.6
36	2.5		7.3	9.7	12.1	14.6	17.0
36	3.0		8.7	11.6	14.6	17.5	20.4

* Expected mature BW (kg)

Apportioning of feed for growing horses

Amounts of roughage in a ration as defined on page 27, is given as kg DM/day.

Table 7 – Amounts of roughage apportioned to growing horses at various ages in several groups of expected mature BW, if fed a restricted ration (kg DM/day)

Age (months)	Amount roughage fed in ration (kg DM/day)					
	BW*	300	400	500	600	700
6		1.8	2.4	3.0	3.6	4.2
9		2.2	2.9	3.7	4.4	5.1
12		2.5	3.4	4.2	5.1	5.9
18		3.1	4.1	5.2	6.2	7.2
24		3.4	4.5	5.6	6.7	7.9
36		3.7	4.9	6.1	7.3	8.6

* Expected mature BW (kg)

Energy requirements of growing horses

Energy requirements for maintenance and growth of growing horses

Daily energy requirements of the growing horse are divided into two components; maintenance and growth requirements, as given on page 24.

As shown in table 8, energy requirements at age 24 months are lower than 18 and 36 months. The decrease in energy requirements from 18 months to 24 months is due to the decline in the energy needed for growth as their age increases. The increase of energy requirement from 24 months to 36 months is due to the elevated BW.

Table 8 – Energy requirements of growing horses at various ages and in several groups of expected mature BW (FEh/day)

Age (months)	Energy requirements of growing horses (FEh/day)					
	BW*	300	400	500	600	700
6		2.6	3.3	4.0	4.7	5.3
9		2.7	3.4	4.1	4.8	5.4
12		2.9	3.6	4.4	5.0	5,7
18		3.0	3.8	4.5	5.2	5.9
24		3.0	3.7	4.4	5.1	5.7
36		3.1	3.9	4.6	5.2	5.9

* Expected mature BW (kg)

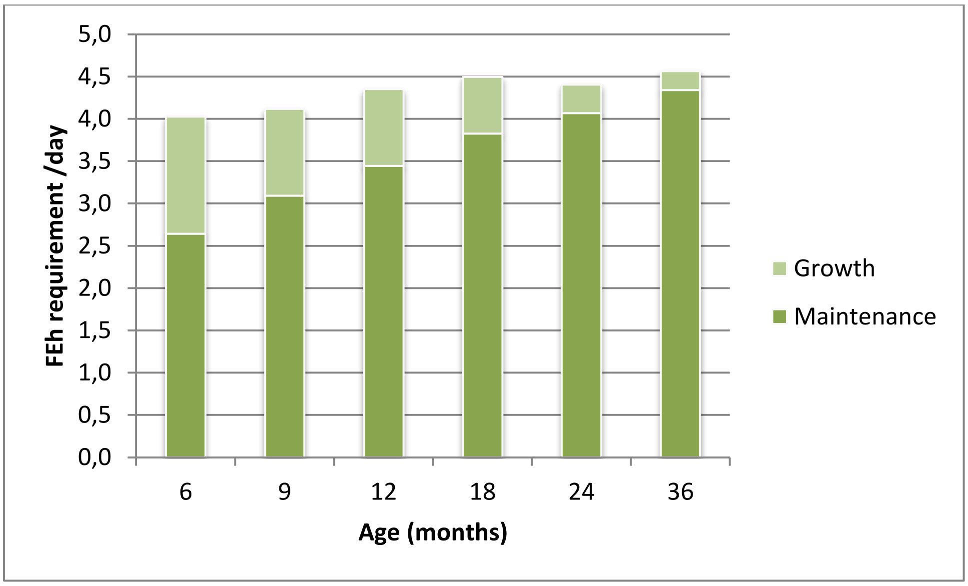

Figure 2 – The parts of energy requirements making up the total energy requirement of a growing horse with 500 kg expected mature BW (FEh/day)

The figure of a 500 kg mature BW horse illustrates how the total energy requirements of growing horses are distributed at various ages, and how this change as the horse grows older, as stated in the equation on page 24 .

Energy requirements of growing horses at outdoor housing

The energy requirement of the growing horse in outdoor housing is calculated based on the premises given on page 24.

Table 9 - Energy requirements of growing horses at various ages in several groups of expected mature BW when stalled at outdoor housing (FEh/day)

Age (months)	Energy requirement for growing horses, outdoor housing (FEh/day)					
	BW*	300	400	500	600	700
6		2.9	3.7	4.4	5.2	5.9
9		3.0	3.8	4.5	5.3	6.0
12		3.2	4.0	4.8	5.5	6.3
18		3.3	4.2	4.9	5.7	6.4
24		3.3	4.1	4.8	5.6	6.3
36		3.4	4.2	5.0	5.8	6.5

* Expected mature BW (kg)

Energy requirements of the growing horse when exercised

The calculations of energy requirements for growing horses at different levels of exercise (FEh/day) are based on levels of intensities listed on page 23.

Exercise of the growing horse

Table 10- Energy requirement of growing horses in several groups of expected mature BW, when undergoing different levels of exercise at various ages (FEh/day)

Age (months)	Intensity	Energy requirement of growing horses at exercise (FEh/day)					
		BW*	300	400	500	600	700
18	**Light**		3.6	4.5	5.4	6.2	7.0
	Moderate		4.2	5.3	6.3	7.3	8.2
	Heavy		4.8	6.0	7.2	8.3	9.4
24	**Light**		3.6	4.5	5.3	6.1	6.9
	Moderate		4.2	5.2	6.2	7.1	8.0
	Heavy		4.8	5.9	7.1	8.1	9.1
36	**Light**		3.7	4.6	5.6	6.3	7.1
	Moderate		4.3	5.4	6.4	7.3	8.3
	Heavy		4.9	6.2	7.3	8.4	9.4

* Expected mature BW (kg)

Protein requirements for growing horses

Daily requirement of protein for growing horses

Daily DCP requirements of the growing animal are the sum of maintenance requirements + requirements of growth, as it is calculated based on energy requirement. The background for daily DCP requirement is given on page 25.

Table 11 –Daily DCP requirements of growing horses at various ages in several groups of expected mature BW (g DCP/day)

Age	DCP requirement of growing horses (g DCP/day)				
(months)	BW* 300	400	500	600	700
6	342.1	434.4	523.4	609.7	693.9
9	353.9	446.5	535.0	620.5	703.6
12	274.7	345.7	413.3	478.5	541.7
18	221.8	275.2	325.3	372.9	418.7
24	238.0	296.8	352.3	405.4	456.5
36	247.4	308.0	365.1	419.5	471.9

* Expected mature BW (kg)

Protein requirement at outdoor housing

The additional 10 % of DCP requirements due to outdoor housing are shown in Table 12, as DCP requirements are calculated based on energy requirement.

Table 12 - Daily DCP requirements of growing horses at various ages in several groups of expected mature BW when stalled at outdoor housing (g DCP/day)

Age	DCP requirements of growing horses, outdoor housing (g DCP/day)				
(months)	BW* 300	400	500	600	700
6	376.3	477.9	575.7	670.6	763.3
9	389.3	491.1	588.5	682.6	774.0
12	302.2	380.2	454.6	526.3	595.8
18	243.9	302.7	357.8	410.2	460.5
24	261.8	326.5	387.6	445.9	502.2
36	272.2	338.8	401.6	461.5	519.1

* Expected mature BW (kg)

Protein requirements of the growing horse when exercised

DCP requirements for growing horses at different levels of exercise (DCP). Background for calculating DCP requirement due to exercise of the growing horse is found on page 23.

Exercise of the growing horse

Table 13- DCP requirement of growing horses at various ages in several groups of expected mature BW when undergoing various levels of exercise (g DCP/day)

Age (months)	Intensity	Protein requirement of growing horses at exercise (g DCP/day)				
		BW* 300	400	500	600	700
18	Light	266.1	330.2	390.3	447.5	502.4
	Moderate	310.5	385.2	455.4	522.1	586.1
	Heavy	354.8	440.2	520.4	596.7	669.8
24	Light	285.6	356.2	422.8	486.5	547.8
	Moderate	333.2	415.5	493.3	567.6	639.1
	Heavy	380.8	474.9	563.7	648.6	730.4
36	Light	296.9	369.6	438.1	503.4	566.3
	Moderate	346.4	431.2	511.1	587.3	660.7
	Heavy	395.9	492.8	584.1	671.3	755.0

* Expected mature BW (kg)

Mineral requirements of growing horses

As given in Table 14, Ca and P requirements of growing horses are the same independent of exercise. Requirements of Mg increase with exercise, but increased requirements are equal at all levels of exercise.

Table 14 - Mineral requirements of growing horses at various ages in several groups of expected mature BW (g/day)

	Age (months)	Mineral requirements of growing horses (g/day)**					
		BW*	300	400	500	600	700
Ca	6		30.8	41.0	51.3	61.5	71.8
	9		27.6	36.8	46.0	55.2	64.5
	12		27.8	37.0	46.3	55.5	64.8
	18		28.2	37.6	47.0	56.4	65.8
	24		26.4	35.1	43.9	52.7	61.5
	36		27.3	36.4	45.5	54.6	63.7
P	6		17.1	22.8	28.5	34.2	39.9
	9		15.4	20.5	25.6	30.7	35.8
	12		15.4	20.6	25.7	30.9	36.0
	18		15.7	20.9	26.1	31.3	36.5
	24		14.6	19.5	24.4	29.3	34.2
	36		15.2	20.2	25.3	30.3	35.4
Mg	6		3.3	4.4	5.4	6.5	7.6
	9		3.6	4.8	6.0	7.2	8.5
	12		4.0	5.4	6.7	8.0	9.4
	18		4.7	6.3	7.8	9.4	11.0
	18 (exercise)		8.9	11.8	14.8	17.7	20.7
	24		4.9	6.6	8.2	9.9	11.5
	24 (exercise)		9.6	12.8	16.0	19.2	22.4
	36		5.3	7.1	8.9	10.6	12.4
	36 (exercise)		10.5	14.0	17.5	21.0	24.4

* Expected mature BW (kg)

** Requirements are calculated as given in NRC x 1.2

4.2 Nutritional requirements for adult horses

The premises of calculations

Intake and apportioning of feed for adult horses

Voluntary intake of adult horses

Estimated VDMI based on values given on page 299, when fed roughage *ad libitum*.

Table 15 – Estimated VDMI of adult horses fed ad libitum roughage (kg DM/day)

Load of exercise	Intake/day % of BW	Average intake fed *ad libitum* (kg DM/day) BW (kg) 300	400	500	600	700
Maintenance	**2.0**	6.0	8.0	10.0	12.0	14.0
«Light» (+ 25 %)	**2.0**	6.0	8.0	10.0	12.0	14.0
«Moderate» (+ 50 %)	**2.25**	6.8	9.0	11.3	13.5	15.8
«Heavy» (+ 75 %)	**2.5**	7.5	10.0	12.5	15.0	17.5
«Intense» (+100 %)	**2.5**	7.5	10.0	12.5	15.0	17.5

Apportioning of feed for adult horses

Amounts of roughage in rations are based on BW, as defined at page 27. This results in the same level of intake at maintenance levels and all levels of exercise.

Table 16 – Amount of roughage apportioned to adult horses in relation to BW (kg DM/day)

Load of exercise	Amount roughage fed in rations (kg DM/day) BW (kg) 300	400	500	600	700
Maintenance and exercise*	3.8	5.0	6.3	7.6	8.8

*All levels of exercise

Energy requirements of adult horses

A more detailed description of the types of horses can be found on page 25.

