Forage analysis for horses: challenges, applications, and opportunities for improvements

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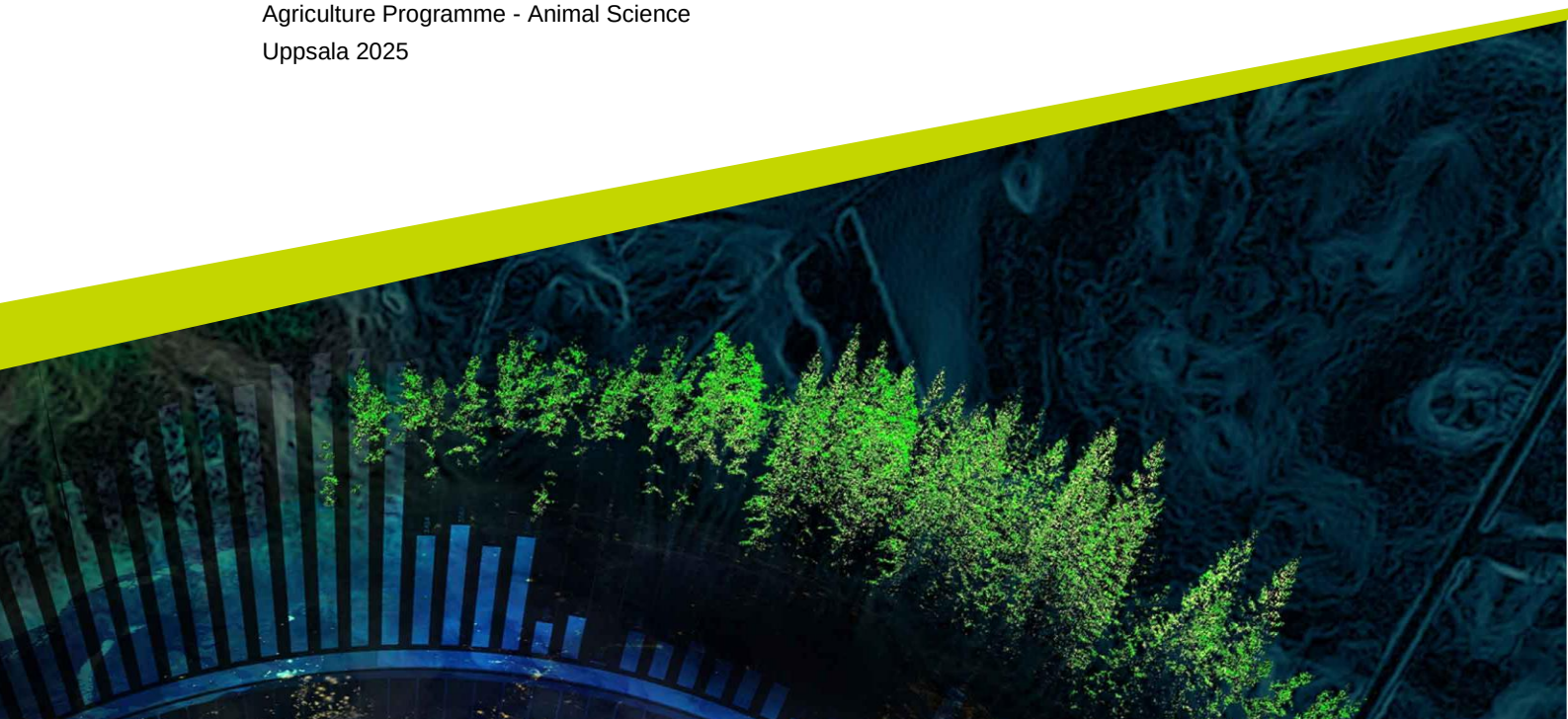

Forage analysis for horses: challenges, applications, and opportunities for improvements

Analys av grovfoder för hästar: utmaningar, användningsområden och förbättringsmöjligheter

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Abstract

Forage analysis is an essential tool in formulating feed ration for horses, yet it is often overlooked according to previous research. Therefore, this report aims to identify forage analysis utilisation, challenges, and highlight potential areas for improvement. This study includes both a literature review and an online survey designed in Netigate, with a mix of single- and multiple-choice questions. The survey was conducted in Sweden in 2024 and targeted Swedish horse owners and -keepers. The responses were kept anonymous, and the data analysis was performed using Excel and Minitab.

The survey received 505 responses, with 425 surveys being completed. Most responders had over 10 years of experience, and were responsible for one or two horses which were primarily leisure horses. The horse feed ration was estimated or calculated by using the forage analysis, which was conducted by 80% of the responders. Basic (metabolisable energy, digestible crude protein, dry matter and could include ash) and macromineral analyses were the most frequently variables the responders had in the forage analytical report. However, not every responder who had an analysis thought it was simple to interpret and apply. Responders wanted it to be cheaper, provide recommendations and have guidelines. In conclusion, the same challenges including a lack of knowledge, interpretation difficulties and scepticism were observed when compared to previous research, despite the fact that responders appeared to have and use a forage analysis. The identified challenges may point to potential areas for improvement, which could establish it as a standard tool for horse owners and -keepers to maintain health and performance.

Keywords: Equine, Hay, Haylage, Nutrition, Nutritive composition, Roughage.

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Abbreviations

Abbreviation	Description
BCS	Body condition score
CP	Crude protein
DCP	Digestible crude protein
DE	Digestible energy
DM	Dry matter
EMS	Equine metabolic syndrome
ESC	Ethanol-soluble carbohydrates
ID	Insulin dysregulation
ME	Metabolisable energy
MJ	Megajoule
N	Number of responders
NE	Net energy
NIRS	Near-infrared spectroscopy
PPID	Pituitary pars intermedia dysfunction
PSSM	Polysaccharide storage myopathy
WSC	Water-soluble carbohydrates

1. Introduction

Knowledge of both nutrition and feeding management are essential for creating a balanced feed ration to maintain equine health and performance (Mastellar *et al.* 2018). An unbalanced feed ration for horses may increase the risk of various health issues as it means that the horse has excesses or deficiencies in vital nutrients (Hoffman *et al.* 2009). The feed ration is often composed of both forage and concentrate. The nutritional value of the concentrate is often analysed by the manufacturer of the feed, whereas the nutritional composition of the forage may require that a forage analysis is made by the purchaser. Knowing the forage nutritional quality is the foundation for designing a feed ration (Richards *et al*. 2021).

