

Final report

Vallfoder för hästar ur ett utfodringsperspektiv Forages for horses from a feeding perspective

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Part 1: Detailed summary

Syfte/hypotes: Syftet med projektet var att kartlägga den vetenskapliga information som finns inom ämnesområdet vallfoder till hästar ur ett utfodringsperspektiv. En systematisk granskning och sammanställning av den litteratur som kan ha relevans för de nordiska länderna har utförts och presenterats i en rapport som publicerats. Syftet har också varit att identifiera kunskapsluckor där mer forskning behövs för att kunna möta framtida utmaningar avseende vallfoder för hästar ur ett utfodringsperspektiv.

Metod: Litteratursökning har gjorts i databaser för vetenskapliga publikationer med söksträngar bestående av sökord som brett beskriver vallfoder och häst. Sökningen genererade totalt 11 316 träffar. Efter bortsortering av dubletter och ej relevanta publikationer och granskning utförd i flera olika steg fanns 438 publikationer kvar. Dessa lästes i fulltext och de referenser som inte uppfyllde inklusionskriterierna (relevanta fullängdsartiklar som publicerats i vetenskapliga tidskrifter och som skrivits på engelska, svenska, norska eller danska samt med fullständig beskrivning av studien, dess

upplägg, metoder och resultat) sorterades bort, varpå 296 publikationer återstod vilka inkluderades i sammanställningen. Dessa omfattade år 1903 till och med april 2022. Ytterligare litteratur har i rapporten använts där det behövs för att tydliggöra eller förklara sammanhanget.

Projektutförande och eventuella avvikelser från projektplan: Projektet har utförts enligt plan med undantag av en två månaders förlängning efter anhållan om detta hos Stiftelsen Hästforskning.

Resultat: De publikationer som återstod efter granskning av litteraturen omfattade i första hand studier av hästars frivilliga konsumtion av vallfoder av olika typer, smältbarhet och/eller näringsinnehåll i olika typer av vallfoder för olika hästkategorier samt hygienisk kvalitet i vallfoder för hästar. Rapporten delades därför in i dessa huvudområden. Här redogörs mycket kort för innehållet i rapporten.

Hästars frivilliga konsumtion av vallfoder: Hur mycket vallfoder en häst kan konsumera avgörs av flera faktorer men en av de viktigaste är vallfodrets innehåll av fiber. Generellt gäller att ju högre fiberinnehållet är, desto mer behöver hästen tugga på fodret och desto längre blir ättiden. Fiberinnehållet i vallfodret avgörs främst av plantans botaniska mognad vid skörd – ju senare plantmognad, desto högre fiberinnehåll. För vallfoder bestående av olika gräsarter har den genomsnittliga frivilliga konsumtionen uppmätts till i genomsnitt 2,1 % torrsbstans (ts) av kroppsvikten och för lusern något högre, 2,6 % ts av kroppsvikten i genomsnitt. Andra faktorer som till exempel konserveringsmetod, växtart och strållängd/partikelstorlek kan också påverka hästars intag av vallfoder och/eller deras preferens och ätbeteende, men dessa är mer sparsamt undersökta.

Smältbarhet och/eller näringsinnehåll i olika typer av vallfoder för olika hästkategorier: Eftersom hästar i olika fysiologiska stadier (till exempel digivande ston, växande unghästar eller hårt tränande hästar) har olika stora behov av energi och olika näringsämnen betyder det också att olika krav behöver ställas på vallfodret till olika hästkategorier. Hästar med högre energi- och näringsbehov, det vill säga hästar i avel och hästar i hård prestation, behöver få så mycket som möjligt av dessa behov täckta av vallfodret medan hästar med lägre energi- och näringsbehov behöver få tillräckligt lång ättid utan att dessa behov överskrids (för att undvika utveckling av fetma). Den faktor som avgör vilket energivärde ett vallfoder får för hästar är smältbarheten, som i sin tur i huvudsak bestäms av fiberinnehåll och fiberkvalitet i vallväxterna. Ju högre fiberinnehåll, desto lägre blir i allmänhet smältbarheten och därmed även energivärdet. Därför kan skörd i en förhållandevis sen plantmognad, då fiberinnehållet är högt, vara lämpligt för hästar med lägre energibehov medan vallfoder för hästar med högre energibehov behöver vara skördat i en tidigare plantmognad. För växande unghästar, föl och avelsston behöver vallfodret innehålla mer råprotein än för andra hästkategorier. Det kan uppnås med skörd i tidig plantmognad och kvävegödsling av gräsvallar eller genom att använda vallbaljväxter. Det finns dock ett begränsat antal studier som visar vilka krav som behöver ställas på vallfodret för att det skall kunna täcka energi- och näringsbehoven hos denna hästkategori.