Energy requirements of the adult horse

Based on the information given on calculating energy requirement of the adult horse as defined on page 25, the following requirements regarding energy have been calculated for adult horses:

Table 17 - Energy requirements of adult coldblooded horses at maintenance, outdoor housing and different levels of exercise (FEh/day)

Coldblooded	Energy requirement of coldblooded horses (FEh/day) BW (kg) 300	400	500	600	700
Maintenance	2.7	3.3	3.9	4.5	5.0
Outdoor housing	2.9	3.6	4.3	4.9	5.5
Light exercise	3.3	4.1	4.9	5.6	6.3
Moderate exercise	4.0	5.0	5.9	6.7	7.6
Heavy exercise	4.7	5.8	6.9	7.9	8.8
Intense exercise	5.3	6.6	7.8	9.0	10.1

Table 18 - Energy requirements of adult warm-blooded horses at maintenance, outdoor housing and different levels of exercise (FEh/day)

Warmblooded	Energy requirement of warm-blooded horses (FEh/day) BW (kg) 300	400	500	600	700
Maintenance	2.8	3.5	4.1	4.7	5.3
Outdoor housing	3.1	3.8	4.5	5.2	5.8
Light exercise	3.5	4.3	5.1	5.9	6.6
Moderate exercise	4.2	5.2	6.2	7.1	7.9
Heavy exercise	4.9	6.1	7.2	8.2	9.3
Intense exercise	5.6	6.9	8.2	9.4	10.6

Table 19 - Energy requirements of adult thoroughbred horses at maintenance, outdoor housing and different levels of exercise (FEh/day)

Thoroughbred	Energy requirement of thoroughbred horses (FEh/day)				
	BW (kg) 300	400	500	600	700
Maintenance	2.9	3.6	4.3	4.9	5.5
Outdoor housing	3.2	4.0	4.7	5.4	6.1
Light exercise	3.7	4.6	5.4	6.2	6.9
Moderate exercise	4.4	5.5	6.5	7.4	8.3
Heavy exercise	5.1	6.4	7.5	8.6	9.7
Intense exercise	5.9	7.3	8.6	9.9	11.1

Protein requirements of adult horses

Protein requirements of the adult horse

Requirements of DCP are listed on page **Feil! Bokmerke er ikke definert.**5. The calculations are given for maintenance, outdoor housing and different levels of exercise are given in the following tables:

Table 20 – DCP requirements of adult coldblooded horses at maintenance, outdoor housing and different levels of exercise (g DCP/day)

Coldblooded	DCP requirement of coldblooded horses (g DCP/day)				
	BW (kg) 300	400	500	600	700
Maintenance	213.4	264.8	313.0	358.8	402.8
Outdoor housing	234.7	291.2	344.3	394.7	443.1
Light exercise	266.7	330.9	391.2	448.6	503.5
Moderate exercise	320.1	397.1	469.5	538.3	604.2
Heavy exercise	373.4	463.3	547.7	628.0	704.9
Intense exercise	426.7	529.5	626.0	717.7	805.6

Table 21 – DCP requirements of adult warm-blooded horses at maintenance, outdoor housing and different levels of exercise (g DCP/day)

Warmblooded	DCP requirement of warm-blooded horses (g DCP/day)				
	BW (kg) 300	400	500	600	700
Maintenance	224.0	278.0	328.6	376.8	423.0
Outdoor housing	246.4	305.8	361.5	414.5	465.3
Light exercise	280.0	347.5	410.8	471.0	528.7
Moderate exercise	336.1	417.0	492.9	565.2	634.4
Heavy exercise	392.1	486.5	575.1	659.4	740.2
Intense exercise	448.1	556.0	657.3	753.6	845.9

Table 22 – DCP requirements of adult thoroughbred horses at maintenance, outdoor housing and different levels of exercise (g DCP/day)

Thoroughbred	DCP requirement of thoroughbred horses (g DCP/day)				
	BW (kg) 300	400	500	600	700
Maintenance	234.7	291.2	344.3	394.7	443.1
Outdoor housing	258.2	320.3	378.7	434.2	487.4
Light exercise	293.4	364.0	430.4	493.4	553.9
Moderate exercise	352.1	436.8	516.4	592.1	664.7
Heavy exercise	410.7	509.6	602.5	690.8	775.4
Intense exercise	469.4	582.5	688.6	789.5	886.2

Mineral requirements of adult horses

The premises for mineral requirements of the adult horse are found on page 275. Mineral requirements for the adult horse increase synonymously with an increased amount of exercise, as shown in Table 23.

Table 23 - Mineral requirements for all types of adult horses at different levels of exercise (g/day)

Mineral	Exercise	Mineral requirement of adult horses* (g/day)					
		BW (kg)	300	400	500	600	700
Ca	Maintenance		14.4	19.2	24.0	28.8	33.6
	Light exercise		21.6	28.8	36.0	43.2	50.4
	Moderate exercise		25.2	33.6	42.0	50.4	58.8
	Heavy/ Intense ex.		28.8	38.4	48.0	57.6	67.2
P	Maintenance		10.1	13.4	16.8	20.2	23.5
	Light exercise		13.0	17.3	21.6	25.9	30.2
	Moderate exercise		15.1	20.2	25.2	30.2	35.3
	Heavy/ Intense ex.		20.9	27.8	34.8	41.8	48.7
Mg	Maintenance		5.4	7.2	9.0	10.8	12.6
	Light exercise		6.8	9.1	11.4	13.7	16.0
	Moderate exercise		8.3	11.0	13.8	16.6	19.3
	Heavy/ Intense ex.		10.8	14.4	18.0	21.6	25.2

* Requirements are calculated as given in NRC x 1.2

4.3 Nutritional requirement coverage by roughage

The previous calculation of nutritional requirements defines the nutritional need of energy and DCP in various horses. When combined with the estimated VDMI or apportioning of feed, the demand for nutritional content of roughage in order to cover nutritional requirements can easily be made for every horse.

Roughage for equines is classified according to energy content (FEh/kg DM) and DCP content (g DCP/kg DM). By calculating and combining this literature, the standards for what roughage is suitable to what horse, have been made.

As the requirement for energy and DCP depends on BW and mature BW, the following figures will display BW and expected mature BW of 300 kg (sample of regular pony) and 500 kg (sample of regular horse) to illustrate nutritional requirements of horses.

Suitable roughage for growing horses regarding energy and DCP demand

When assessing the coverage of growing horses, *ad libitum* feeding is assumed as feeding roughage as part of restricted ration will not at any level be relevant regarding energy or DCP coverage.

The demand for energy in roughage for the growing horse at different age

The energy requirement of growing horses is given in Table 8.

Expected mature BW 300 kg

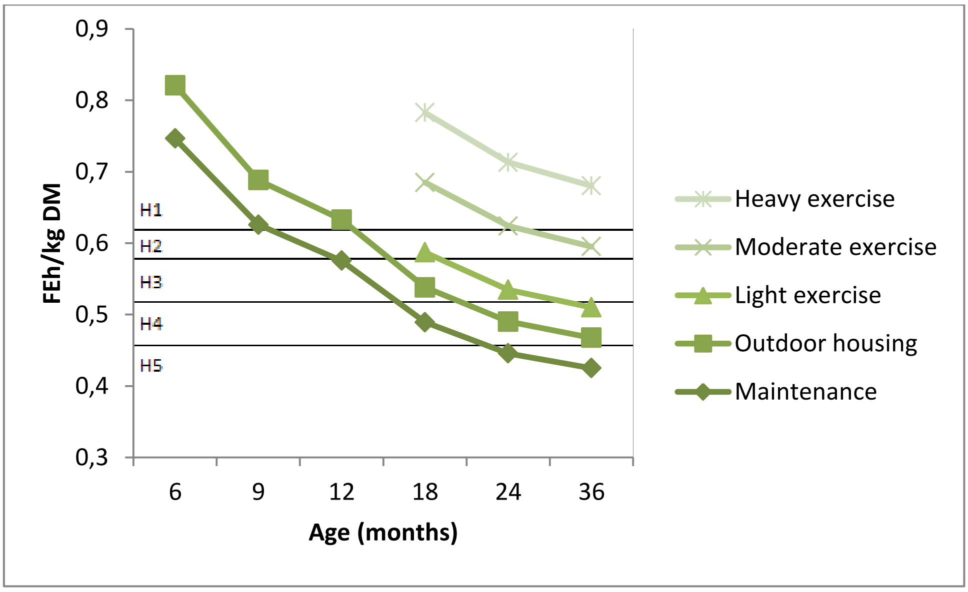

Figure 3 – Demand for energy in roughage (FEh/kg DM) in order to cover the requirement of growing horses with expected mature BW of 300 kg at VDMI 2.5% of BW

As the figure shows, growing horses with expected mature BW of 300 kg at age 9 months and younger, does not receive an adequate amount of energy, even if fed on H1. In outdoor housing, often used for growing horses, H1 may supply adequate energy content for growing horses starting at 12 months of age. At 24 months of age, H5 may provide adequate energy at no outdoor housing or exercise performed.

Expected mature BW 500 kg

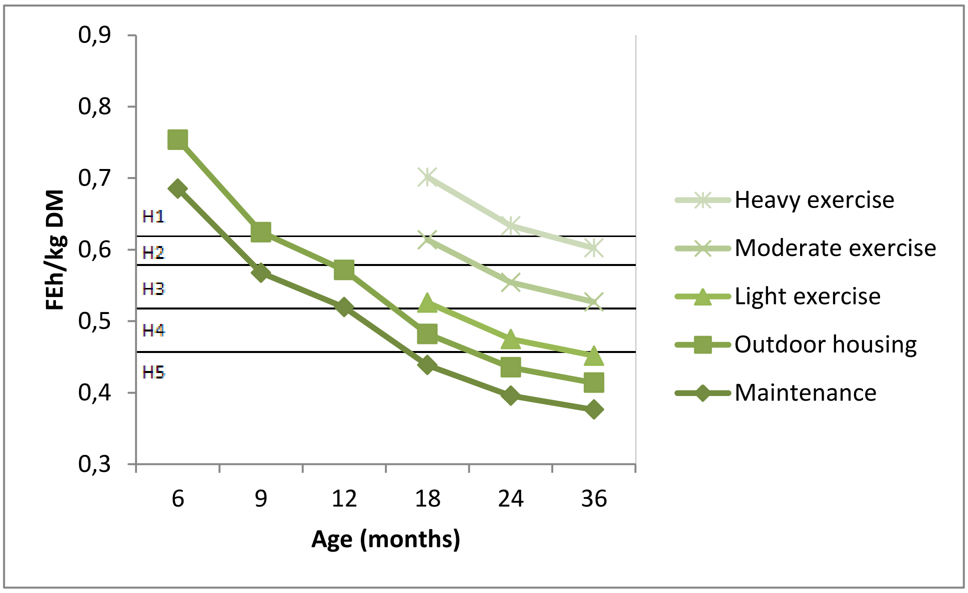

Figure 4 - Demand for energy in roughage (FEh/kg DM) in order to cover the requirement of growing horses with expected mature BW of 500 kg at VDMI 2.5% of BW

As for the growing horse with mature BW of 500 kg, the demand for energy content in roughage is lower than for those mature BW of 300 kg. The growing horse with expected BW of 500 kg may cover the energy requirement from high H1 roughage already at age less than 9 months (regular housing) and 12 months (outdoor housing). The energy requirement of "light exercise" for the growing horse with expected mature BW 500 kg can be covered solely by roughage.

The demand for protein in roughage for the growing horse at different age

Expected mature BW 300 kg

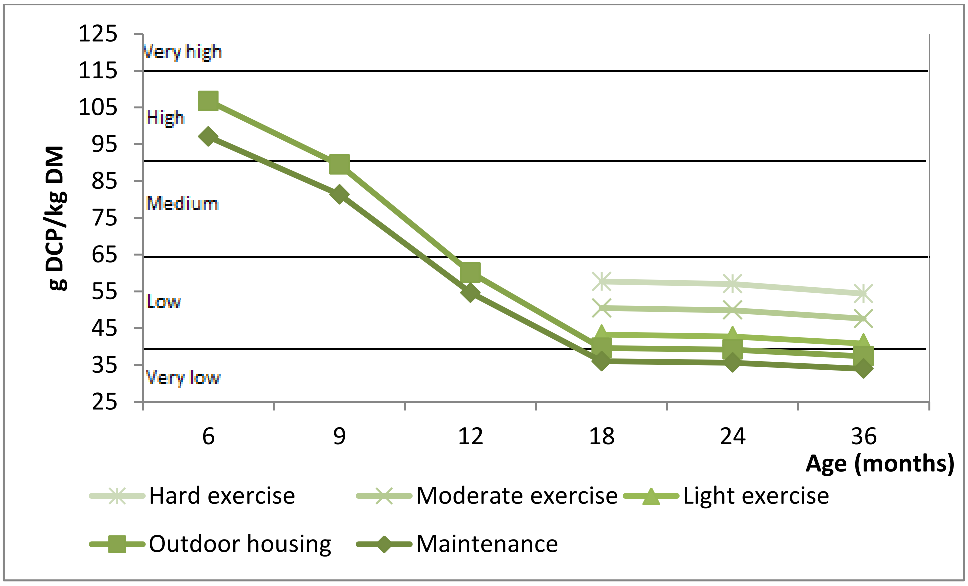

Figure 5- Demand for protein in roughage (g DCP/kg DM) in order to cover the requirement of growing horses with expected mature BW of 300 kg at VDMI 2.5% of BW

As figure 5 shows, the DCP demand decreases as the age of the horse increases. Even so, the demand for DCP in roughage for a growing horse with expected mature BW 300 kg starts within the "high" level of DCP at 6 months of age, both at regular stalling (98 g DCP/kg DM) and outdoor housing (107 g DCP/kg DM). No growing horses at age over 12 months have a DCP demand of roughage to be higher than level "low", even at exercise.