Research conducted in other countries examining general horse nutrition and feeding management has indicated that forage analysis is often overlooked, with horse owners perceiving it as expensive and difficult to interpret (Mastellar *et al.* 2018; Moore-Colyer *et al.* 2023; Kenny & Smarsh 2024). No more than 28% of responders in previous surveys have had a forage analytical report (Mastellar *et al.* 2018; Moore-Colyer *et al.* 2023; Kenny & Smarsh 2024). The majority of the responders (74%) with no analytical report stated the analysis as unnecessary, where some (16%) were unaware of its existence (Moore-Colyer *et al.* 2023). A majority of the responders (62%) from another survey had never conducted a forage analysis (Kenny & Smarsh 2024). Less than 50 % of the responders stated that they had confidence in how to interpret the analytical report (Mastellar *et al.* 2018; Kenny and Smarsh, 2024). These previous findings indicate that horse owners might find the forage analytical report difficult and unnecessary to use. Therefore, there is a need for a better understanding of how forage analysis can be applied for horses, as well as its importance for horse owners and -keepers. A better understanding and usage of forage analyses is a crucial tool for designing feed rations for horses. In order to improve the use of forage analysis for horse feeding, it is necessary to gain better knowledge of how horse owners use the analysis and the challenges they experience with it needs to be identified.

1.1 Purpose

This study aimed to examine the usage, knowledge level and problems associated with forage analysis for horses and highlight possible areas for improvement. The overarching issue examined was: What changes are necessary to encourage horse owners to use forage analysis? The report will also explore how forage analyses are used, its significance and challenges from the horse owners and -keepers perspective.

2. Methods

To answer the questions of this study, a literature review and an online survey for horse owners and -keepers were conducted.

2.1 Literature review

In order to gain a more comprehensive understanding of why forage analysis is crucial, and to see if other research had examined its usage and challenges, a literature review was implemented. Both Google Scholar and Web of Science were used to find concrete references. Literature searches were conducted using the keywords: forage analysis, horse nutrition, horse owners' knowledge, forage for horses. The target was to find a minimum of 20 references that were published after the year 2000, and the focus was on forage analysis for horses, as it can differ from analysis for ruminants. When comparing findings from different studies, factors such as climate, horse management, feed recommendations, and analytical techniques were regarded as they may differ between regions.

2.2 Survey

An online survey was created using the software Netigate and conducted in Sweden in December 2024 in Swedish. Four individuals tested the survey before the release: the supervisor and three horse owners with varying levels of education, different types of horses, and one who harvests their own forage. The test aimed to ensure the questions were simple to comprehend and contained diverse viewpoints. The survey was open for three weeks and was distributed via email to several Swedish forage analytical companies, social media (Facebook, Instagram and blogs), and online groups on Facebook with a horse theme.

The target group were horse owners and -keepers responsible for feeding management, and the answers were kept anonymous to encourage a higher number of responses to the survey. The survey's questions are listed in the Appendix. The questions covered knowledge, utilisation and challenges around forage analysis. There was a combination of single-choice and multiple-choice questions. Additionally, some provided an open alternative where responders wrote their own responses. If the responders wrote an answer similar to the pre-written alternative the answer was moved to the correct alternative. Three questions were not mandatory to be answered, and one of them was an open question with no pre-written alternatives.

2.2.1 Statistics

Excel and Minitab were used to analyse the survey results. Excel tables and figures were created to view the total responses to each question. The total number (N) and per cent of responders are shown in the results. Minitab was used to conduct cross-tabulations and identify associations between two questions. Cross-tabulations was made between responders' educational level and tools they used for interpretation and how difficult they thought it was to interpret the forage analysis. It was also made for years of experience and how difficult the responders thought it was to interpret the analysis. Lastly, cross-tabulations was made between what type of forage analysis they had and if they had the variables they thought were important.

The Chi-square test (Pearsons Chi-square test) was used to assess whether the difference observed in the data can be attributed to random chance or indicate a statistically significant effect, with a significance level of $p < 0.05$. The test was conducted in Minitab and required a minimum of 80% of the cells in the cross tabulation to have a value of at least five or more. Chi-square tests were used to check for associations between how responders obtained the analytical report and which different combinations of analytical variables that were used, if there was an association between educational level and how the analysis was utilised, and whether the educational level and tools used for interpreting the analysis were associated.

Even if a responder did not complete the survey, results were still used. In cross-tabulation, the responders who did not answer both questions were not included along with responders selecting the open alternative and could not be moved to a pre-written alternative.

3. Literature review

The literature review provides an overview of published surveys to examine what is known about horse owners' usage, knowledge and challenges related to forage analysis. There will also be a review of the importance of forage analysis, the procedures involved in conducting an analysis, and potential challenges.

3.1 Forage analytical reports in equine nutrition

A survey for horse owners in the upper Midwest region in the United States was conducted by Mastellar *et al.* (2018). Most responders (71%) reported having over 10 years of experience, and on average, owned or managed four horses, with 57% expressing that responders' horses had none to a light workload. The understanding and confidence in interpreting the results of forage analysis was investigated and a potential barrier for owners between the cost and time required to understand and interpret the analysis was found (Mastellar *et al.* 2018). Forty-seven out of 115 responders felt secure in interpreting the forage analysis, but only 13 of them conducted one. Additionally, the report assessed responders' knowledge of nutrition; 123 completed all the questions, and on average, responders had 11 out of 20 correct answers (Mastellar *et al.* 2018). Notably, there was no correlation between the responders' number of correct answers and the responders' years of experience, or the number of horses owned or managed (Mastellar *et al.* 2018).

Two surveys were conducted among horse owners in the United Kingdom, with 504 responders in the first and 834 in the second survey (Moore-Colyer *et al.* 2023). In the first survey the type of horses and educational background among horse owners was examined. The educational background did not correlate with the responder's knowledge about feed, feeding choices or management practices (Moore-Colyer *et al.* 2023). Forty-five per cent of responders owned leisure horses, and among the 504 responders, 89% did not have a forage analysis. Of those, 74% felt no need for an analysis, 9% stated it was too expensive, and 16% were unaware of analysis (Moore-Colyer *et al.* 2023). In the second survey it was found that 74% of the responders did not receive a forage analysis along with the forage, and only 4% conducted their own analysis when none was provided (Moore-Colyer *et al*. 2023). Among those who conducted analyses, 75% analysed the concentration of fibre, digestible crude protein (DCP) and water-soluble carbohydrates (WSC) (Moore-Colyer *et al.* 2023).

In Pennsylvania, a survey with 435 hay buyers were conducted by Kenny and Smarsh (2024). The subgroup was primarily leisure riders (76%), with a statistically significant proportion having over 10 years of experience with

purchasing hay (70%). A majority of 87% of the responders purchased hay from a local farm, and 20% of the responders reported harvesting their own hay indicating that some both harvest their own as well as purchased. The importance of hay analysis was acknowledged by 38% of the responders (Kenny & Smarsh 2024). Furthermore, 62% had never analysed forage, 15% conducted analyses occasionally and 12% analysed only when feed-related problems arose (Kenny & Smarsh 2024). When looking at the responders' interest in having hay tested, 36% expressed a high interest, and 35% indicated a moderate interest. However, confidence in understanding and interpreting the analysis was lacking, as only 29% felt confident, and 32% reported having a small degree of confidence (Kenny & Smarsh 2024). The rest of the responders in the survey stated no confidence and 32% had never even seen a forage analytical report.