Hästarnas mineralämneshöjningar kan täckas av vallfodret med undantag av natrium och selen, men vallfoders innehåll av mineralämnena varierar mycket och det bör därför analyseras, särskilt om foderstaten enbart består av vallfoder. Vallfodrets innehåll av vitaminer antas täcka hästars behov av detsamma då vitaminbrist är ovanligt förekommande hos häst, men antalet studier på detta område är litet.

Vallfodrets innehåll av socker kan vara av betydelse för hästar med olika typer av störningar i sin metabolism, som till exempel insulinresistens och korsförslamning. För dessa bör vallfodrets innehåll av socker analyseras, eftersom det kan variera stort beroende på de rådande förutsättningarna vid vallens tillväxt och skörd samt i någon mån påverkas av vilka gräsarter som ingår. Ensilage innehåller dock generellt lägre koncentration av socker än hö eftersom sockret används under ensileringsprocessen. Hösilage har en begränsad ensileringsprocess på grund av dess lägre vattenhalt och därför varierar också sockerinnehållet mer i detsamma.

Hur vallfodret skördas och/eller konserveras kan påverka dess sammansättning vilket i sin tur kan inverka på smältbarheten, hästens ämnesomsättning och prestation, men antalet studier på detta är begränsat. Hästar som utfodrats med jämförbart ensilage, hösilage och hö, det vill säga som

producerats från samma ursprungsgröda, har dock uppvisat liknande smältbarhet för fodertyperna och likadana prestationer vid arbetstest oberoende av vilken vallfodertyp de utfodrats med.

Hygienisk kvalitet i vallfoder för hästar: Vallfodrets hygieniska kvalitet påverkas av både skörde- och lagringsförhållanden samt av hur fodret hanteras vid utfodring, och behöver vara hög för att inte påverka hästars hälsa negativt. Hö behöver i allmänhet skyddas mot uppfuktning av omgivande luft redan under tidig höst (oktober) för att motverka tillväxt av mögelsvampar i höets yta. Inplastat vallfoder behöver istället skyddas mot skador på plasten eftersom syreinträde i balarna ökar risken för mögeltillväxt i fodret. Jämförelser av hö och inplastat vallfoder (hösilage) som används till hästar har visat att hö generellt innehåller högre koncentration av inandningsbara partiklar, oftast i form av mögelsporer, vilka kan medverka till att hästens utvecklar kroniska luftvägssjukdomar. Mögelgifter kan också förekomma i möjligt vallfoder av alla slag men antalet studier på vilken inverkan dessa kan ha på hästars hälsa är begränsat (med undantag för några enstaka av mögelgifterna). Tillväxt av oönskade bakterier kan också ske i vallfoder, framför allt då fodret kontaminerats av kadaver både före och efter skörd. Utfodring av vallfoder med nedsatt hygienisk kvalitet till hästar kan, utöver kroniska luftvägsproblem, medföra allvarliga hälsostörningar som förgiftningar av mögel- eller bakterietoxin (till exempel av botulin som orsakar sjukdomen botulism) vilka inte sällan har dödlig utgång.

Engelskt rajgräs och rörsvingel kan vara infekterade av så kallade endofytsvampar vilka kan bilda giftiga substanser i fält. Dessa substanser kan bland annat orsaka komplikationer vid följning. Studier på endofytinnehållande vallfoder till hästar har framför allt utförts i USA, och svenska studier saknas trots att ämnesområdet är relevant för det nordiska klimatet. Vissa vallväxter, särskilt vallbaljväxter, kan innehålla antinutritionella substanser som till exempel växtöstrogener, oxalat eller fotosensitiverande substanser. Antalet studier på dessa substanser och deras betydelse för hästhälsan är begränsat men de studier som finns indikerar att området skulle behöva undersökas vidare.