Expected mature BW 500 kg

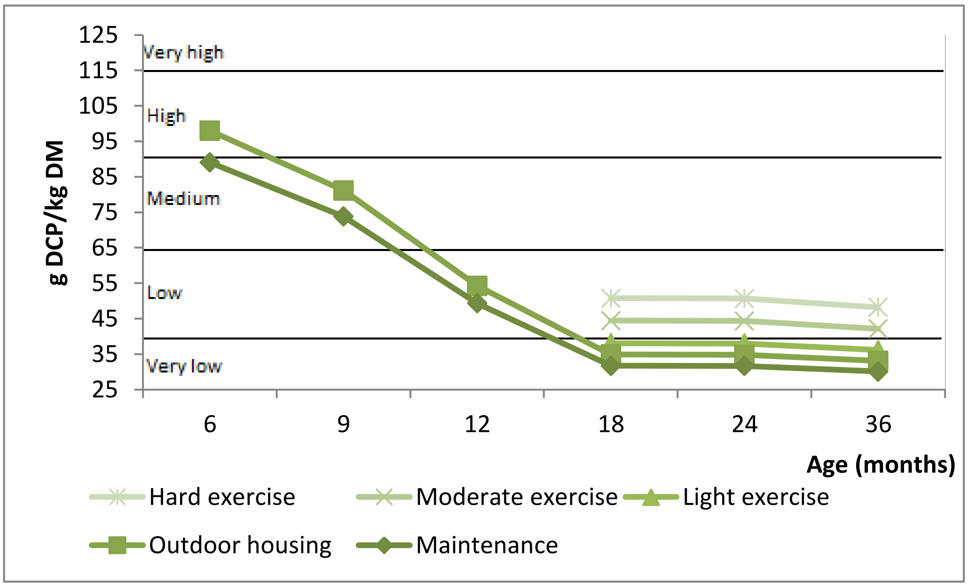

Figure 6- Demand for protein in roughage (g DCP/kg DM) in order to cover the requirement of growing horses with expected mature BW of 500 kg at VDMI 2.5% of BW

The above figure shows DCP requirement of growing horses with adult BW expected to be 500 kg. The demand for DCP/kg DM in the roughage is somewhat lower than those in

Figure 5, showing how the heavier horses have a lower demand of each kg DM regarding both energy and DCP. At 18 months of age, the demand for DCP in the roughage is within the "very low", during both housing conditions and light exercise.

The demand for minerals in roughage for the growing horse at different age

The mineral requirements of g/kg DM are equal to all growing horses at different expected adult BW, but decreases as age increases. As mentioned on page 21, the average Ca content of roughage for equines is 3 – 5 g/kg DM. As table 24 shows, this content may be at high levels in order to cover the needs of the growing horse at 18 months and older, or it may not cover the needs of growing horses overall. The average content of P is 2-3 g/kg DM. As shown in table 24, this may also cover the needs of the 18 months old and older if being at a high level, or it may not cover the requirement of P overall. When looking at Mg, the average content is 1.2 – 2.2 g /kg DM, a level safely covering the Mg requirement of growing horses, possibly also during all levels of exercise.

Table 24 – Demand for mineral content in roughage (g/kg DM) in order to cover mineral requirement of growing horses at various ages at VDMI 2.5% of BW

Age (months)	Demand for mineral content in roughage for growing horses (g/kg DM)			
	Ca	P	Mg	Mg (exercise)
6	8.72	4.85	0.93	-
9	6.35	3.53	0.83	-
12	5.52	3.07	0.80	-
18	4.58	2.55	0.76	1.44
24	3.95	2.19	0.74	1.44
36	3.75	2.09	0.73	1.44

Suitable roughage for adult horses regarding energy and DCP demand

When assessing the coverage of adult horses, both *ad libitum* and roughage fed in a restricted ration may be relevant to research regarding energy or DCP coverage.

The demand for energy in roughage for the adult horse

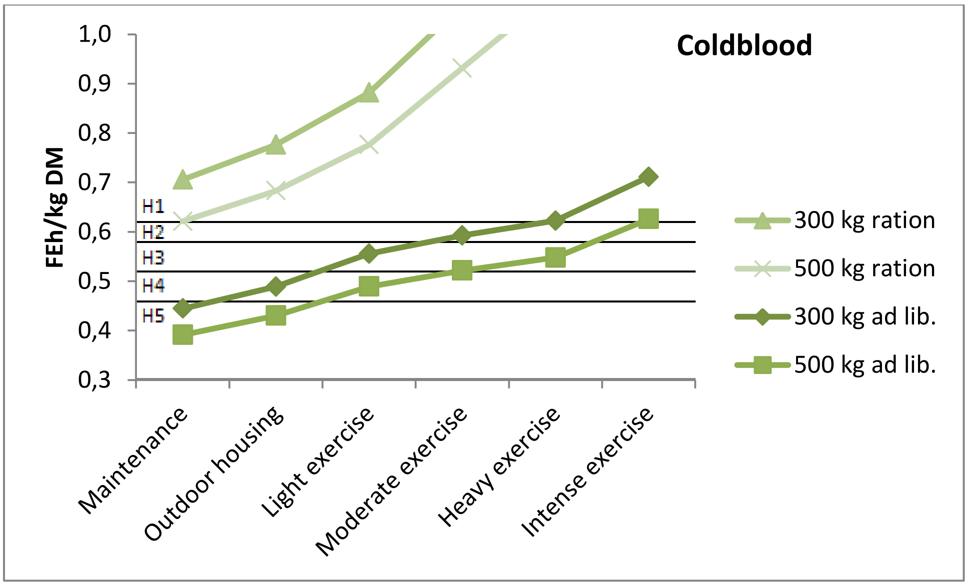

Figure 7 – Demand for energy in roughage (FEh/kg DM) in order to cover the requirement of coldblooded horses 300 and 500 kg BW, fed roughage in a restricted ration (apportioned) or ad libitum (VDMI according to exercise intensity)

As figure 7 shows, an apportioned roughage only diet will have an energy demand of roughage being H1 in order to supply adequate energy content to a coldblooded 300 kg and

500 kg BW horse. During exercise of either horses, as well as outdoor housing, roughage will not provide the energy needed if fed restricted ration. When looking at ad libitum feeding of roughage, both sampled weight classes cover their need at maintenance level if fed hay of energy content H5. Ponies (example by 300 kg BW) have a somewhat higher demand for energy in the roughage; needing H4 in outdoor housing.

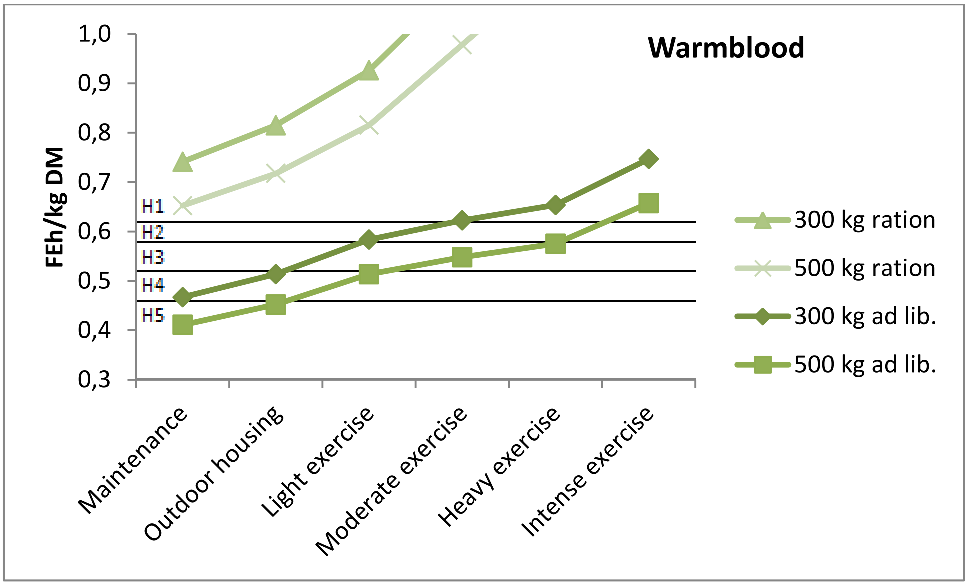

Figure 8 - Demand for energy in roughage (FEh/kg DM) in order to cover the requirement of warm-blooded horses 300 and 500 kg BW, fed roughage in a restricted ration (apportioned) or ad libitum (VDMI according to exercise intensity)

For warm-blooded horses, roughage only diets fed as ration may only be able to cover a regular size horse (example by 500 kg BW) at maintenance level. Ad libitum feeding will, however, cover the needs of the 500 kg BW horse at all levels except at "intense exercise". Maintenance level of the 500 kg BW has a H5 demand for energy in roughage, while the 300 kg BW horses have a demand at H4.

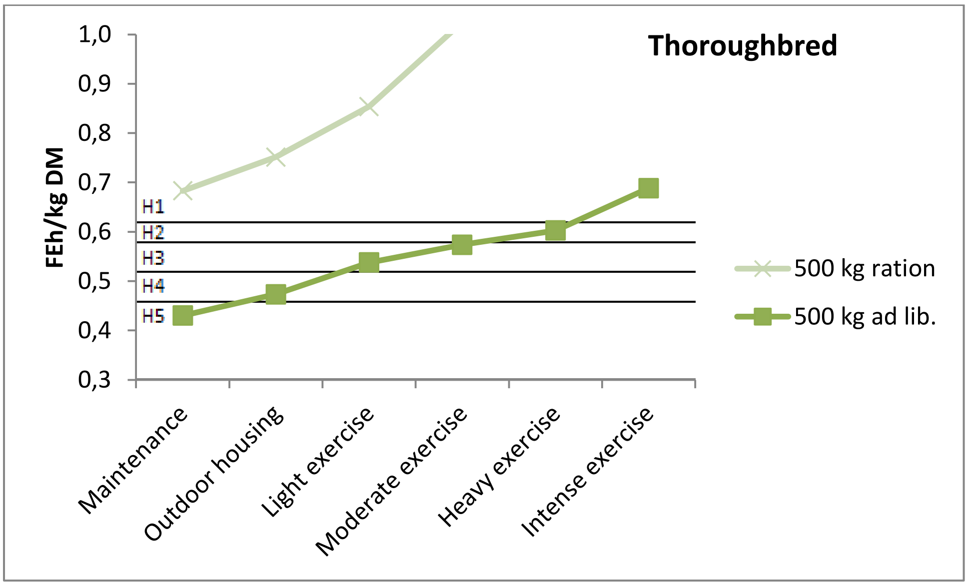

Figure 9 - Demand for energy in roughage (FEh/kg DM) in order to cover the requirement of thoroughbred horses 500 kg BW, fed roughage in a restricted ration (apportioned) or ad libitum (VDMI according to exercise intensity)

As the figure shows, the thoroughbred horses are not be able to obtain the required energy from a roughage only diet. If fed ad libitum however, the thoroughbred horse weighing 500 kg BW will, like the warm-blooded horse, have a demand of energy in roughage starting at H5 during maintenance and approximately increasing by one energy level class for each adjustment of housing and exercise intensity. The energy requirement of “intense exercise” will not possibly be covered by horses fed forage diets only.

The demand for protein in roughage for the adult horse

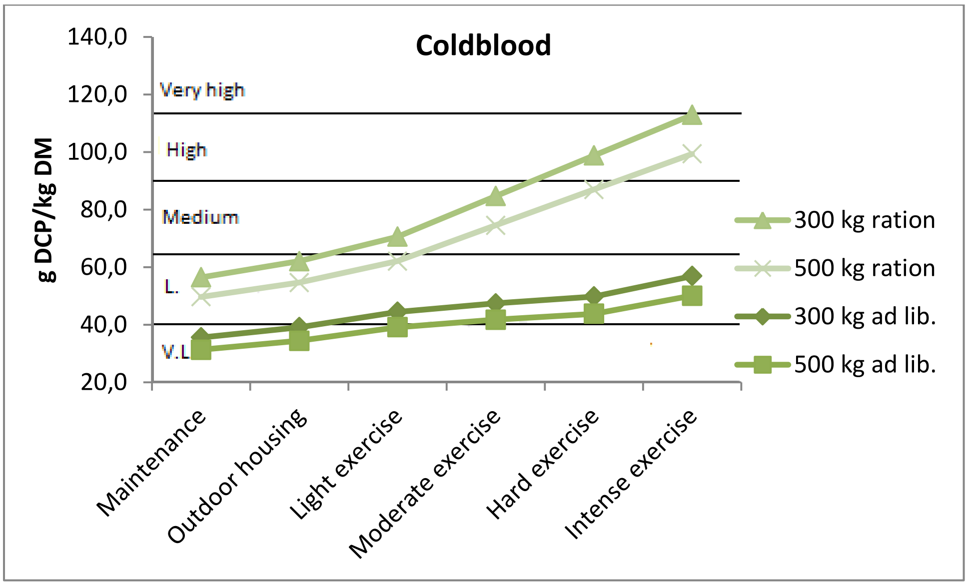

Figure 10 - Demand for protein in roughage (g DCP/kg DM) in order to cover the requirement of coldblooded horses 300 and 500 kg BW, fed roughage in a restricted ration (apportioned) or ad libitum (VDMI according to exercise intensity)

If apportioned a roughage only diet, the demand for DCP is still at a “low” level for the coldblooded horse during maintenance and outdoor housing at all weight groups. Exercising the ration fed horse requires a steeper increase of DCP demand in roughage, but the coldblooded horse does not have a demand within the level of “very high” at any point.