A survey was conducted in Finland in 2010 with 142 responders; to see how common and important a forage analysis was to forage producers and stable owners (Uotila *et al*. 2012). The subgroup was mainly people offering riding lessons, breeders and trotter trainers, having around 20 horses in their stable. Most of the stable owners produced their own forage, 50% had a forage analytical report, and 16% conducted an analysis when it was missing from the seller. Fifty per cent of the ones with no analysis would conduct one if it were cheaper (Uotila *et al.* 2012). Three out of four stable owners could interpret and understand the concept of the forage analysis. The three most important values for both producers and stable owners were found to be digestible crude protein (DCP), sugar and DM content in the forage (Uotila *et al.* 2012).

A comprehensive study across 100 countries, with many responders from the United Kingdom, United States, Canada and Australia with 6,538 responders were conducted by Murray *et al*. (2015). In this survey, 95% of the responders considered nutrition to be important. The internet and veterinarians were the most common sources of information regarding feeding and may point to a potential issue as research indicate that veterinarians lack the confidence to provide nutritional advice (Murray *et al.* 2015). The internet contains multiple sources, and not all of them are scientifically based. The responders reported feeding the horses without any knowledge of the horse requirements and that 70% of responders fed their horse by volume rather than weight. The conclusion highlights a possible issue; many horse owners may rely on information that is not scientifically based. This might be a result of owners consulting multiple sources about nutrition, a finding supported by both Hoffman *et al.* (2009) and Murray *et al*. (2015). In New England a survey was conducted with 67 responders (Hoffman *et al.* 2009). The report found that veterinarians, trainers and the internet were popular sources of information, and that most of the responders relied on more than one source. The responders answered a few questions about general knowledge of horse nutrition, where the responses indicated that horse owners

may have a limited understanding of general nutrition. Data indicated that information could often be found in sources without a scientific base (Hoffman *et al.* 2009)

3.2 Why forage nutrients should be analysed for horses

Feeding forage is an essential part of the horse's mental and physical health. It is not only providing the horse with majority of the necessary nutrients (Richards *et al.* 2021). It also supports the horse natural eating behaviour and promotes healthy gastrointestinal function (Harris & Dunnett 2016). Analysing forages minimises the risk of under- and overfeeding, and it will also result in cost savings by reducing the use of unnecessary supplements (Saastamoinen & Hellämäki 2012).

3.2.1 Important nutrients

Without a forage analysis, the risk of under- or overfeeding nutrients increases, and the analysis can be seen as an essential tool (Saastamoinen & Hellämäki 2012). Energy is required for the horse to maintain life-sustaining functions; an energy deficiency will therefore lead to energy taken from body reserves, like body fat and muscles (McDonald *et al.* 2011). Both energy and DCP deficiency can result in poor growth, decreased muscle mass and weight loss (Ringmark 2017). It can also lead to poor hair and hoof growth, and for pregnant horses, it can result in an early fetal loss and reduced fertility (Mok & Urschel 2020). Overfeeding CP gives a minimal risk for health issues and is more seen as an environmental problem (Mok & Urschel 2020).

Horse owners with horses that have a healthy glucose metabolism and are in a good body condition score (BCS) do not need to consider the sugar content in a forage (Müller 2017). However, horses with an impaired glucose metabolism and with a high BCS would benefit from being fed a forage with low sugar concentration and energy value to decrease the risk of laminitis episodes and other health issues related to obesity (Ringmark & Jansson 2013). Horses with an impaired glucose metabolism are horses with diseases like insulin dysregulation (ID), equine metabolic syndrome (EMS), pituitary pars intermedia dysfunction (PPID) and polysaccharide storage myopathy (PSSM) (Müller 2017). Horses with impaired glucose metabolism have been seen to benefit from sugar concentrations lower than 10-12% of DM, as it can reduce both glycaemic and insulinemic responses after meals (Frank *et al.* 2010). It promotes metabolic health and improves insulin sensitivity in horses with impaired glucose metabolism (Frank *et al.* 2010). Even a high DCP intake has been shown to play a role in glucose metabolism, because it can increase the insulin response (Ringmark & Jansson 2013). The connection between sugar, DCP and energy may highlight the

importance of considering all variables when selecting a forage for horses with an impaired glucose metabolism, as they may all have an impact on horse health (Ringmark & Jansson 2013).

Usually, mineral elements are supplemented in the diet; however, selecting the appropriate mineral supplement requires knowledge of the forage mineral content (Saastamoinen & Hellämäki 2012). When feeding the bare minimum of forage for maintenance, the concentrations of phosphorus, sodium, cobalt, copper, selenium, iodine, and zinc in forages from Sweden and Norway can be insufficient for adult horses (Zhao & Müller 2015). Two vital mineral elements that are essential for the animals are calcium and phosphorus (Jansson *et al.* 2012a). Their ratio also matters, and just as calcium and phosphorus work together to support certain body processes, so do other mineral elements (Jansson *et al.* 2012a). However, when the forage originates from mineral-rich fields, microminerals are often provided in sufficient amounts and may not require supplementation (Jansson *et al*. 2012a).

3.2.2 Factors influencing forage nutritional quality

Forage nutritional quality can be defined as the ability of forage to provide vital nutrients for animal performance (Fulgueira *et al.* 2007). The chemical composition of a forage varies largely which requires analysis of the forage to be visualized (Fulgueira *et al.* 2007). This is extra important for horses in exercise, pregnancy, lactation or growth (Jansson *et al.* 2012a), as well as for horses with clinical conditions (Harris *et al*. 2017). Forage nutritional quality can be influenced by plant-related factors, management factors and the environment (Fulgueira *et al.* 2007; Harris *et al.* 2017).

Plant related factors influencing forage nutritional quality are *e.g.* crop species; legumes are generally higher in DCP than grasses (Fulgueira *et al.* 2007). Plant maturity is the most influential factor on forage nutritive quality and refers to the plant growth stage when harvested. The plant can change significantly in chemical composition over two to three days (Fulgueira *et al.* 2007). Management factors are seasonal time of harvest, as well as the harvest technique (Fulgueira et al. 2007), where leaf and stem proportion have an influence (Harris *et al.* 2017), as it both change the digestibility of the forage and nutritional value (McDonald *et al*. 2011). The number of cuts has been seen to influence the concentration of all macrominerals except sodium, as well as copper and iodine, in the forage (Zhao & Müller 2015).