Vallfoder kan behandlas på olika sätt innan utfodring. Det rör sig framför allt om ångbehandling eller blötläggning av vallfoder för att minska mängden inandningsbart damm (ibland också sockerhalten). Både ångbehandling och blötläggning av hö har visat att halten av inandningsbara partiklar minskat kraftigt till följd av behandlingen, men också att hästarnas respons i luftvägarna på blötlagt eller ångbehandlat foder verkar variera. Blötläggning av vallfoder för att minska sockerhalten har gett mycket varierande resultat, från ingen till ca 50 % reduktion av sockerhalten, och som en bieffekt kan även råprotein och mineralämnen lakas ur vilket kan behöva kompenseras för vid utfodring. Dessa behandlingar kan med dagens kunskapsläge därmed inte betraktas som effektiva åtgärder.

Kunskapsluckor: Ett flertal kunskapsluckor har identifierats i sammanställningen. Några exempel är att ökad kunskap behövs om hur olika vallarter, inklusive vallbaljväxter, kan användas i vallfoder för att kunna energi- och näringsförsörja olika hästkategorier med fokus på både hälsa, välfärd och prestation. Hur detta påverkar vilka metoder som kan användas för att konservera fodret och vallfodrets hygieniska kvalitet eller innehåll av antinutritionella substanser är också kunskap som behöver tas fram för en hållbar framtida vallfoderförsörjning av hästpopulationen.

Implementering: Rapporten har spridits i enlighet med vad som beskrivits i projektplanen samt införlivats som kurslitteratur i SLUs utbildningsprogram och fristående kurser inom ämnesområdet veterinärmedicin och husdjursvetenskap. Vidare implementering sker även via andra organisationer, t ex LRF Häst, Hushållningssällskapen och Svenska Vallföreningen. Rapporten är fritt tillgänglig här: <https://www.slu.se/globalassets/ew/org/inst/huv/publikationer/rapport-308-vallfoder-till-hastar-ur-ett-utfodringsperspektiv-slutversion-230228.pdf> samt med en populärvetenskaplig sammanfattning här: <https://www.slu.se/ew-nyheter/2023/2/ny-rapport---vallfoder-till-hastar-ur-ett-utfodringsperspektiv/>

Part 2: Main report (max. 10 pages)

Forages for horses from a feeding perspective

Introduction, background and objective

Grasslands play a vital role in ensuring a sustainable future for global agriculture both as feed for livestock including horses, and as carbon sinks. Being a carbon sink, grasslands diminish CO₂ and nitrous oxide emissions to the atmosphere, thereby delaying increases in global temperature. Grasslands also provide other benefits, such as improving soil organic matter and fertility which increase the yield of the following crop, decreasing use of pesticides and improving biodiversity. As grasslands cover the soil during a whole vegetation period and over several years, more sunlight is caught through photosynthesis, more carbon is sequestered into the soil and the risks of soil erosion and nitrogen leakage is decreased, compared to cultivation of annual crops (Soussana & Lüscher, 2007). In fact, grass production for horses has been reported to be an unexpected source of carbon binding in Swedish agricultural soils from 1970s and onwards (Popleau *et al.*, 2015), due to the increase in the number of horses from 70 000 in the 1970s to about 360 000 in 2016 (SJV, 2016). At present, the horses are consuming about 30-35 % of the annual grass forage production within Sweden (Cederberg & Henriksson, 2020). Forage production for horses thereby constitutes a large part of the total forage production in Sweden.