When fed ad libitum, the coldblooded horse at both 300 kg BW and 500 kg BW only requires a “very low” and “low” level throughout all exercise intensities.

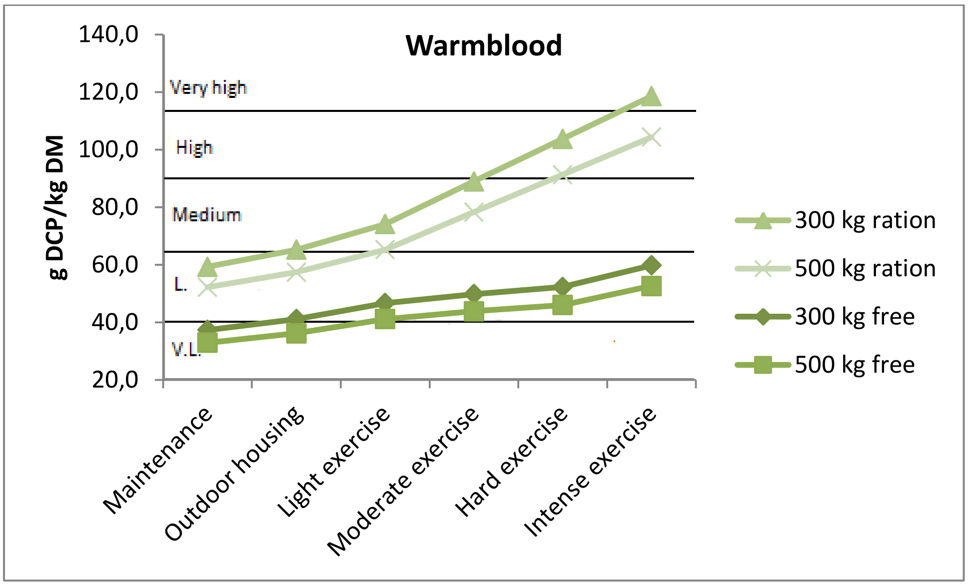

Figure 11 - Demand for protein in roughage (g DCP/kg DM) in order to cover the requirement of warm-blooded horses 300 and 500 kg BW, fed roughage in a restricted ration (apportioned) or ad libitum (VDMI according to exercise intensity)

While apportioning feed to the warm-blooded horse, feeding a roughage only diet will cover the requirement at "low" level of DCP/kg DM during maintenance and outdoor housing.

As in the coldblooded horse, the warm-blooded horse also requires a "very low" and "low" content of DCP at ad libitum feeding of roughage for both the 300 kg BW and 500 kg BW horse at maintenance, outdoor housing and all levels of exercise.

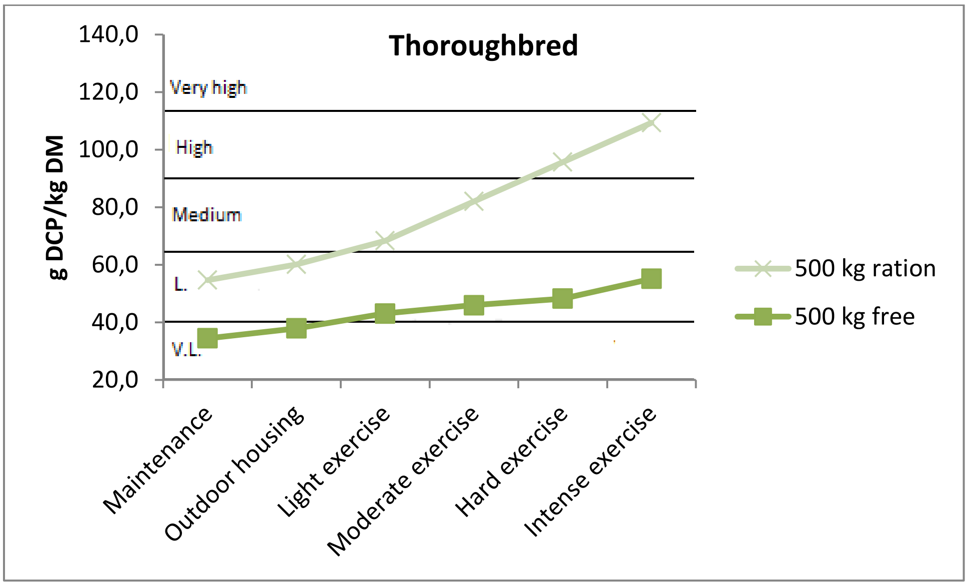

Figure 12 – Demand for protein in roughage (g DCP/kg DM) in order to cover the requirement of thoroughbred horses 500 kg BW, fed roughage in a restricted ration (apportioned) or ad libitum (VDMI according to exercise intensity)

As seen by figure 12, the thoroughbred horse at 500 kg BW fed *ad libitum* roughage has a DCP demand of roughage at "very low" content during maintenance level and outdoor housing, only increasing to "low" during all levels of exercise. When apportioned roughage in roughage only diets, the demand for DCP in roughage increases rapidly in relation to exercise intensity.

The demand for minerals in roughage for the adult horse

As mentioned on page 21, the average Ca content of roughage for equines is 3 – 5 g/kg DM. As table 25 shows, this surely covers the maintenance requirement of Ca in the adult horse, and may also cover the requirement at all points. The average content of P is 2-3 g/kg DM, is also surely cover the requirement at maintenance level and may cover the requirement at all points. When looking at Mg, the average content of is 1.2 – 2.2 g /kg DM, a level safely covering the Mg requirement of the adult horse, possibly also during exercise, the same as seen in the growing horse.

Table 25 - Demand for mineral content in roughage (g/kg DM) in order to cover mineral requirement of adult horses when fed ad libitum (VDMI according to exercise intensity)

	Mineral requirement of roughage for adult horses (g/kg DM)		
Age (months)	**Ca**	**P**	**Mg**
Maintenance	2.40	1.68	0.90
Light exercise	3.60	2.16	1.14
Moderate exercise	3.73	2.24	1.23
Heavy exercise	3.84	2.78	1.44
Intense exercise	3.84	2.78	1.44

5. Results

5.1 Roughage analyses of 2007, 2008 and 2012

The three chosen years of roughage production is selected based on the general opinion of being in distinctive, yet still being among the latest growth seasons.

Weather reports shows the actual situations of the selected years, and reveal how the general opinion may or may not be accurate. However, weather reports are given by the Norwegian Weather Bureau; "Meteorologisk Institutt" (www.met.no) as an overview of the country, where regional differences are not presented to a large extent. The areas Nordland, Troms and Finnmark are names of the northern parts of the country. Roughage productions in these regions are minimal, and are therefore not counted as appreciable regarding production results. Weather reports covering these areas are therefore considered of less influence.

The growth season includes the months of May – September, where temperatures and rainfall are related to average given in the period of 1961-1990.

2007 roughage production

2007 growth season and weather report

2007 is recalled to be an unfavorable and rainy growth season. Results did show that this year did display H3 as typical value, did not differ noticeably in DCP distribution, but were lower than the other chosen years regarding mineral content.

Rainfall

The spring of 2007 received 145% of average rainfall when looking at the country in total. "Vestlandet" (west regions) and northern parts of Trøndelag received great amounts of rainfall above average, while parts of "Østlandet" (eastern regions) only received 60 – 80% of average. During the summer, the rainfall was 110% of average, where "Østlandet" received 175 – 200% of average. These rainfalls are reported as concentrated, resulting in areas being flooded.

Temperature

In regards to temperature, the mean temperature during spring 2007 was 2.1 °C above average. Since 1900, only 2002 and 2004 have had a warmer spring than 2007. Finnmark and "Østlandet" were the areas with highest deviation, whereas the coastline received the highest mean temperature throughout the spring. The mean temperatures of the summer season were 1 °C above average. Temperature measurements were above average for the country in whole, except for eastern parts of Finnmark. Some areas have 2007 as their record holder of high mean temperatures during the summer.

2007 roughage production results

Eurofins analysis of roughage for equines from the growth season of 2007 are covering n = 798 analysis of energy, DCP and DM, and n= 269 analysis of minerals. Typical value does display the interval covering the majority of the samples. These results displayed following:

Table 26 - Summary of 2007 roughage analysis results, per kg DM

		FEh (n = 798)	**DCP (g)** (n = 798)	**Ca (g)** (n = 266)	**P (g)** (n = 266)	**Mg (g)** (n = 266)
Total 2007	Mean	0.58	68.9	2.30	1.66	0.96
	SD	0.08	27.5	0.79	0.47	0.36
	Max	0.83	176.3	5.91	3.28	2.56
	Min	0.33	1.5	0.30	0.56	0.26
	TV	> 0.66*	-	-	-	-

* does place at the high part of group H1, but H2 + H3 does cover the majority of samples

The total production of roughage for equines is divided into hay and haylage + silage in table 27.

Table 27 - 2007 roughage analysis results grouped according to DM, per kg DM

		FEh	DCP (g)	Ca (g)	P (g)	Mg (g)
Hay	n	235	235	92	92	92
	Mean	0.55	64.8	2.51	1.86	1.09
	SD	0.07	28.2	0.80	0.49	0.41
	Max	0.77	140.9	5.55	3.28	2.56
	Min	0.33	1.5	1.18	0.95	0.51
Haylage and silage	n	561	561	174	174	174
	Mean	0.60	70.6	2.19	1.55	0.89
	SD	0.08	27.1	0.77	0.42	0.31
	Max	0.83	176.3	5.91	2.60	1.88
	Min	0.39	13.0	0.30	0.56	0.26

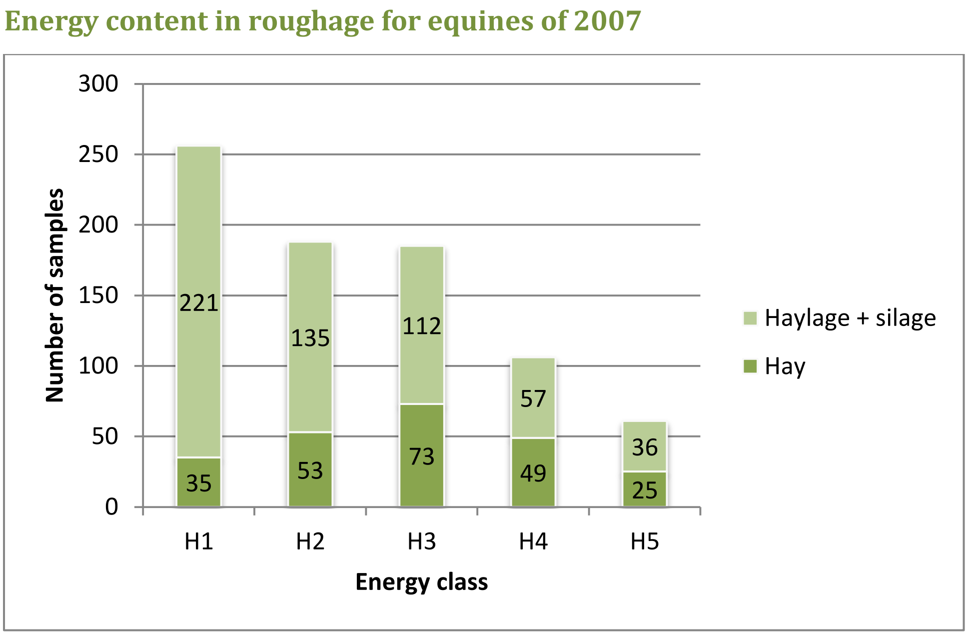

Figure 13- The energy distribution of hay and haylage + silage in all analyzed roughage for equines produced in 2007 (number of samples)

The group of H1 includes 258 samples, making 32% of the total amount of 798 samples from 2007. H5 includes 61 of the samples, making up 8% of the total of 2007.