Forage quality is also influenced by the weather, as rain and wet weather can delay the harvest, which can result in overmature plants (Fulgueira *et al.* 2007). Both temperature and water availability change forage quality; high temperature can decrease the nutritional quality while drought stress can increase it (Fulgueira *et al.* 2007).

3.3 Forage analysis

Forage analysis is an important tool for creating a correct feed ration for the individual horse (Jansson *et al.* 2012a). Forage is the foundation of the horse diet, and without an analysis, most nutrients are unknown (Richards *et al.* 2021). Wet chemistry is a traditional method used to analyse the chemical composition of forage (Fulgueira *et al.* 2007). It is time-consuming and is based on biochemical and chemical principles (Fulgueira *et al.* 2007). A newer technique that laboratories have changed to is near-infrared spectroscopy (NIRS), which is more time-efficient and less expensive (Harris *et al.* 2018). However, traditional wet chemistry methods are still needed to calibrate NIRS data for different forages and seasons for an accurate result (Longland 2012). Additional advantages of NIRS itself are that it does not require chemicals and is a non-destructive method (Harris *et al.* 2018). However, it is crucial to be aware that CP has been observed to be underestimated when using NIRS, and the sample preparation is important, as water affects the infrared radiation (Harris *et al.* 2018). One important aspect for both wet chemistry and NIRS is that the methods do not always relate to the horse ability to absorb the nutrients (Longland 2012), they only show the composition and/or the estimated values of the sample.

3.3.1 A representative sample

When analysing the forage nutritional quality, a good sampling technique is vital for a representative sample (Fulgueira *et al.* 2007). A non-representative sample should not be used, as it could result in a false value that may cause long-term deficiencies or an excess of nutrients (Ringmark & Jansson 2013). The sample represent the batch, and the accuracy of the analytical result depends on the sampling and requires careful handling of the sample at the farm and the laboratory (Fulgueira *et al.* 2007).

The sampling technique differs both between the information source and between if it is sampling from field, hay and haylage bales (Fulgueira *et al.* 2007; Jansson *et al*. 2012a). However, both hay and haylage require sampling from several bales if sampling is not performed in the field at harvest (Fulgueira *et al.* 2007; Jansson *et al*. 2012a). Additionally, it should be noted that the botanical composition may differ both within and between bales (Harris *et al.* 2018). For hay, sampling can be done without opening a bale, and it is advised to take smaller samples from 20 bales and combine to one sample (Fulgueira *et al.* 2007). Swedish feeding recommendations recommended to open the bales and sample at least five bales for a representative hay sample (Jansson *et al*. 2012a). For haylage, a hole is drilled from at least three bales within the same batch to gather a representative sample (Jansson *et al*. 2012a).

3.3.2 Forage nutritive values and nutritive requirements of horses

Water content in a forage analysis is often analysed, and the feed composition is expressed in the DM, to compare nutritional values between forages with different DM concentrations (McDonald *et al*. 2011). Additionally, horses have a DM intake requirement; the Swedish recommendation is that horses should be provided with a minimum of 1 kg of DM/100 kg of body weight (Jansson *et al*. 2012a). Haylage contains less DM than hay and more kg of haylage per day is required to reach the DM requirements than if hay is fed (Jansson *et al.* 2012b).

There are different ways to calculate energy value; some countries use digestible energy (DE), some use metabolisable energy (ME) and some use net energy (NE) (McDonald *et al*. 2011). In Sweden, energy values in feed are calculated as ME with megajoules (MJ) as a unit (Jansson *et al.* 2012a). The ME requirement for a horse depends on the horse body weight, type of horse as in easy, normal or hard keeper, activity (riding, growing or lactating), as well as sex (Jansson *et al.* 2012a). Other factors that affect the ME requirements are age, group housing, cold weather and body condition adjustment (Jansson *et al.* 2012a).

Protein content in the feed is typically expressed as DCP with the unit gram (Jansson *et al.* 2012a). The DCP requirement is calculated from the ME requirement, where the horse needs 6 g DCP/MJ ME for maintenance (Jansson *et al.* 2012a). This is because both the synthesis and breakdown of body protein require energy to work (Mok & Urschel 2020). When analysed, it is often expressed as CP and represents all the nitrogen present in the sample (Fulgueira *et al.* 2007).

The most common way to analyse sugars in forages is by WSC or ethanol soluble carbohydrates (ESC) analysis (Müller 2017). However, in ESC, fructans are fully or partly missing and needs to be estimated by using other methods (Müller 2017). There is a debate on the wet chemistry techniques for analysing sugar fractions, as some fractions may be left out depending on what type of method is used (Harris *et al*. 2018). There has been a discussion on differences arising when using wet chemistry or NIRS for analysis of WSC as NIRS showed a higher WSC concentration compared to wet chemistry methods (Harris *et al.* 2018). Another issue discovered was that sugar concentration had a low repeatability within an analytical method (Harris *et al*. 2018). When conducting an analysis of sugar concentration in forage, it should therefore be clear which method the laboratory is using, and further research is needed within the calibration of NIRS with different wet chemistry methods and sugar fractions (Harris *et al.* 2018).

The concentration of the macrominerals calcium, phosphorus and magnesium is recommended to be analysed in the forage (Jansson *et al.* 2012a). There is

generally no negative effect with high concentration of the minerals as long as the Ca/P-ratio is above 1.2 in the total feed ration, and the requirements of all of the mineral elements is fulfilled, but deficiencies can affect long-term health (Jansson *et al.* 2012a). Microminerals should also be given within the recommended range as both excess and deficiency symptoms may be a result of over- or underfeeding these (Jansson *et al*. 2012a). It should be considered that the minerals interact with each other, and a diet with too much of a mineral element can interfere with the uptake of other mineral elements (Jansson *et al.* 2012a).

4. Results

There were 425 completed surveys out of 505 responders. The survey was successfully distributed through online groups and social media; however, the analytical companies that were contacted through email for a broader distribution did not reply.

4.1 Demographics of responders

The majority (83%, 419 of 505) of the responders had over 10 years of experience in owning or working with horses, and 63% (319 of 505) had over 20 years of experience (Table 1). Thirteen per cent (67 of 505) had five to ten years of experience, and 4% (19 of 505) had four years or less of experience with horses.