Climate change in the form of increased temperature will have significant impacts at northern latitudes in the future. The longer growing season during recent decades has led to a demand for leys that produce high yields during three to four cuts every year, and grass species with a high regrowth capacity have a natural advantage in this regard (Brink *et al.*, 2010). This forage harvest strategy may result in forages highly suitable for horses with high energy and nutrient requirements (or for high-yielding dairy cows), but the largest proportion of horses are adult animals in low-intense training, which thereby have comparably low energy and nutritive requirements. For this horse category, forages with lower digestibility and lower nutritive value are desired in order to fulfil the requirements of long eating times in horses without causing overfeeding and obesity. Adult, low-performing horses do not benefit from an energy-dense forage suitable for high-performing horses or broodmares, and vice versa. If forages that have insufficient energy and nutritive values are used for horses with higher requirements, it is necessary to supplement the forages with other feeds. Such feeds are most often concentrate feeds that could be of better use for other animal species with less capacity than horses to utilize forage (*e.g.* pigs, poultry, fish), and/or are often imported feeds (*e.g.* soy bean) where both the production and transportation may add to an undesirable environmental impact. Many of these concentrate feeds also contain high levels of starch which is undesirable in horse feeding as several studies have shown associations between feeding starch-rich feeds and health problems such as gastric ulcers (*e.g.* Sykes *et al.*, 2015; Galinelli *et al.*, 2019), exertional rhabdomyolysis (*e.g.* Firshman *et al.*, 2003; McKenzie *et al.*, 2003), colic (*e.g.* Reeves *et al.*, 1996; Tinker *et al.*, 1997; Hillyer *et al.*, 2002) as well as a less diverse microbial ecosystem in the hindgut of the horse which increases the risk of hindgut digestive disturbances (*e.g.* Hansen *et al.*, 2015). Feed rations with a low proportion of roughage also increases the risk of horses developing oral stereotypic behaviours such as crib biting and wind sucking (*e.g.* McGreevy *et al.*, 1995). These are all strong arguments for emphasizing the importance of a high forage proportion in feed rations for horses. Understanding and making correct use of the variation in energy value and nutritive contents that follows from different harvest strategies of forage leys is therefore important to cover equine requirements without increasing the risk of impaired health and welfare in horses, and for a sustainable equine feeding based on grasslands.

Different methods to harvest, conserve and store forages may have implications for its composition, which in turn may influence how the forages can be used for feeding horses. It is important to understand the basic principles of forage conservation to be able to harvest, store and use the forages correctly and to avoid impaired hygienic quality in the feeds, as it may have severe health effects in horses. A high hygienic quality in feeds is also a requirement by law as stated in "Djurskyddslagen" (SFS 2018:1192) and in "Lag om foder och animaliska biprodukter" (SFS 2006:805).

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The knowledge on how to harvest, conserve, store and feed forages is important for both forage producers and horse keepers. Only about half of the horse keepers are producing their own forage (SJV, 2016), indicating that many of them are dependent on the forage producers as they have to purchase the forage required. The forage producers on the other hand needs to know what type of forage to produce for it to be sellable in the horse community. Collecting the current knowledge on forages for horses in a report will facilitate for both forage producers and horse keepers to find the existing knowledge on the topic, which can aid in different decisions important for a successful forage production and forage feeding. The aim of this project, as addressed in the call text, was to create a report based on national and international research and knowledge on forages for horses from a feeding perspective. The project was limited to include harvested forage, leaving pasture/grazing out of the report. The overall goal was to collect, summarize and present available knowledge within the area in a report directed to forage producers, horse keepers and similar stakeholders, as well as to identify knowledge gaps where further research within the area is needed for a sustainable forage production and feeding.

Material and methods

A literature search was performed in databases comprising scientific publications (search strings available in supplementary file 1 in the main report). The literature search generated 11316 hits. After deduction of duplicates and screening titles for relevance to the subject (removing references not including horses or forages), 9815 hits were removed and 1501 references remained. These 1501 references were screened by reading their abstract, and references not written in English, Swedish, Danish or Norwegian were deduced, as were references only comprising crops not relevant for Nordic climate conditions as well as abstracts of conference proceedings where no full text existed. This step resulted in removal of 1063 references, while 438 references remained. The full-text of the remaining references was read, and those that did not meet the set inclusion criteria were removed. The inclusion criteria comprised experimental design, statistical model or evaluation, number and type of horses used in the study, type of forages used in the study, and forage analytical methods used, as this was information required to critically evaluate the results. After this step 296 references remained while 142 had been removed as they did not meet the inclusion criteria. The 296 references were included in the main report and presented in sections covering forage intake in horses, forage energy and nutritive value and the possibility to cover the energy and nutritive requirements of different horse categories with different forages, harvest and conservation methods of forages for horses, forage hygienic quality and post-harvest treatments of forages for horses. No year limits were used in the literature search but it was performed in March 2022 and publications of a later date were therefore not included. References on poisonous plants were excluded, as a national database of it already exists (at the website of the National Veterinary Institute, www.sva.se).