Protein content in roughage for equines production of 2007

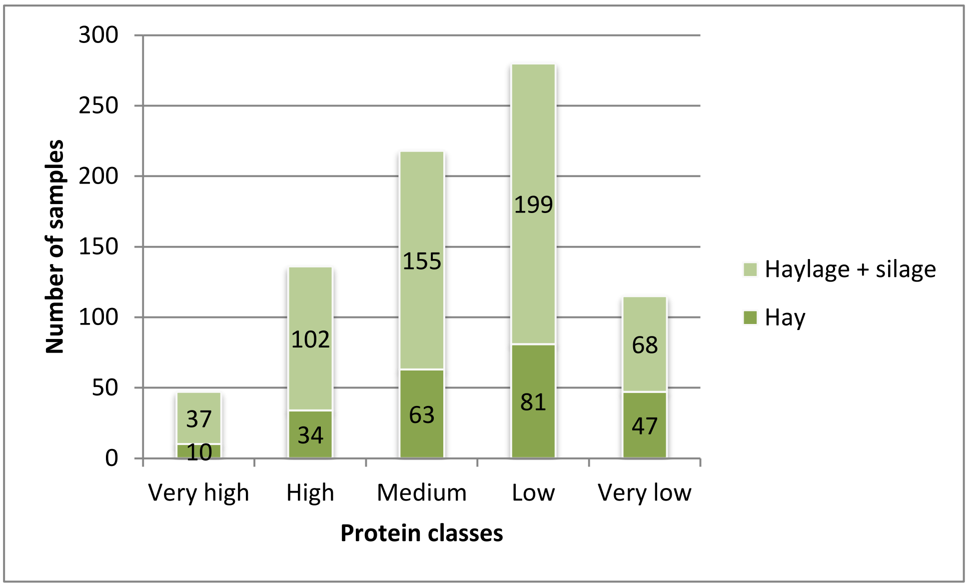

Figure 14 – The protein distribution of hay and haylage + silage in all analyzed roughage for equines produced in 2007 (number of samples)

The group of "low" makes up 35% of the total, while "medium" makes up 27% of the total 798 samples of 2007 production.

Dry matter content in roughage for equines of 2007

As shown in table 27, only 30% of analyzed samples were categorized as hay (> 84% DM). In the group of silage and haylage, the majority of the samples (501 samples) were categorized as haylage, making up 63% of total production of 2007, whereas only 61 of the samples were classified as silage.

Energy class H3 did hold the largest number of samples being hay, whereas the largest amount of haylage and silage were found in energy class H1. As for DCP, the largest amount of samples from both hay and haylage + silage were classified as "low".

Mineral content in roughage for equines of 2007

As shown in table table 26, the roughage produced in 2007 did have a mean value of Ca at 2.30 g/kg DM (SD: 0.79). Mean value of P was 1.66 g/kg DM (SD: 0.47), while it had a mean value of manganese at 0.96 g/kg DM (SD: 0.36). The mean values of all three minerals are below the mineral content on roughage for equines stated as average by Eurofins (www.eurofins.no), displayed on page 21.

20% outermost of 2007 roughage for equines

The groups covering the highest and lowest 20% of samples in regard of energy have been summarized in table 28.

Table 28 - Summary of 20% outermost of 2007 roughage analysis results, per kg DM

Total 2007		FEh (n = 160)	DCP (g) (n = 160)	DM (%) (n = 160)
20% highest	**Mean**	0.69	86.7	65.8
	SD	0.03	28.8	13.7
	Max	0.83	176.3	90.9
	Min	0.66	18.7	30.0
20% lowest	**Mean**	0.46	45.6	77.2
	SD	0.04	17.9	13.5
	Max	0.51	93.2	93.3
	Min	0.33	1.5	35.3

The mean value of the highest 20% of 2007 is 0.69 FEh/kg DM, a value clearly placing it in H1. Lowest value of the group is at 0.66 FEh/kg DM, also within H1. The highest 20% have a DCP mean value of 86.7 g DCP/kg DM, which is placed in DCP category of "medium".

The lowest 20% of the samples from 2007 have a mean value of 0.46 FEh/kg DM, placing the group in the low end of H4. The highest value of the group is however 0.51 FEH/kg DM, showing that there are no samples of the lowest 20% ranging higher than H4. The lowest 20% have a DCP mean value of 45.6 g DCP/kg DM, placing at the lower portion of the category "very low".

2008 roughage production

2008 growth season and weather report

2008 is remembered as having a successful growth season. The results show this to be accurate, as the production of this year has the noticeably highest energy content, typical value and mineral content. The distribution of DCP was somewhat equal to the other chosen years.

Rainfall

During the growth season of 2008, rainfalls were below average in close to all regions of the country. Some areas of the southern and eastern parts and Troms and Finnmark were the only places receiving more rainfall than average. The remaining regions of the country had rainfall being 50-75% of their average.

Temperature

During the growth season of 2008, the temperatures were above average in close to all regions, where those areas receiving less rainfall were the same areas to receive the highest positive temperature deviation. Troms and Finnmark were the only areas measured to receive temperatures 0 – 0.5 °C below average.

2008 roughage production results

Analysis results from the growth season of 2008 are covering n = 1009 analysis of energy, DCP and DM. Mineral analysis from roughage for equines of 2008 production are n = 160. Typical value does display the interval covering the majority of the samples. The results displayed following:

Table 29 - Summary of 2008 roughage analysis results, per kg DM

		FEh (n = 1009)	DCP (g) (n = 1009)	Ca (g) (n = 160)	P (g) (n = 160)	Mg (g) (n = 160)
Total 2008	Mean	0.63	68.3	3.59	2.28	1.42
	SD	0.06	29.7	1.41	0.56	0.51
	Max	0.81	201.1	11.68	4.16	3.34
	Min	0.39	2.5	1.07	1.03	0.64
	TV	>0.66*	-	-	-	-

* does place at the high portion of group H1

The total production of roughage for equines is divided into hay and haylage + silage in table 31.

Table 30 - 2008 roughage analysis results grouped according to DM, per kg DM

		FEh	DCP (g)	Ca (g)	P (g)	Mg (g)
Hay	n	361	361	51	51	51
	Mean	0.60	63.3	3.20	2.19	1.35
	SD	0.06	31.8	1.17	0.60	0.44
	Max	0.78	192.5	7.03	3.70	2.90
	Min	0.39	2.5	1.47	1.03	0.64
Haylage and silage	n	647	647	109	109	109
	Mean	0.64	71.1	3.77	2.32	1.45
	SD	0.06	28.1	1.48	0.54	0.54
	Max	0.81	201.1	11.68	4.16	3.34
	Min	0.42	10.1	1.07	1.25	0.73

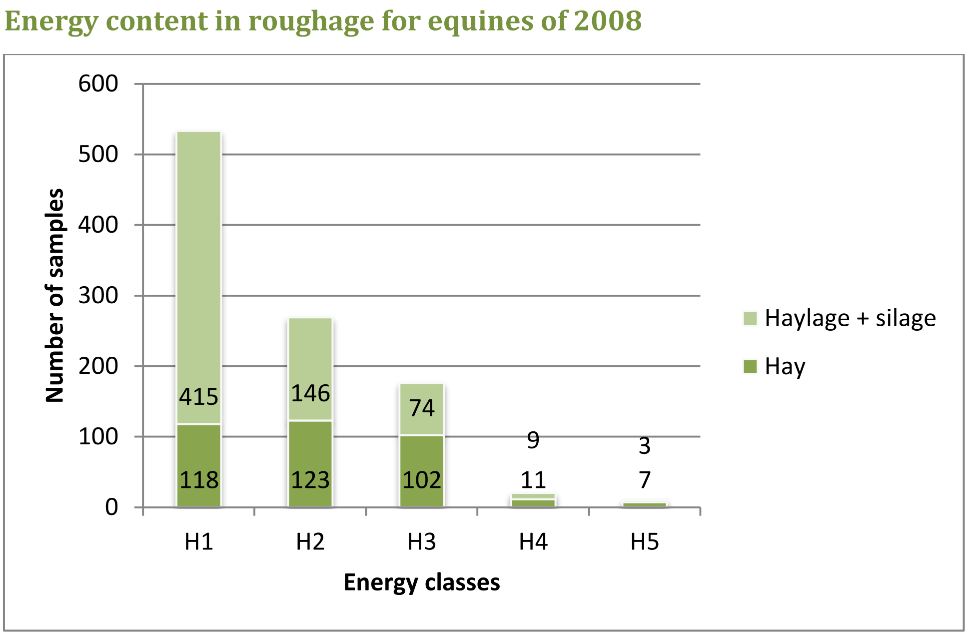

Figure 15 – The energy distribution of hay and haylage + silage in all analyzed roughage for equines produced in 2008 (number of samples)

From the 1009 analyzed samples, the group of H5 includes only 10 of the samples, counting only 1%. H1 includes 534 samples, making 53% of the total analysis from 2008.

Protein content in roughage for equines production of 2008

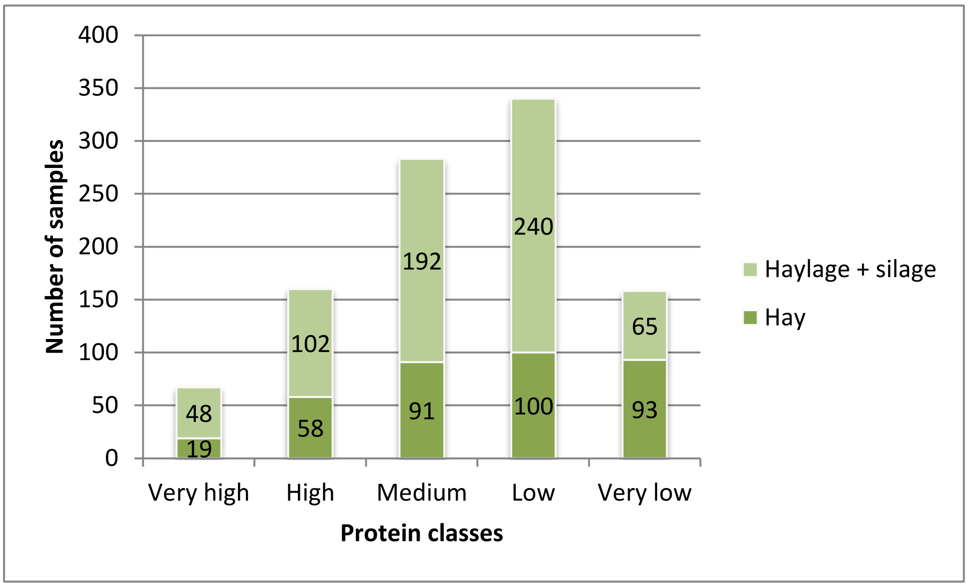

Figure 16 - The protein distribution of hay and haylage + silage in all analyzed roughage for equines produced in 2008 (number of samples)

The group of "low" is counting 346 samples, and makes up 34% of the total of 1009 samples analyzed in 2008.

Dry matter content in roughage for equines of 2008

From the roughage for equines production of 2008, a number of 578 samples were classified as haylage, making 57% of total, while only 70 samples had DM higher than 50% and were classified as silage. 361 of the samples were classified as hay, making up 36 % of the total roughage for equines produced in 2008.

As for the hay, the majority of the samples are evenly distributed among H1 – H3, shown in figure 15. The majority of samples being haylage + silage are classified as H1 (64%). Regarding DCP, 78.7% of the hay samples are almost evenly distributed at the three lowest DCP groups, while the majority of DCP in haylage + silage is classified as "low" (37%) and "medium" (29.7%)

Mineral content in roughage for equines of 2008

The mineral content of Ca, P and Mg in 2008 roughage for equines are all ranging within the average mineral content of roughage for equines stated by Eurofins (www.eurofins.no), although all three being at the lower end. The roughage from 2008 did have 3.59 g Ca/kg DM as mean value (SD: 1.41). The mean P content were 2.28 g P/kg DM (SD: 0.56), while the amount of Mg had a mean value of 1.42 g Mg/kg DM (SD: 0.51). The additional maximum and minimum values are found in table 310.

20% outermost of 2008 roughage for equines

From the growth season of 2008, the highest and lowest 20% of samples (energy content) display the following values.

Table 31 - Summary of 20% outermost of 2008 roughage analysis results, per kg DM

Total 2008		FEh (n = 202)	DCP (g) (n = 202)	DM (%) (n = 202)
20% highest	**Mean**	0.71	94.6	71.8
	SD	0.03	30.2	13.5
	Max	0.81	201.1	95.3
	Min	0.68	14.9	25.1
20% lowest	**Mean**	0.54	44.9	78.3
	SD	0.03	22.8	14.7
	Max	0.57	118.0	94.8
	Min	0.39	2.5	18.0

The 20% highest ranging samples of 2008 does have a mean of 0.71 FEh/kg DM. This is high within the class of H1. Lowest value of the group is 0.68 FEh/kg DM, which is clearly a H1, showing that results from 2008 are high regarding energy content. When looking at DCP content, the highest 20% does have a mean DCP content of 94.6 g DCP/kg DM, placing it in group “high”.