Table 1. Responders' years of experience in owning or working with horses in different year intervals in numbers and per cent. Single-choice question, N = 505

Years of experience with horses	Numbers of responders	Per cent of responders
Less than a year - 4 years	19	4
5 - 10 years	67	13
11 - 20 years	100	20
More than 20 years	319	63

Fifty-two per cent of the responders (261 of 505) had no horse-related education (Figure 1). The most frequently selected educations for responders were single-subject courses (19%, 96 of 505), followed by high school (15%, 78 of 505), and vocational education (10%, 51 of 505). Other educations among the responders were university education, riding instructor education and folk high school education, all horse-related. The responders had the opportunity to choose more than one education. Responders could also select the open alternative and write an answer of their own, and those were placed in the appropriate pre-written alternatives.

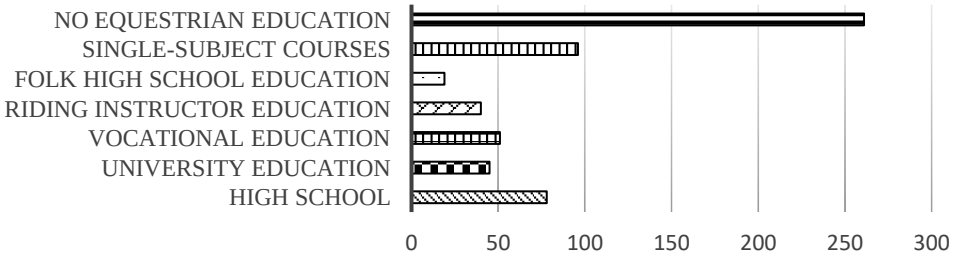

Figure 1. Responders' equine-related education and number of responders in different types of horse-related educations. Multiple-choice question, N = 505.

The majority of the responders (56%, 281 of 505) were responsible for the feeding management of one to two horses, while 25% (128 of 505) of the responders were responsible for three to four horses and 18% (93 of 505) were responsible for five or more horses (Table 2). The remaining proportion, 1% (3 of 505), of the responders were not responsible for feeding management of any horse.

Table 2. The number of horses the responders were responsible for regarding feeding management, amount and per cent of responders in different amount of horse intervals. Single-choice question, N = 505

Number of horses in responders care	Number of responders	Per cent of responders
0 horses	3	1
1-2 horse/horses	281	56
3-4 horses	128	25
5 or more horses	93	18

The most frequently horse category cared for by the responders in regard to feeding management were leisure horses (81%, 407 of 505), followed by training and competition horses (38%, 191 of 505) (Figure 2). Sixteen per cent (82 of 505) of the responders had breeding horses, 5% (24 of 505) education or sale horses, and 4% (21 of 505) were responsible for feeding management of horses at riding schools. Working horses were the least prevalent horse type among the responders, with 3% (17 of 505) having at least one such horse.

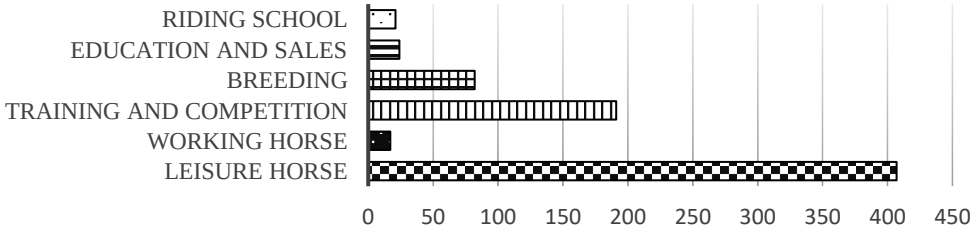

Figure 2. The type of horse responders cared for regarding feed management, number of responders in different horse categories. Multiple-choice question, N = 505.

4.2 Forage analysis usage

The majority of responders (75%, 377 of 503) purchased their forage, while 19% (96 of 503) harvested their own forage. Additionally, 6% (30 of 503) of the responders harvested their own forage but also required supplementation with purchased forage.

Eighty per cent (402 of 503) of the responders in the survey had access to a forage analytical report, while the remaining proportion (20%, 101 of 503) had no access to a forage analytical report.

Forage sellers were commonly responsible for submitting forage samples for analysis, as 46% (223 of 482) of the responders received a forage analytical report from the seller (Figure 3). Additionally, 19% (91 of 482) of the responders submitted a forage sample for analysis due to the forage seller having no analytical report, while the same proportion (89 of 482) of responders harvested their own forage and sent their own forage sample.

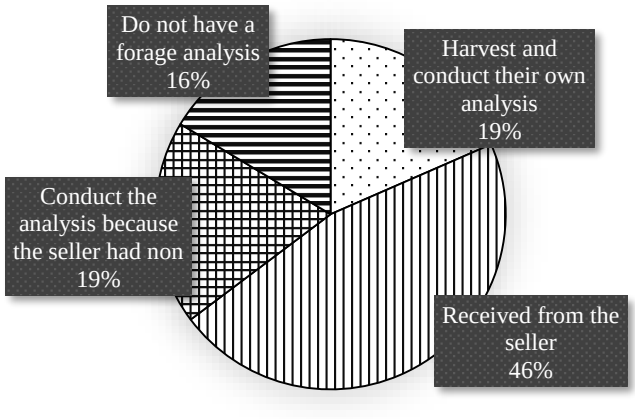

Figure 3. Per cent of responders who submitted the forage sample for analysis or received it from the forage seller. Single-choice question, N = 482.

A basic analysis of the forage, which included DM, ME, DCP, and could include ash, was the most commonly obtained type of analysis (82%, 394 of 482) (Figure 4). Macromineral analysis was the second most common (67%, 331 of 482), followed by sugar analysis (46%, 224 of 482). The sugar analysis could either be for concentration of WSC or ESC. Forty-one per cent (196 of 482) of the responders had a micromineral analysis and 13% (65 of 482) had a selenium analysis. The open alternative contained 15 responses; two responders were uncertain of which parameters that were included in their analysis, and six responders occasionally analysed for more variables. One respondent analysed hygienic quality, three responders wanted ESC and not WSC to be analysed, and two thought the analysis was unnecessary.

The chi-square test showed no correlation between the number of variables included in the analytical report and how the responders obtained the forage analytical report (who submitted the forage sample) (X^2 (4, 400) = 0.261, p = 0.261). Eleven per cent (51 of 482) of the responders had an analysis for all variables, 19% (93 of 482) of the responders had analytical values for all variables except for selenium, and 53% (256 of 482) of the responders had one or more but

not all possible variables.