During the project the main applicant attended weekly meetings with project- and work package leaders in a parallel project “Ley from a Nordic perspective” (R-21-41-605, Stiftelsen Lantbruksforskning) to harmonise the work and to discuss similar challenges and solutions arising in both projects.

A first draft of the report was sent to the reference group, whose comments and questions were addressed in detail to improve clarity and readability of the report. The report was checked for accessibility before publication.

Results and discussion

The content of the report was naturally decided by the content in the papers that were found in the literature search and that fulfilled the inclusion criteria. This means that some areas that were intended to be included are absent in the report, as no such studies were found or had insufficient quality. These areas comprise *e.g.* the use of silage additives in silage and haylage for horses, and information on how to protect hay from moist air during winter storage by wrapping dry hay bales only partially. Other areas were not included in the application but was found in the literature search, such as *e.g.* steaming and soaking of hay, effects on intake and digestibility of pelleting or chopping hay, acid-

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preserved hay for horses and presence of insects and foreign physical objects in forages, and those have therefore been included in the report.

The main findings in the report are summarized below, and main knowledge gaps are highlighted. More details are available in the report, which can be found here:

<https://www.slu.se/globalassets/ew/org/inst/huv/publikationer/rapport-308-vallfoder-till-hastar-ur-ett-utfodringsperspektiv-slutversion-230228.pdf>

Intake of forages in horses

The voluntary intake of forages in horses can be influenced by several factors, but plant species, harvest and/or conservation method, chemical composition of the forage and plant maturity at harvest has been studied in most of the reports, and plant maturity/plant species (not always possible to separate) seems to have the largest impact. The voluntary dry matter intake (VDMI) of forages comprising grass species was on average 2.1 percent of body weight (BW) with a minimum of 1.4 and a maximum of 2.8 percent of BW, while it was on average 2.6 % for lucerne (*Medicago sativa*) with a minimum of 1.7 and a maximum of 3.9 % of BW (references please see Table 1 in the report). The VDMI of Canary reed (*Phalaris arundinacea*) and Teff grass (*Eragrostis tef*) generally seems to be somewhat lower compared to other species, but the number of studies on VDMI of these species is low. Comparisons of VDMI of different plant species is generally difficult as effects of plant maturity and effects of plant species may not be separable. Meta-analyses of several forage intake studies (Edouard et al., 2008; Meyer et al., 2010) have shown that VDMI in horses decrease slightly with increasing fibre content in the forage, but also that it may differ between individuals as some horses increased and other decreased VDMI with increasing fibre content (Edouard et al., 2008). Predictions of VDMI from the chemical composition of the forage has also been reported to not be as valid in horses as in ruminants (Dulphy et al., 1997b). How the forage has been conserved or processed can also influence the voluntary intake of it in horses. The voluntary intake has been reported to be larger when grass or lucerne was offered as pellets or hay cubes (Haenlein et al., 1966; Schurg et al., 1978; Cymbaluk & Christensen, 1986; Todd et al., 1995) compared to as long-stemmed hay.