The lowest 20% of the samples from 2008 have a mean value of 0.54 FEh/kg DM, placing the mean in group H4. The highest value in the group is at upper range of group H3 (0.57 FEH/kg DM). This confirms the results from 2008 to be at a high level in regard of energy. The mean value of DCP is placed in “low” with 44.7 g DCP/kg DM.

2012 roughage production

2012 growth season and weather report

The year 2012 provides the latest results of roughage for horses in Norway. The 2012 production results displayed relatively even distributed energy content through all five energy classes. The DCP content of 2012 had slightly higher mean values and distribution throughout the five categories of DCP.

Rainfall

The growth season of 2012 received rainfall being 106% of average throughout the country, with the "Østlandet" and Finnmark being the areas receiving the largest portions. "Østlandet" received 115% of average, whereas Trøndelag and Nordland only did receive 45% of their average (making this year rank nr. 2 of the driest seasons since 1961) (www.met.no).

Temperature

The mean temperature of the growth season for country in total was 0.2 °C below average. There was no marked variation in any of the areas, where most of the measurements reported temperature just below average throughout the season.

2012 roughage production results

Analysis results from the growth season of 2012 are covering n = 906 analysis of energy, DCP and DM, while mineral analysis of 2012 are covering n= 174. Typical value does display the interval covering the majority of the samples. The results displayed following:

Table 32 - Summary of 2012 roughage analysis results, per kg DM

		FEh (n = 906)	**DCP (g)** (n = 906)	**Ca (g)** (n = 174)	**P (g)** (n = 174)	**Mg (g)** (n 174)
Total 2008	Mean	0.55	62.3	2.78	2.14	1.21
	SD	0.08	28.1	1.09	0.64	0.42
	Max	0.85	162.9	8.21	4.05	2.63
	Min	0.36	2.0	1.00	0.77	0.45
	TV	0.55 -0.58*	-	-	-	-

* does place at the higher portion of group H3

The total production of roughage for equines is divided into hay and haylage + silage in table 33 .

Table 33 - 2008 roughage analysis results grouped according to DM, per kg DM

		FEh	DCP (g)	Ca (g)	P (g)	Mg (g)
Hay	n	238	238	44	44	44
	Mean	0.50	50.9	2.49	1.91	1.17
	SD	0.07	24.9	0.75	0.54	0.46
	Max	0.70	124.7	4.23	3.25	2.20
	Min	0.36	2.0	1.35	0.77	0.45
Haylage and silage	n	668	668	130	130	130
	Mean	0.60	66.3	2.88	2.22	1.22
	SD	0.08	28.1	1.16	0.66	0.41
	Max	0.85	162.9	8.21	4.05	2.63
	Min	0.36	10.7	1.00	1.24	0.50

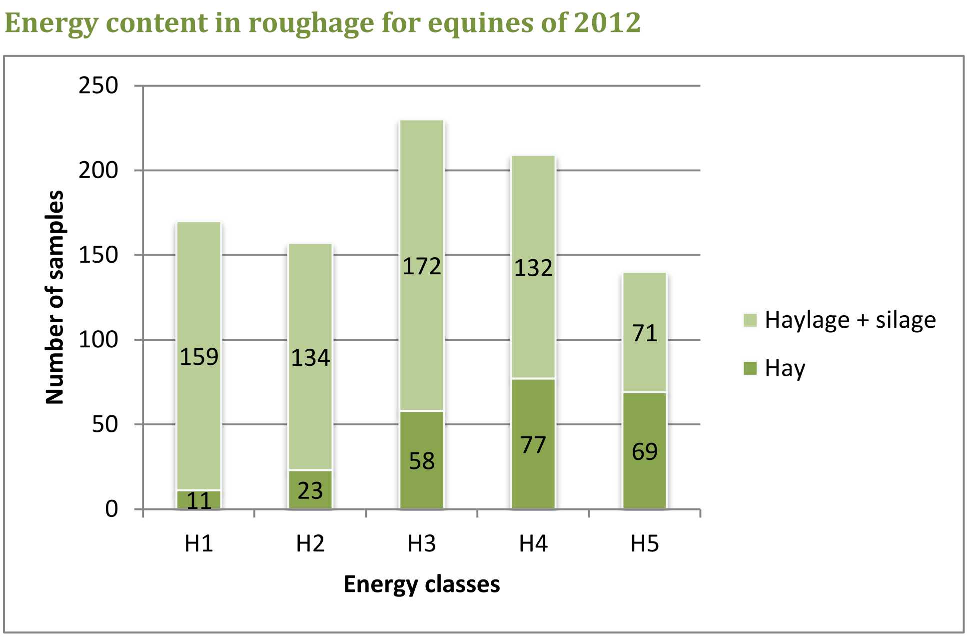

Figure 17 – The energy distribution of hay and haylage + silage in all analyzed roughage for equines produced in 2012 (number of samples)

The energy content of analyzed roughage for horses in 2012 is evenly distributed regarding energy content. The group of H5 includes 140 of the samples, which makes up 15% of the 906 samples. H1 includes slightly more; 170 samples, and makes 19% of the total.

Protein content in roughage for equines production of 2012

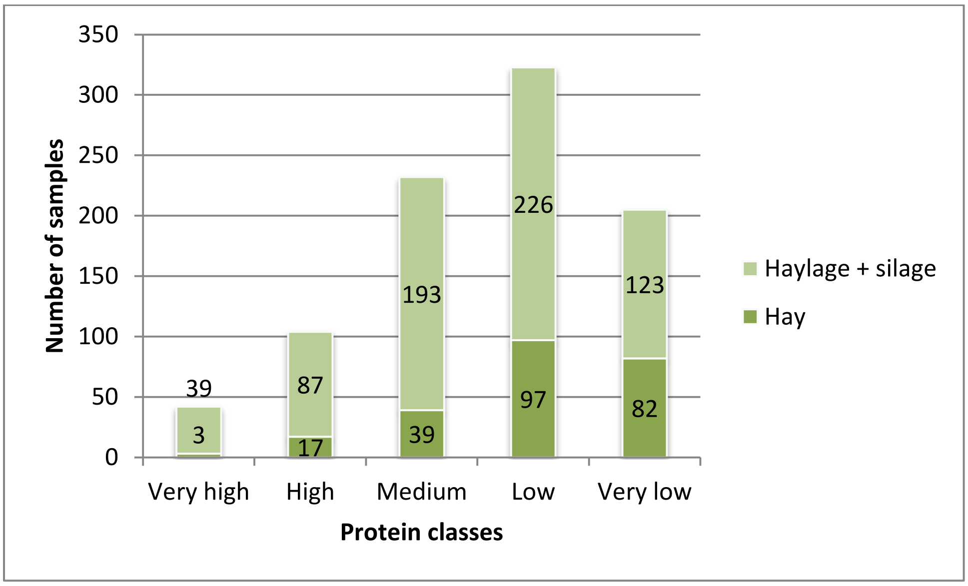

Figure 18 - The protein distribution of hay and haylage + silage in all analyzed roughage for equines produced in 2012 (number of samples)

Of the 906 samples analysed, 327 of them makes up the category of "low", the result being 36% of the total samples from the growth season of 2012.

Dry matter content in roughage for equines of 2012

If reviewing the results in DM of the 2012 roughage, it shows that 238 of the samples were hay (> 84% DM). This makes 26% of the total, and is mainly found in the H3 – H5 energy classes. Haylage is the major group as it is covering 67%, counting 606 samples, whereas 62 of the samples are classified as silage (< 50% DM). The haylage + silage group is somewhat evenly distributed throughout all energy classes.

The majority of the DCP in hay from 2012 is found at level "low" (40.1%) and "very low" (34.5%). The majority of DCP found in haylage + silage were classified as "medium" (28.9%) and "low" (33.8%).

Mineral content in roughage for equines of 2012

The mineral content of 2012 roughage for equines has been analyzed to be 2.78 g Ca/kg DM (SD: 1.09). The content of P was 2.14 g P /kg DM (SD: 0.64) while there were 1.21 g Mg/kg DM (SD: 0.42). Among these values, P and Mg are ranging within the low end of average mineral content values stated by Eurofins (www.eurofins.no), while Ca are below these values.

20% outermost of 2012 roughage for equines

The 20% highest and lowest analyzed samples regarding energy content are reviewed separately.

Table 34 - Summary of 20% outermost of 2012 roughage analysis results, per kg DM

Total 2012		FEh (n = 181)	DCP (g) (n = 181)	DM (%) (n = 181)
20% highest	Mean	0.66	89.9	65.0
	SD	0.04	28.9	15.1
	Max	0.85	162.9	93.2
	Min	0.62	28.7	24.3
20% lowest	Mean	0.44	40.7	80.7
	SD	0.03	19.0	11.1
	Max	0.48	108.5	95.0
	Min	0.36	2.0	19.3

The mean value of the highest 20% is 0.66 FEh/kg DM; placing it in H1. The group does however consist of samples with downwards energy content including 0.62 FEh/kg DM, which means it does cover some samples in group H2 (11 samples). The mean value of DCP content in the 20% highest proportion is 89.9 g DCP/kg DM. This value does place in the group of “medium” DCP content.

The lowest 20% of the 2012 samples have a mean value of 0.44 FEH/kg DM. This is placing the group in H5. The highest value of the group is 0.48 FEh/kg DM, which means the group does cover partly H4 (41 samples). The DCP content of the lowest 20% does have a mean value of 40.7 g DCP/kg DM, which will place it at the very low part of the “low” DCP content class.

Comparing the production results from 2007, 2008 and 2012

It is not commonly focused on how energy and nutritional content of roughage production are distributed within and between years, seen separate or in relation to weather conditions during growth season. Because of this, it may be hard to determine a normal distribution and production of roughage for equines in relation to factors affecting this, and how the chosen years are differing from this. Although three individual growth seasons will not represent a quantitatively adequate dataset, the reason to why production does vary may still be indicated in the year's weather report.

When comparing the years to each other, distributions from each year is given as percent.

Comparing energy content from the three chosen years

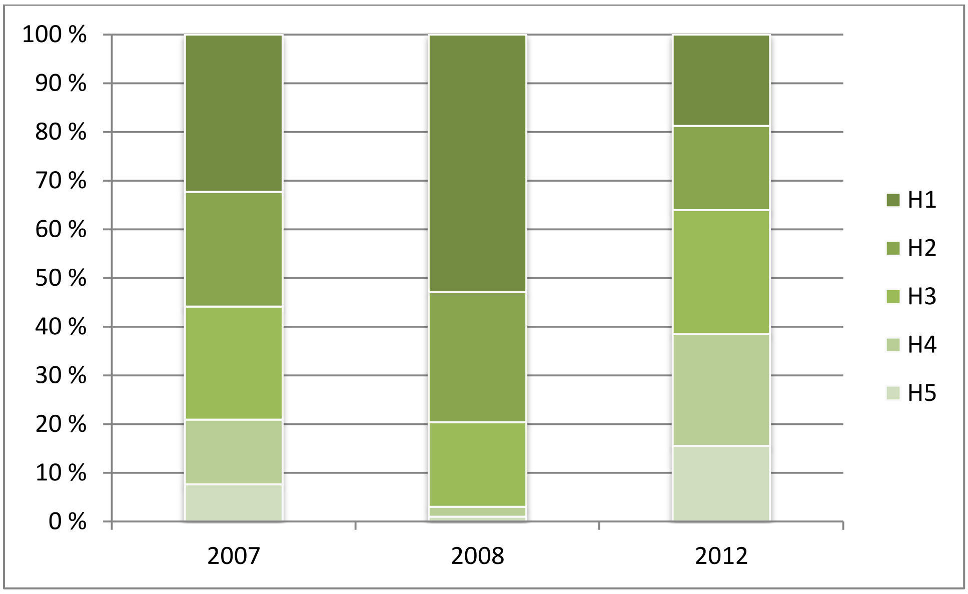

Figure 19 – The total distribution of energy in analyzed roughage for equines produced in 2007, 2008 and 2012 (%)

As figure 19 shows, 2008 display a distribution where majority is at a high energy content, as H1 and H2 makes up 80% of the total samples analyzed. The figure also shows how 2012 has a somewhat more even distribution of energy classes compared to the two other years.