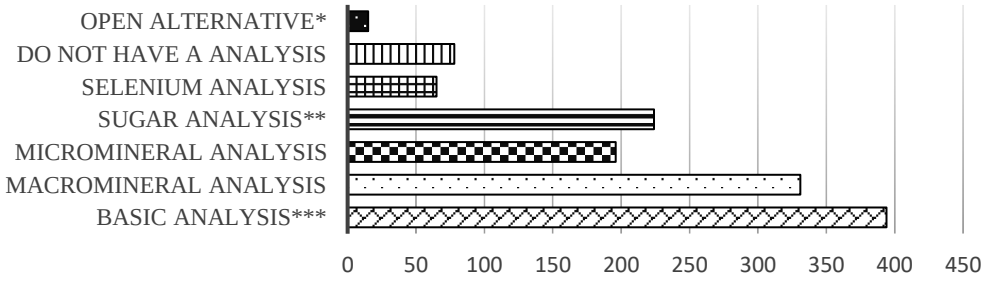

*Figure 4. Responders' forage analytical report contained variables, number of responders with different types of variables included in the forage analysis (n). Multiple-choice question, n = 1303 and N = 482. * The open response alternative included "uncertain, sometimes analyse more values, hygienic quality, wants ethanol-soluble carbohydrates and not water-soluble carbohydrates, analysis is unnecessary". ** Sugar analysis includes both water-soluble carbohydrates or ethanol-soluble carbohydrates. ***Basic analysis includes dry matter, digestible crude protein, metabolisable energy and could include ash.*

The forage analysis was used by 41% (196 of 482) of the responders to calculate a balanced feed ration, and almost the same proportion (40%, 192 of 482) used it to estimate a feed ration (Figure 5). The open alternative contained 17 responses where six responders "looked at the horse" when designing a feed ration and five used the analysis to find a suitable forage batch for the horse and as guidelines. Three of the responders expressed interest in specific values due to the horses having EMS. One per cent (5 of 482) of the responders used the analysis only when there was a feed-related problem. The chi-square test showed that the responders utilisation of the forage analytical report was not influenced by their horse related education or their lack of such education (X^2 (4, N = 482) = 1.361, p = 0.851).

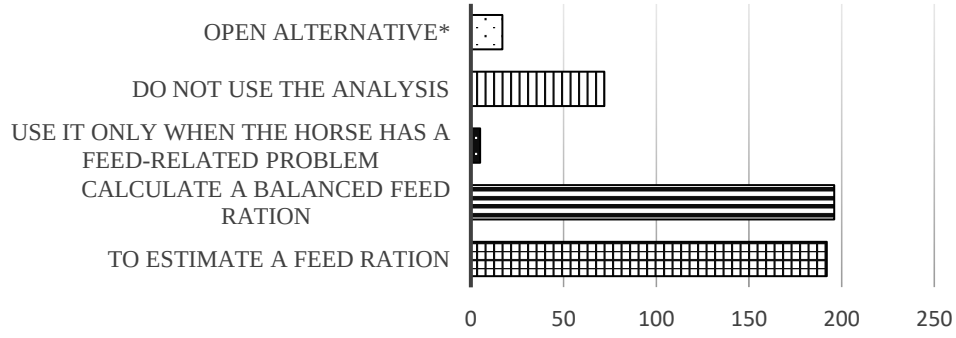

*Figure 5. How the responders used the forage analysis, number of responders in different usage categories, Single-choice question. N = 482. *The open response alternative included "see if the analysis works for the horses, guidelines, looking at some values to help with equine metabolic syndrome, looked at the horse too".*

4.3 Interpretation of the forage analysis

Feed ration calculation programs were the most frequently used tool by the responders to interpret the forage analytical report (51%, 228 of 444). Nineteen per cent (86 of 444) of the responders had education, while a similar proportion (83 of 444) used an advisor to interpret the analysis. Eighteen per cent (82 of 444) of the responders had learnt to interpret the analysis through experience, while 13% (56 of 444) used friends for help, and 10% (46 of 444) did not have any analysis. The open alternative contained 11 responses; four used Excel to calculate a feed ration, three used Google, three got help or used a program if something looked wrong and one guessed.

A feed ration calculation program was primarily used regardless of educational background, according to descriptive data comparing whether responders with different educations used different tools to calculate or compose a feed ration (Table 3). Chi-square tests were conducted which showed differences (X^2 (24, N = 752) = 161.19, p = 0.0001) between the responders educational background and tools they used, even though all the educations primarily used feed ration programs. University-educated responders used their own education (43%, 27 of 63) as a tool and less friends (2%, 1 of 63) and advisors (5%, 2 of 63) to interpret the analysis. Responders with no horse-related educational background used advisors to a higher degree (34%, 101 of 298) as a tool when interpreting the analysis.

Table 3. Per cent of responders who, across their horse-related educations, used different tools to calculate or design a feed ration for the horse, distributed over the responders´ horse-related educations, N = 433

Educational group	Advisor (Per cent)	Program (Per cent)	A friend (Per cent)	Education (Per cent)	Experience (Per cent)	Total numbers of responders
High school	10	40	12	30	9	115
University	5	43	2	43	8	63
Vocational	10	33	15	32	11	75
Riding instructor	12	42	15	25	7	60
Folk high school	10	32	16	29	13	31
Single-subject courses	14	38	11	23	15	110
No education	34	39	11	1	16	298

Most responders (80%, 404 of 503) thought the forage was “very important” in meeting the horse nutritional requirements, with 18% (92 of 503) of the responders stating, “quite important.” Less than 1% of the responders selected the alternatives “less important” (2 of 503), “not important” (3 of 503) and

"uncertain" (2 of 503) when questioned about responders' opinion of the forages significance in meeting the horse nutritional requirements.

The three most common variables responders stated as "important" were DCP (78%, 345 of 441), ME (74%, 324 of 440), and the ratio of g DCP/MJ ME (66%, 291 of 439) (Figure 6). The three most frequently chosen variables responders stated as "quite important" were microminerals (43%, 189 of 439), macrominerals (41%, 179 of 438), and Ca/P ratio (34%, 151 of 442). The most frequently chosen variables responders stated as "not important" were macrominerals (18%, 81 of 439), macrominerals (12%, 52 of 438), and sugar (11%, 50 of 442). The responders also expressed uncertainty about the relative importance of the variables in the forage analysis; the three most frequently stated variables were microminerals (13%, 58 of 439), macrominerals (12%, 52 of 438), and Ca/P ratio (10%, 43 of 442).

Cross-tabulations were conducted to determine if responders had an analysis of the variables they stated were "important". Since DM is included in every analysis it was left out. Thirteen per cent (42 of 323) of the responders who stated ME value was "important" did not have the basic analysis. For responders stating DCP was "important", 12% (40 of 344) did not have basic analysis and 10% (30 of 290) of responders that stated DCP/MJ ME ratio were "important" did not have the analysis. Regarding minerals, 13% (20 of 152) of the responders that stated macrominerals as "important" did not have that analysis, whereas the proportion for microminerals was 28% (31 of 110), and for Ca/P ratio 19% (41 of 221). The sugar analysis was lacking for 40% (97 of 242) of the responders that stated sugar concentrations was important, and for selenium 82% (90 of 110) of the responders stated the concentration as "important" but lacked the analysis of these variables.