Forage energy value and nutritive content for different horse categories

The energy value in forages is determined by its digestibility, which in turn is decided largely by the fibre concentration and -composition, which differs with plant maturity at harvest (e.g. Fannesbeck et al., 1967; Ragnarsson & Lindberg, 2008, 2010; Müller, 2012; Särkijärvi et al., 2012). From the literature there is no doubt that adult horses in none to moderate exercise can fulfil their energy requirement from forage only (with no inclusion of concentrate feeds in the diet), and research has shown that both adult (Connysson et al., 2010, 2017) and growing (Ringmark et al., 2013, 2017a,b) high-performing horses can cover their full energy requirement from forage only if the forage has sufficiently high digestibility. For other horse categories, such as mares in late pregnancy and lactation, the information is more scarce regarding which forage nutritive quality that is required for the horses to be able to cover their requirements fully from forages. Harvest in early plant maturity and inclusion of forage legumes (or grass leys being N-fertilized) are generally required to cover the protein requirement of these mares (Doreau et al., 1990). For adult horses that are not in heavy exercise the challenge is often the other way round – in order to fulfil the long eating time requirements without overfeeding energy the forage needs to have a comparably low digestibility (e.g. Ragnarsson & Lindberg, 2010; Müller, 2011, 2012).

The requirements of macro- and microminerals in different horse categories can be covered by the mineral concentrations in forages, except from sodium (Na) and selenium (Se) which are deficient in forages grown in Scandinavia. The concentrations of minerals in forages may however vary widely with several factors such as botanical composition, plant maturity at harvest, fertilization and soil characteristics, and therefore the forage should always be analysed for its mineral composition (Kienzle et al., 2008; Zhao & Müller, 2016).

The requirements of vitamins in different horse categories is assumed to be covered by vitamins in the feed as vitamin deficiencies in horses are uncommon. The scientific background is scarce regarding vitamin concentrations in forages and how they may cover the vitamin requirements

in horses. It is known that beta-carotene content in hay and silage is oxidised during storage (Fonnesbeck et al., 1967; Müller et al., 2007), that a higher concentration of beta-carotene has been found in lucerne hay compared to in grass hay, and that plasma concentration of vitamin A has been higher when horses were fed lucerne hay compared to grass hay (Fonnesbeck et al., 1967; Crozier et al., 1997). None of the hays however resulted in any deficiency of vitamin A in the horses.

The concentration of sugars in forages is important for horses diagnosed with diseases such as Equine Metabolic Syndrome (EMS) and pituitary pars intermedia dysfunction (PPID) to avoid development of laminitis (McGowan, 2008; Lindåse, 2017) or polysaccharide storage myopathy (PSSM) to avoid tying-up (Firshman et al., 2003). However, for healthy horses no information is available on the effects of different sugar concentrations in forages on the metabolic health. For horses with the mentioned diseases, the sugar concentration in the forage should be analysed as it may vary widely and is difficult to forecast. Forages consisting of cocksfoot (*Dactylis glomerata*) has consistently shown a lower sugar concentration compared to forages consisting of perennial ryegrass (*Lolium perenne*) or tall fescue (*Festuca arundinacea*), but several environmental factors during grass growth have a large impact on the sugar concentration (Kagan et al., 2011; Kagan et al., 2019; Kramer et al., 2020). How the forage is harvested and conserved also affects sugar concentration as silage (with dry matter concentration lower than 50 %) is generally lower in sugar compared to haylage and hay due to sugars being used for lactic acid production during ensiling (Müller, 2005; Müller et al., 2016). Furthermore, soaking hay in water prior to feeding has been suggested as a method to reduce sugar concentration, but results from soaking studies shows a highly variable reduction of sugars (from 0 to about 50 % or original concentration) as well as losses of crude protein and minerals (e.g. Martinson et al., 2012a,b; Bochnia et al., 2021) that needs to be compensated at feeding.

Forage harvest and conservation methods and its influence on equine digestion and performance

How the forage is harvested and conserved may influence its composition, which may in turn influence equine digestion, metabolism and performance, but the number of studies within this area is restricted. Horses fed comparable silage (<500 g DM per kg), haylage (from 500 to 840 g DM per kg) and hay (>840 g DM per kg), all produced from the same crop and same harvest, have shown similar digestibility, retention time and digestive characteristics (Müller et al., 2008; Miyaji et al., 2008a,b) and similar performance at exercise tests irrespective of which forage type they were fed (Muhonen et al., 2008b). No consistent effects of chopping or pelleting hay compared to long-stemmed hay has been reported regarding the digestibility in horses (Haenlein et al., 1966; Todd et al., 1995; Drogoul et al., 2000a,b).