Comparing protein content from the three chosen years

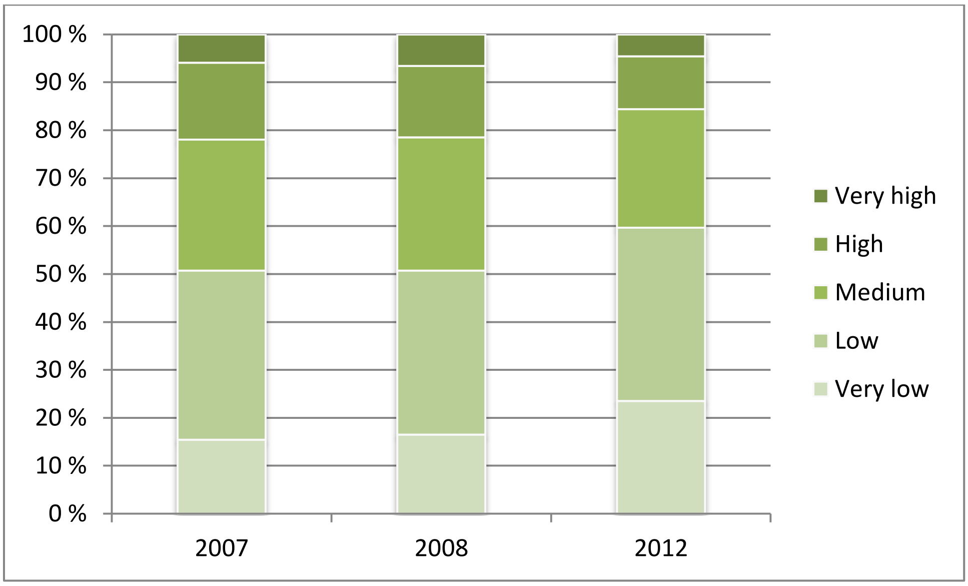

Figure 20 – The total distribution of protein (DCP) in analyzed roughage for equines produced in 2007, 2008 and 2012 (%)

Figure 20 shows how approximately only 50% of the samples makes up the groups of "low" and "very low" all three years. The figure shows that variation of DCP content of the roughage between years is minimal. However, the figure does somewhat illustrate the mean values of DCP distribution of roughage for equines, although on the basis of three years of productions only.

Especially are the DCP content of 2007 and 2008 evenly distributed, while 2012 show a distribution generally lower. The mean values of DCP from 2007 and 2008 are almost equal, being 68.9 g/kg DM (2007) and 68.3 g/kg DM (2008), while 2012 is slightly lower (62.3 g/kg DM).

Within all three years, the variation of DCP content did have great variations among the samples. Reviewing the maximum and minimum values of DCP reveals a range of 1.5 – 176.3 g DCP/kg DM in 2007, 2.5-201.1 g DCP/kg DM in 2008 and 2.0 – 162.9 g DCP/kg DM in 2012.

Comparing the "hay" and "haylage + silage" groups from the three chosen years

Differences are seen among hay, as 2008 had the greatest proportion being hay (35.8% of all samples), displaying an energy content of H1- H3 (95% of samples being hay). 26.5% of the samples from 2012 were hay, where the majority of hay from this year did have energy content distributed among H3 – H5 (85% of the samples being hay).

When comparing the DM content of the three chosen years, there are minor differences regarding amount being silage, as 2007 did have 7.6% of the samples, 2008 did have 6.9% of the samples, while 6.8% of the samples of 2012 were classified as silage. These results cause haylage proportion of 2012 to be the largest (66.7% of all samples), followed by 2007 (62.8% of all samples) and thereafter 2008 (57.3% or all samples).

Distribution of DCP content related to DM reveals how the distributions of DCP in hay and haylage + silage were similar throughout all three chosen years.

Comparing mineral content from the three chosen years

When comparing the mineral content of the three chosen years, 2007 does show somewhat lower mean value of all three minerals with values of Ca: 2.30 g/kg DM, P: 1.66 g/kg DM and Mg: 0.96 g/kg DM. This makes 2007 the only one of the chosen years to have all mineral mean values below what stated by Eurofins. 2008 did have the highest mean mineral values, with Ca: 3.59 g/kg DM, P: 2.28 g/kg DM and Mg 1.42 g/kg DM. 2012 were slightly lower than the mean values of 2008, as it did result with Ca: 2.78 g/kg DM, P: 2.14 g/kg DM and Mg: 1.21 g/kg DM.

As in case for DCP content, the standard deviation of minerals is also prevalent within all three years.

20% outermost from the three chosen years

20% highest

When reviewing the 20% highest proportions of all three years, it is evident that 2008 is the year of the highest mean energy value (0.71 FEh/kg DM), followed by the highest mean value of 2007 (0.69 FEh/kg DM), while the highest proportion mean energy value of 2012 is placed at lowest (0.66 FEh/ kg DM). The three mean values do all range within energy class H1. When looking at minimum value however, it is clear that the maximum 20% of 2012 does cover the complete group of H1 + 6% of H2, in contrast to the 20% highest of 2008 who only covers 37.8% of H1.The 20% highest of 2007 covers 69.1% of H1.

The mean DCP value of the 20% highest portion does show a greater variety than the total mean DCP value of the years. 2012 does display highest mean value, at 94.6 g DCP/kg DM, which makes this year the only year to have highest 20% mean value of DCP to be classified as “high”. Standard deviations of DCP content in the 20% highest groups is however great within all years, displayed by low minimum values. Standard deviations of DCP are high at all three years.

20% lowest

The 20% lowest part regarding energy content for all three years shows that 2008 displays the highest mean value within the 20% lowest part, meaning that this year’s roughage production generally contained higher energy values than 2007 and 2012. The lowest 20% of 2008 roughage does display a mean value of 0.54 FEh/kg DM (middle H3 energy class), covering H5, H4 and 97.7% of H3 produced this year.

The lower 20% of 2007 cover all H5 and 93.3% of H4, and has a mean value of 0.46 FEh /kg DM, falling just within the lower part of H4. The 2012 roughage production does have a lower 20% with mean value of 0.44 FEh/kg DM (H5), who did cover H5 and 19.4% of H4. From all three years, this indicates the largest proportion of lowered energy content.

2012 roughage production does also show the lowest mean value of DCP, being 40.7 g DCP/kg DM. 2008 does show 44,.9 g DCP/kg DM, but also displays the highest standard deviation (SD: 22.8). The high total standard deviation from all three years is reflected within the 20% lowest group. 2007 roughage production does have a slightly higher mean value than 2008, showing 45.6 g DCP/kg DM.

5.2 Nutritional requirement coverage by roughage from different years of production

Nutritional requirement coverage in the growing horse

When looking at the production results from the three chosen years combined with the estimation of energy requirement coverage in section 4.3, a correlation can be made of how the variation between years does influence the energy requirement coverage.

Energy requirement coverage of the growing horse

2007

For a 300 kg mature BW growing horse, the 2007 production mean energy value (0.58 FEh/kg DM) will possibly cover the daily energy requirement for maintenance and growth at 12 months of age. If stalled in outdoor housing, this roughage may cover the energy requirement starting at 18 months, as well as light exercise starting at 24 months. For the 500 kg mature BW growing horse, this roughage may cover the energy requirement at lower age, starting somewhere around 9-12 months and exercise at 18 months age.

2008

Among the three chosen years, 2008 did produce the highest mean and overall energy content. As growing horses does require a sufficient amount of energy, this year is the most suitable regarding younger growing horses and growing horses during exercise. The typical value of 2008 is placing at the high proportion of H1 (0.66 FEh/kg DM), as does the mean value (0.63 FEh/kg DM); being adequate for 9 months growing horses at outdoor housing (both 300 and 500 kg BW mature) as well as moderate exercise at 24 months (300 kg mature BW) and intense exercise at 24 months (500 kg mature BW).

2012

The 2012 energy production does display the lowest mean value (0.55 FEH/kg DM) and typical value (H3) making it least preferable to the younger growing horses. This energy content will be adequate for outdoor housing growing horses at 18 months, daily requirement for maintenance and growth at approximately 12 months (300 kg mature BW), and will at no point cover the energy requirement of moderate or heavy exercise of the growing horse at 300 kg mature BW. For the growing horse with mature BW 500 kg, the mean and typical value of 2012 will cover the daily energy requirement at no extra load approximately 10 months, all light exercise, as well as moderate exercise starting at 24 months of age.

Protein requirement coverage of the growing horse

As shown in figure 20 on page 75, the variation between years regarding DCP content is being negligible. The figure shows how approximately only 50% of the DCP content does make up the groups of “low” and “very low” all three years. However, the figure does somewhat illustrate the mean values of DCP distribution in roughage for equines, although on the basis of three datasets only. The DCP content of the various years of production are therefore united when looking at the degree of DCP requirement coverage.

As the energy requirement coverage is used as principle, the DCP content is given second priority. As seen in figure 5 and 6, the growing horse with mature BW 300 kg and 500 kg only require roughage at “low” DCP content at age 12 months, maintenance and growth only. If feeding these horses the required H3/H4 from 2007, the DCP content doe have a mean value of 60.7 g DCP/kg DM (H3). The DCP requirement of this age horse is however 54 g DCP/kg DM and 50 g DCP/kg DM for the 300 kg and 500 kg mature BW, respectively. This meaning that the production results from all three years display a disadvantageously high DCP content, respectively 68.9 g DCP/kg DM, 62.3 g DCP/kg DM and 62.3 g DCP/kg DM for the years 2007, 2008 and 2012.

The possibility for roughage to cover mineral requirement of growing horses

As to be expected from section 4.3, the mean values of Ca from 2007, 2008 and 2012 does not cover the requirements of the growing horse even if fed *ad libitum.* The mean values of P from 2008 and 2012 may cover the needs of older growing horses (> 24 months), while the mean Mg values from 2008 and 2012 may cover the requirement for Mg at no exercise.

Nutritional requirement coverage in the adult horse

As done with the growing horses, the production results from the three chosen years together with the calculations made in section 4.3, does reveal how the variation between years also does influence the degree of nutritional requirement coverage in adult horses.

Energy requirement coverage of the adult horse

2007

With a mean value of 0.58 FEh/kg DM, and majority being H3 and H2, the production of 2007 display a higher energy content than what will be preferable to most adult horses. The coldblooded type 300 kg BW will require this energy content at somewhere between "heavy" and "intense" exercise, as will the 300 kg BW coldblooded horse require this at "moderate" exercise. The warm-blooded horse will require the mean energy content of 2007 at an earlier stage, being at "light" exercise and "heavy" exercise for 300 kg BW and 500 kg BW respectively. The thoroughbred 500 kg BW horse will require this at "moderate" exercise.

2008

The high level of energy found in 2008 roughage production will provide excessive energy to most adult horses fed *ad libitum*. The mean and typical values of 2008 (0.63 FEh/kg DM and H1) are required at exercise level of "intense" exercise for 300 kg BW coldblooded horses and 500 kg BW warm-blooded horses, as well as "heavy" load of exercise for 500 kg BW thoroughbred horses.

If looking at the roughage only diets fed in ration, the heavier coldblooded and warm-blooded horse (500 kg BW) may receive adequate amounts of energy from the 2008 mean and typical value at maintenance level. 2008 is the only production year displaying mean and typical values capable of covering energy requirement at roughage only diet.

2012

Being opposite of the suitability for the growing horses, the production year of 2012 displays the lowest mean- and typical values (0.55 FEh/kg DM and H3) making it the most suitable for the majority of adult horses at maintenance and outdoor housing requirement levels, as seen in Figure 7 to 9. The thoroughbred horse is an example of a horse displaying the highest requirements related to BW, but also these horses does have a maintenance energy requirement starting at H4 (300 kg BW) and H5 (500 kg BW). The coldblooded horse does have a maintenance requirement at H5 for all weight classes, while warm-blooded are ranging between the two. This causes the 2012 roughage production to be the most suitable for adult horses.

Protein requirement coverage of the adult horse

As stated on previous page, the variation between years regarding DCP content is minimal, and although only relying on the datasets from the three chosen years, it may give general indication of the DCP content in roughage for equines. Therefore, results of DCP requirement coverage are seen of all three years united.

The adult horse does require a lower DCP content than does the growing horse. As shown in Figure 10 to 12, the DCP requirement of roughage for equines range within "very low" at maintenance and outdoor housing for coldblooded and warm-blooded horses, as well as "very low" and "low" for the thoroughbred at maintenance and outdoor housing, respectively. No levels of exercise of all types and weight classes of horses does range either above or below the DCP requirement of "low" if fed ad libitum, except from the coldblooded horse 500 kg BW requiring 39 g DCP/kg DM (level of "very low").

The possibility for roughage to cover mineral requirement of adult horses

The mean mineral content of the roughage from 2008 and 2012 may cover Ca maintenance requirements for the adult horse, P requirement at "light" exercise and Mg requirement at "moderate exercise". The mean mineral values of 2007 are not sufficient to cover any requirements of minerals at *ad libitum* feeding overall.

6. Discussion

Roughage analysis results

The roughage analysis results from each of the chosen years display a variation in energy content, illustrated by the mean values of energy ranging within energy class of H1, H2 and H3 in 2008, 2007 and 2012, respectively. Literature reviewed in section 2.1 is therefore confirmed by the results presented in the thesis. The variations displayed also show how energy content in hay is being mostly dependent on weather conditions. This concurs with the previous statements made.