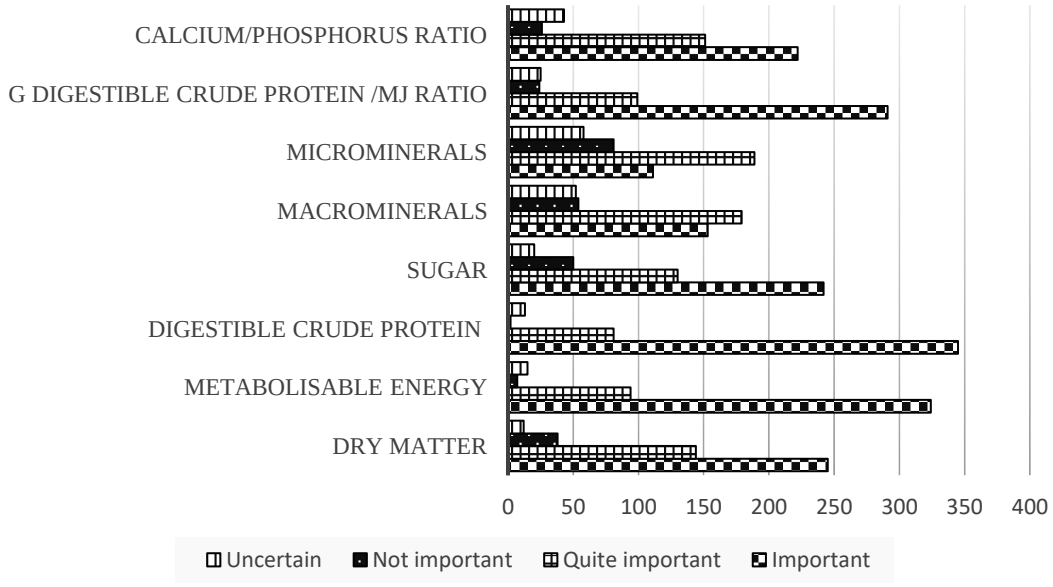

Figure 6. The responders perceived importance of the different variables of the forage analysis, numbers of responders in different statements of importance distributed over

different variables in the forage analysis. Single choice question, N = 439 on dry matter, microminerals and digestible crude protein /MJ ratio, N = 438 on macrominerals, N = 440 on metabolisable energy, N = 441 on Digestible crude protein and N = 442 on sugar and Calcium/Phosphorus ratio.

The largest proportion of how easy responders thought it was to make a balanced feed ration (that met the requirements of the horse) by using the analytical report was "okay" with 51% (221 of 413) of the responders (Figure 7). Of the responders, 32% (131 of 413) stated that creating a balanced feed ration by using the analytical report was "easy." Additionally, 11% (44 of 413) felt "uncertain" about how to make a balanced feed ration, while 6% (27 of 413) stated that it was "impossible" to create a balanced feed ration using the analytical report.

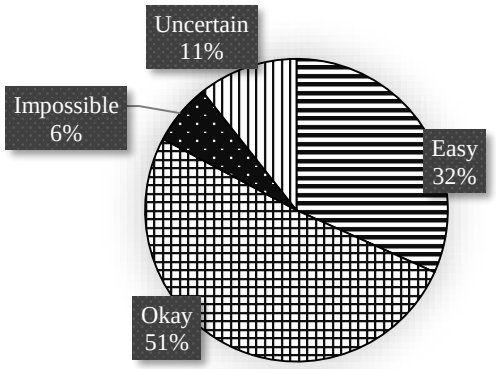

Figure 7. Proportion of how easy responders thought it was to make a balanced feed ration based on a forage analytical report. Single-choice and a non-mandatory question, N = 413.

The most frequently selected alternative when asked why they did not use the forage analysis was that there was no problem with it (38%, 84 of 223) (Figure 8). The open response alternative was the second most frequently selected alternative (34%, 76 of 223). The third most frequently (19%, 42 of 223) selected alternative was that the responders thought it was difficult to obtain a representative sample. The following proportion of 9% (21 of 223) of the responders stated that the values are not always accurate, 9% (21 of 223) thought that the forage analysis was unnecessary, while 9% (20 of 223) were uncertain of the sampling (20 of 223), and 8% (17 of 223) thought that the analysis was too expensive.

The open alternative contained 76 responses; 36 of the responders stated that the analysis was used, six of the responders thought that the horse can sort out what it needs and that it is better to "feed with the eye". There were also three responders having specific forage and could not change it irrespective of what the analysis showed, and lastly three of the responders had their horse on *ad libitum*

access to forage and they did not know how much the horses ate during the day.

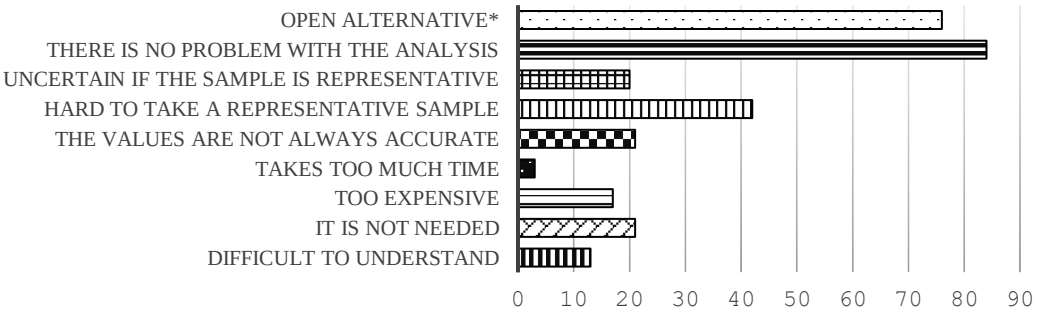

*Figure 8. Responders' reasons to not use the forage analysis, number of responders in different statements. Multiple-choice and a non-mandatory question, N = 223. * The open response alternative included "used the analysis, different values in every bale, the horse can sort out what it needs, have the horse on ad libitum access to forage".*

The majority of responders (54%, 231 of 426) stated that interpreting the forage analysis was "easy" (Figure 9). It was followed by a proportion of 32% (136 of 426) of responders who thought it was "okay", 9% (40 of 426) thought it was "hard", and 5% (19 of 426) had never interpreted an analysis or were "uncertain" of how difficult it was.

Cross-tabulations were conducted on responders' years of experience compared with how difficult it was to interpret the results from the analysis. Of the responders with up to four years of experience, 28% (5 of 18) thought it was "easy", 39% (7 of 18) stated it was "okay", 22% (4 of 18) thought it was "hard", and 11% (2 of 18) stated they were "uncertain" on how difficult it was to interpret the forage analysis. Of the responders with more than 20 years' experience, 61% (170 of 277) stated it was "easy", 29% (80 of 277) "okay", while 7% (18 of 277) thought it was "hard" and 3% (9 of 277) were "uncertain."