Hygienic quality in forages for horses

The hygienic quality of forages for horses is important from a health aspect, as forages with impaired hygienic quality may cause severe illness in the horse, not rarely leading to death or euthanasia. Forage hygienic quality is affected by conditions at harvest, storage and feed-out. Hay needs to be dried to at least 840 g DM per kg and have a water activity of maximum 0.70 to have sufficient storage stability and not become mouldy (Gregory et al., 1963). Generally hay needs to be protected from moist air already during early autumn (October) to inhibit moisture uptake in the hay, which in turn reduces the opportunity for moulds to proliferate (Sundberg et al., 2008). Wrapped forages such as silage and haylage bales needs to be protected against damages in the wrapping as oxygen-rich air that leaks into the bales results in mould growth in the forage (e.g. Schenck et al., 2019). Dry matter contents above 600 g per kg haylage and less than eight stretch film layers in the wrapping of haylage bales have been shown to increase the risk of finding visible fungi in the feed (Schenck et al., 2019). Comparisons of hay and haylage have shown that hay generally contains higher concentrations of respirable particles (predominantly mould spores) (e.g. Raymond et al., 1997; Vandenput et al., 1997). A high concentration of respirable particles can contribute to horses developing equine asthma, which is a serious chronic condition affecting both welfare, health and performance of the horse (e.g. McGorum et al., 1998). Attempts to reduce the concentration of respirable particles in forages have led to the development of different treatments of forages before feeding, such as soaking and steaming of hay. Both soaking and steaming have been reported to greatly reduce the concentration of respirable

particles in hay (e.g. Moore-Colyer & Fillery, 2012) but the airway response in horses fed soaked or steamed hay seems to vary more (e.g. Orard et al., 2018; Dauvillier et al., 2019).

Mould growth in forages of any type can also result in mycotoxins being formed (Raymond et al., 2000), but the number of studies within this area as well as on effects on horses of the most frequently found mycotoxins in forages are low. A specific area where very little is known in European conditions are endophytic fungi and their relevance for horse health, as there are few studies and almost all of them have been performed in the USA. These toxins may primarily cause problems at parturition (e.g. Monroe et al., 1988). Case reports from Europe however exists (e.g. Sander et al., 2017) and from a German study it was reported that both endophytic fungi and their alkaloid toxins were present in grass seed mixtures commercially available and directed towards horse farms (Krauss et al., 2020).

Growth of undesired bacteria in forages may result from contamination by cadavers or soil at harvest or during storage. The most serious example in the literature is growth of *Clostridium botulinum* in both hay and silage, resulting in production of the neurotoxin botulin which after ingestion causes botulism in the horse, a disease with very high mortality (e.g. Theiler & Robinson, 1923; Johnson et al., 2010).

Anti-nutritional substances, such as photosensitizing substances or phytoestrogens, may be present in some forages. The number of studies on these substances and their effects on horse health are limited, but some case reports include primary and/or secondary photosensitization in horses being fed lucerne (Puschner et al., 2016) or alsike clover (*Trifolium hybridum*) (Hjärre & Carlström, 1933). Phytoestrogens may be present in some forage legumes, and negative effects on the uterus was reported in mares being fed clover- and lucerne haylage with a high concentration of coumestrol (Ferreira-Dias et al., 2013).

Main knowledge gaps- conclusions

Several knowledge gaps were identified, which also serve as conclusions for this project. One of the main gaps involve how forage legumes can be used in forages for horses to supply sufficient energy and protein to different horse categories with focus on health, welfare and performance. How this affects which methods that are suitable for forage conservation and forage hygienic quality, or concentration of anti-nutritional substances, is important knowledge for a sustainable future forage provision for the horse population. Another knowledge gap is how forages adapted in its nutrient concentrations for specific horse categories can be produced. Examples include forages with low concentration of sugars for horses with metabolic diseases where daily sugar intake is of interest, or forages for high-performance horses which requires high digestibility and energy value in their forage. A general difficulty within the area of hygienic quality in forages and health risks for horses is that many of the studies are case reports or correlation/association studies, which can not be used as showing a cause- and effect. It would in most cases not be ethical to perform the latter type of studies due to the severity of the health issues, but more systematic approaches in such studies would improve our understanding of health- and welfare effects on horses from using hygienically compromised forages. Safe forages are a prerequisite for a sound and sustainable feeding of horses, and areas of emergence may include forage mycotoxins and endophyte fungal toxins and their effect on horses, which are currently poorly understood.