The roughage analysis results also show how the DCP content do not rely on the same factors as energy, as 2007 and 2008 did differ in weather conditions and energy content, but does display a similar DCP distribution. The study of analysis of roughage for equines done by Saastamoinen and Hellämäki (2012) did find that the CP did vary more in hay than in haylage, ant that haylage did have a 1.7% -units higher content than hay.
Although a relation between energy content and DCP content may be expected to display higher levels simultaneously, the results from 2007 and 2008 disprove this.

For the practical use of roughage for equines, the results confirm that the energy content of the haylage + silage fraction does vary less between years than the variation seen in hay. To the customer, purchasing hay may therefore cause greater adjustments to the total ration for the horse, and need to be continuously considered by roughage analysis.

Although looking at the mean values of each year, these values are being guidelines of the total year of production. It is important to consider how the portions of higher and lower levels are varying between the years as well. By looking at the outermost 20% from each year (table 28, table 31 and 34), it shows that also the outermost productions does vary in relation to the mean value. This illustrates that all roughage is influenced by weather conditions. During 2008, the portion of 20% highest energy levels was all H1, covering 37.5% of the H1 group. The portion of 20% highest energy in 2012 did cover the entire group of H1 in addition to 6% of samples being H2. As for the roughage being at the lower portion of energy content, the variations are also evident; the portion of 20% lowest energy levels of

2008 did cover 97.7% of the samples being H3 in addition to all H4 and H5, whereas 2012 only did cover 19.4% of the samples being H4 and all samples of H5.

As mentioned earlier, the national references of nutritional content in forages, “Fôrtabellen” (UMB & Mattilsynet, 2008), displays the average nutritional content of different forages. When comparing the mean values from each year of analysis, it is also interesting to compare the correlating energy values in “Fôrtabellen”, as these values are used for reference of forages when analysis is not present. The roughages represented from “Fôrtabellen” are chosen based on energy content in order to illustrate differences between the analysis results and table values. Since Timothy is predominate specie of roughage of roughage for equines, this specie is used as a reference.

The chosen roughage from “Fôrtabellen” corresponding with 2007 and 2012 mean energy values does have a markedly lower DCP content than the mean DCP content of the respective years. According to “Fôrtabellen” as shown in table 35, Timothy harvested at heading does place in energy class H1, while placing in H3 if harvested at flowering. In regard of the DCP content, the Timothy place in group of “medium” at heading, while being at “very low” at stage of flowering.

Table 35 – Comparison of nutritional content in roughage with similar energy content, being analyzed roughage for equines and nutritional value of roughage listed in «Fôrtabellen», per kg DM

	n/n(minerals)	**FEh**	**DCP (g)**	**Ca (g)**	**P (g)**	**Mg (g)**
Mean value 2007	798/266	0.58	68.9	2.3	1.7	1.0
Fôrtabellen*	3/3	0.59	41.6	3.4	2.6	1.2
Mean value 2008	1009/160	0.63	68.3	3.6	2.3	1.4
Fôrtabellen**	7/6	0.64	73.8	4.1	3.2	1.0
Mean value 2012	906/174	0.55	62.3	2.8	2.1	1.2
Fôrtabellen***	8/7	0.54	38.3	3.4	2.1	0.5

* Hay-mixture (Timothy and Meadow Fescue), first harvest, heading (UMB & Mattilsynet, 2008)

** Hay: Timothy, first harvest, heading

*** Hay: Timothy, first harvest, flowering

The analyzed roughage does not hold information about composition of species or stage of maturity at harvesting in relation energy content. The majority of roughage of 2007 and 2008 however, is not likely harvested at same stage of development due to difference in weather conditions. Interestingly, what differ the mean values of 2007 and 2008 in correlating values in “Fôrtabellen” is the mixture of species. This show that it is difficult to predict nutritional content of roughage based on “Fôrtabellen”, and that the composition of species must be taken in considerations at such estimation. It also shows how analyzing the roughage is necessary in order to determine the nutritional content of roughage for horses.

In order to fully utilize and adjust the roughage as the main feedstuff to cover the energy needs for the horse, a roughage analysis is needed. As stated in the report from The Center of Rural Research, only 1/3 of customers did get roughage analysis of the purchased product in 2012 (Norsk senter for bygdeforskning, 2012). When preparing and adjusting the feed ration of the horse to such analysis, the accuracy of the analysis must be considered. As seen through the results presented, uses of analyses from previous years are of no interest. People purchasing roughage for equines were loyal to their producers as more than 70% did purchase from the same producer every year (Norsk senter for bygdeforskning, 2012). Roughage production does not provide a uniform product even from one producer during one single year. Factors such as renew of the land at various years, first and second harvest being mixed during storage, and not harvesting all sections of land at the same time may cause even the current roughage analysis to misinform.

Nutritional requirement coverage

As the results in 5.2 shows, both energy and DCP requirements in growing and adult horses may be sufficiently and excessively covered for horses fed roughage only diets at *ad libitum* feeding management. Saastamoinen and Hellämäki (2012) concludes that 60% of haylage and 40% of hay from analysis covering a ten year period did provide too much energy to horses with low exercise intensity. Late cut forage (seeding to late seeding) is reported as able to fulfill the energy and protein requirements of horses at maintenance level (Ragnarsson & Lindberg, 2008).

The variations between the chosen years does indicate how some horses meet their requirements for energy and protein at better state than others at each certain year, changing from one year to another. A forage analysis study performed by Saastamoinen and Hellämäki (2012) showed that the "high nutritional quality" roughage was suitable for horses in training on energy basis when fed according to requirements. Results from this study showed that early cut haylage can be fed trotters in training. The roughage was also suited for weaned foals and growing horses, if supplemented with lysine. The study performed by Müller (2012) did conclude that that all horses in good health are able to get energy- and DCP requirements covered by roughage only diets, if fed suitable nutritional content based on analysis of the roughage.

Whether the horse covers its energy requirements or being fed excess energy depends of the variation in VDMI, which again depends of the BW. Calculated requirements show that smaller horses, both growing (expected mature BW 300 – 400 kg) and mature (BW 300- 400 kg) are to be the first to experience shortage at border areas of coverage, as VDMI (kg DM/day) decrease at higher rate than does the nutritional requirements. As both figure 3 and figure 4 shows, the 6 months old growing horse does require higher energy concentration of the roughage as it holds a low VDMI. The requirement for energy does decrease at increased age, due to increase of VDMI as a result of increased BW combined with decrease of requirement for growth, as shown in figure 2 on page 40. Therefore, energy requirement coverage for growing horses older than 12 months may not occur. The results in section 5.2 shows that roughage produced in 2008 does meet the requirements of the growing horse in almost every situation, while roughage produced in 2007 may be more desirable for the adult horse.

The demand for DCP concentration does not change rapidly among the types of horses when fed *ad libitum*, as shown in figure 10, 11 and 12. When fed roughage in restricted ration of hay (1.5% of BW), the demand for DCP does increase in relation to exercise intensity for all types of horses. The DCP content of analyzed roughage is more congruent with the demand for DCP of the adult horse if fed a restricted ration of hay (1.5% of BW). However, as shown in section 4 it is clear that restricted ration feeding do not cover energy requirement at exercise, and supplement of energy is required through grain mixtures in such situations. As shown in table 3, the mixtures does supply adequately amount of DCP required at such level of exercise, and a the higher levels of DCP in roughage will therefore at all occasions cause excess of protein to adult horses.

Although the adult horse does have a lower Ca, P and Mg requirement than the growing horse at maintenance, exercise does elevate the required values for mineral content of the feed for the adult horse. The results of the thesis confirm the importance of mineral supplement to be distributed to all horses fed roughage only diets.

Variation seen in nutritional content of the roughage does influence on how the nutritional requirement of the horse is covered each year, if fed roughage only diet. Monitoring the condition of the horse and adjusting the diet according to this must be performed, and these adjustments are founding rations with no analysis of roughage. However, the great variations in energy seen among the three chosen years does reveal how this will influence the coverage of energy in such diets, especially during changes of batches or years. A roughage analysis will provide nutritional information at an earlier point and at a more detailed level. It will therefore provide information in order to adjust diets before leading to potential malnourishment, reduction of growth, overweight, or other factors reducing the welfare of the horse.

Viewing the economic aspects of adjusting a diet

Horses are commonly fed rations consisting of roughage and grain mixtures combined. These rations mostly apportion roughage, and the suggested minimum ration being 1.5% of BW/day fed as hay (1.26 kg DM/100 kg BW, at 84% DM) is used as restricted ration reference throughout the thesis. The discussion of why feeding a horse restricted roughage in order to supply remaining energy and protein requirements by using grain mixtures are left unrevealed, and assumptions are made that many prefer to feed their horses roughage at a confined level and not *ad libitum*. However, the beneficial qualities provided by roughage to the digestive tract and welfare of the horse should not be underestimated in regard of economic aspects. Feeding greater amounts of roughage in ration may benefit to prevention of diseases and promote welfare in the horse; reducing expenses caused by illnesses and descending welfare.

Nevertheless, there is a range of possible increase of roughage to be made without reaching the limit of VDMI, yet still decreasing the proportion of grain mixtures in the diet. As this may possibly be beneficial to behavioral and digestive issues, the economic aspects of such adjustments are of interest. As an example to this, a 500 kg BW warm-blooded horse at light exercise are being used. Such horse has a requirement of 5.1 FEh/day and 410.8 g DCP/day.

As the retail prices given in section 2.6 shows, a restricted ration (1.5% of BW) of mean value hay from 2012 (0.55 FEH/kg DM and 62.3 g DCP/kg DM), will provide 3.5 FEh and 392.5 g DCP at a cost of 35.5 NOK/day (6.3 kg DM/day) (Gjesti-Furasje, 2013). The remaining 1.6 FEh and 18.3 g DCP are covered by grain mixtures at the price of 5.75/FEh (Pionér Sport, average price of grain mixture) being 9.2 NOK/day (Norgesfôr, 2013). Total price of such ration will be 44.7 NOK/day, and there will be 205 g DCP excess.

If the same horse were to be fed roughage only diet from the same crop, it would require 9.3 kg DM/day (being 92.7% of VDMI). The price of this will be 52.5 NOK/day. In addition, mineral supplement are required at a cost of 2.0 – 5.6 NOK/day. The total price of roughage only diet would be 54.0 – 57.6 NOK/day, (Felleskjøpet, 2013; Norgesfôr, 2013) and there would be 168.6 g DCP excess.

When no difference in price is given for variation of energy content by one of the leading distributors of roughage in Norway (Gjesti-Furasje, 2013), adjustments can preferably be made by purchasing a higher energy content roughage, resulting in lowering the demand for DM/day in order to cover nutritional requirements. As an example, if feeding this horse an average 2008 roughage (0.63 FEh/kg DM and 68.3 g DCP/kg DM), it would require 8.1 kg DM/day (being 80.9% of VDMI). The price of this would be 45.7 NOK/day. Including mineral supplement, the price of this diet will be 47.7 – 51.3 NOK/day, and there would be 105.9 g DCP excess.

7. Conclusion

The results of analyzed Norwegian roughage for equines from three various years shows variations between years regarding nutritional content. The energy content is the parameter that displays the greatest variation between years, and the roughage grouped as "hay" varies most between years. Results did show that warmer and drier growth conditions did result in higher energy content of the roughage (2008 results and weather reports), while rainy and cooler growth season resulted in lower content (2007 and 2012 results and weather report). The content of DCP did not vary between the years to the same extent as energy content, as DCP content did have minimum variation between years. However, variations in DCP content within years were significant all three years. Average mineral levels of roughage were below demand of most horses, and did confirm how mineral requirement are required as additive to roughage only diets.

Coverage of nutritional requirement is dependent on dry matter intake. At *ad libitum* feeding management, VDMI of 2.5% were estimated for growing horses (no extra), while the adult horse was estimated with 2% (maintenance), 2.25% (light exercise) and 2.5% (heavy and very heavy exercise) VDMI.

The average energy concentration for all the three years is higher than necessary to cover the energy requirements for adult horses at maintenance, light and moderate exercise level. The growing horse does get energy requirements covered in most situations, although the younger (> 12 months) and smaller horses are being the first ones to possibly attain shortage of energy coverage. Energy requirement due to exercising the growing horse may not be covered by feeding roughage only diet.

Despite the variation of DCP content within each year, the average levels of roughage for equines do display an unfavorable high level for the adult horse. This also applies to the older growing horse (> 18 months), while the DCP content does meet the requirement of younger growing horses (< 18 months).

The results displaying the variation in nutritional content of roughage confirms how roughage analysis is needed in order to adjust the feeding of horses with fully utilize the potential of roughage nutritional value.

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