Relevance for the practical horse sector incl. recommendations

In this project the existing knowledge of forages for horses from a feeding perspective has been collected, critically reviewed, summarized and published in a report in Swedish that is freely available to anyone. The content of the report may serve as a lexicon for horse owners and forage producers and as an aid when different questions in horse feeding arise, or to help with decision making in production and use of forages for equines.

The report has been implemented in teaching on all animal science and veterinary medicine education programs at SLU as well as been made available to advisory services within the

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agricultural and horse sector. Further investigations within different areas, as stated in conclusions, are required in order to have a sustainable production of safe forages for the horse population.

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Part 3: Result dissemination

Scientific publications, published	<p>Sara Ringmark, Malin Connysson, Katarina Arvidsson Segerkvist, Anna Jansson, Cecilia E. Müller. 2023. Vallfoder till hästar ur ett utfodringsperspektiv – en kunskapssammanställning från 1903-2022 (Forages for horses from a feeding perspective- a collection of knowledge from 1903 to 2022). Report 208, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden. ISSN:0347-9838, ISRN:SLU-HUV-R-308-SE. https://www.slu.se/globalassets/ew/org/inst/huv/publikationer/rapport-308-vallfoder-till-hastar-ur-ett-utfodringsperspektiv-slutversion-230228.pdf</p>
Scientific publications, submitted	<p>None yet.</p>
Scientific publications, manuscript	<p>In manuscript, submission planned before end of 2023: Ringmark, S., Connysson, M., Arvidsson Segerkvist, K., Jansson, A., Martinson K., Müller, C.E. 2023/24, Forages for horses from a feeding perspective – a systematic literature review. Journal to be decided.</p>
Conference publications/ presentations	<p>Sara Ringmark, Malin Connysson, Katarina Arvidsson Segerkvist, Anna Jansson, Cecilia E. Müller. 2023. Vallfoder till hästar ur ett utfodringsperspektiv – en kunskapssammanställning från 1903-2022. Vallkonferens 2023 poster presentation, Uppsala, 7 – 8 February 2023, https://www.slu.se/institutioner/husdjurens-utfodring-vard/nyheter-huv/vallkonferens-2023/</p>
Other publications, media etc.	<p>Vallfoder till hästar ur ett utfodringsperspektiv, 2023, https://brunbergsfoder.se/produkt/vallfoder-till-hastar-ur-ett-utfodringsperspektiv/</p> <p>https://www.veterinarmagazinet.se/2021/11/slu-far-medel-till-projektet-vallfoder-till-hastar-ur-ett-utfodringsperspektiv/</p> <p>HästSverige: https://hastsverige.se/hastens-miljo/grovfoder/ (please scroll down the side to find the report)</p> <p>SLU: https://www.slu.se/ew-nyheter/2023/2/ny-rapport---vallfoder-till-hastar-ur-ett-utfodringsperspektiv/</p>

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	<p>Tidningen Ridsport: https://www.tidningenridsport.se/studie-om-vallfoder-ska-ge-bättre-hasthalsa/</p> <p>Tidningen Ridsport: Interview 20230609, to be published 20230616</p>
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	Land Lantbruk, interview 20230315: published in paper version
	Borgeby fältdagar 2023 (Borgeby agricultural fair days)- Svenska Vallföreningen: the report is presented at the stand of Svenska Vallföreningen.
Oral communication, to horse sector, students etc.	The report is used for students in all animal science programs, veterinary program and veterinary nurse program at SLU as well as in non-program courses within the subject area.
	Hötappen Svenska Vallbrev: A short summary of the report will be included in number 6 of this publication in 2023 (will be published in October 2023).
	Report sent to Hästnäringens Nationella Stiftelse for publication on website (not yet been published by them).
	Report sent to LRF Häst for publication on website (not yet published by them).
Student theses	None (not applicable)
Other	-

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