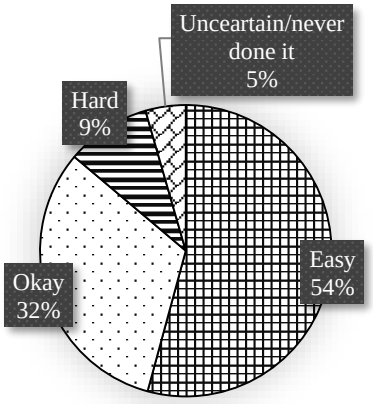

Figure 9. How difficult the responders thought it was to interpret the result from a forage analysis, per cent of responders in different categories of difficulty. Single-choice question, N = 426.

Cross-tabulations were made between level of education and how difficult the responders thought it was to interpret the result of an analysis (Table 4). The responses in the open response alternative were not included. The educational group with most responders thought it was “easy” to interpret the analysis was a university education (90%, 36 of 40). The group with the lowest proportion choosing the alternative “easy” was the group with no horse-related education (41% 88 of 214).

Table 4. The responders’ perception of how easy to difficult it was to interpret the result of a forage analysis, distributed over the educational groups, in per cent, N = 426

Educational group	Easy (Per cent)	Okay (Per cent)	Hard (Per cent)	Unknown (Per cent)	Total numbers of responders
High school	64	26	5	4	73
University	90	10	0	0	40
Vocational	71	17	6	6	52
Riding instructor	64	31	0	5	36
Folk high school	65	35	0	0	20
Single-subject courses	52	30	16	1	86
No education	41	41	11	7	214

4.4 Practical application of the forage analysis

Thirty-nine per cent (168 of 426) of the responders stated that a lower price for the forage analysis would facilitate the use of a forage analytical report, followed by 32% (135 of 426) of the responders requesting recommendations along with the forage analytical report. Thirty per cent (130 of 426) of the responders requested additional guides to facilitate the interpretation of the analysis, while 28% (127 of 426) stated that no changes were necessary. Seventeen per cent (76 of 426) of the responders requested facilitated sampling. The open alternative contained 14 responses; seven responders wanted it to be easier to calculate a feed ration, four thought the analysis was unnecessary, and three wanted to know how

laboratories analyse and calculate the values with standardised units.

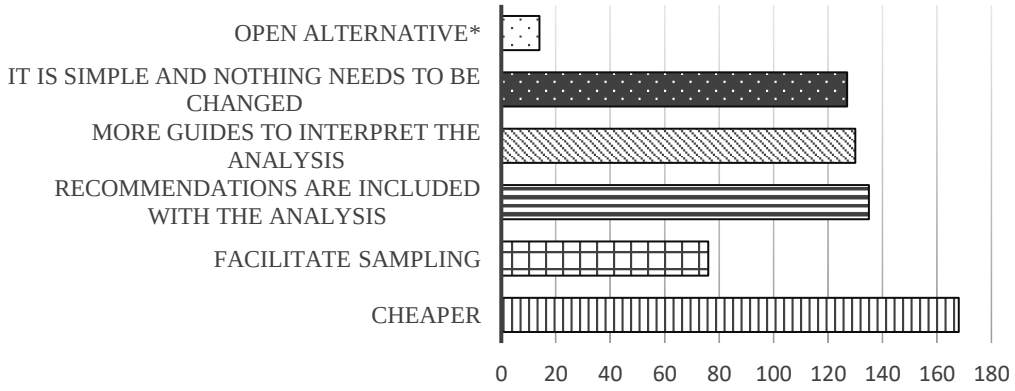

*Figure 10. Responders' statements on how to facilitate the forage analytical report, number of responders in each statement. Multiple-choice question, N = 426. * The open response alternative included "easier to calculate, unnecessary, wants to know how laboratories analyse and calculate, and uses standardised units."*

In the final question, responders had only an open response alternative and were asked to share ideas on how to facilitate for horse owners to interpret and use the forage analytical report, and it was a non-mandatory question (N = 123). The two most frequently occurring suggestions, with over 20 responders, wanted both cheaper analysis and to have guidelines in the analytical report with tips and advice on how to use it. Around 20 responders wanted to have better information and education on how to interpret the analysis. Ten responders wanted a better feed ration calculation program, and the same proportion wanted a more secure analysis with the same units and a better standardisation. A handful of responders wanted better advisory services, independent from a feed company and easier methods to take a representative sample. A few responders wanted to rent a haylage core sampler, and some wanted more experience and an easier way to calculate feed rations. Some responders wanted it to be mandatory to have an analytical report to be able to sell the forage, so the buyer always had an analysis.

5. Discussion

To answer the research questions, the literature review and findings from the survey are discussed below.

5.1 Limitations

Due to the distribution method of the survey, the true response rate could not be determined. Although the exact number of horses in Sweden is unknown, it has been estimated that there were 355,000 horses in 2016 (Swedish Board of Agriculture 2018). A comprehensive survey of Swedish horse keepers was conducted by the Swedish Board of Agriculture in 2016 which included 3,234 responders. In contrast to the result showed by the Swedish Board of Agriculture (2018), this survey only covered a small portion of horse owners and -keepers in Sweden. Nevertheless, it was larger than the number of responders reported by Hoffman *et al.* (2009), Uotila *et al.* (2012) and Mastellar *et al*. (2018), and comparable data presented by Moore-Colyer *et al*. (2023) and Kenny and Smarsh (2024). The number of responders may be considered as a limitation, providing only a sample of the entire population and preventing a full picture of the issues. The responders' demographic may have been influenced by the surveys reach, since there may be a specific group of horse owners who are interested in participating. A similar result was also reported by Kenny and Smarsh (2024).

The survey results indicated that a higher number of responders had a forage analytical report, compared to the data presented by Uotila *et al.* (2012), Mastellar *et al.* (2018), Moore-Colyer *et al.* (2023) and Kenny and Smarsh (2024). This could indicate a bias, as those who have an analysis are probably more interested in participating. A small number of responders in the current study expressed the belief that a forage analysis is unnecessary or that the horse can sort out what it needs itself from the forage. It is possible that a greater number of individuals hold the same attitude than reflected in this report, as they may not spend time on a survey to evaluate something they believe is unnecessary. In other studies, a high number of responders have indicated that they thought forage analysis is unnecessary (Moore-Colyer *et al.* 2023), and that statement could have been underestimated in this survey.

There may also be differences in target groups; data presented from a study conducted in Finland showed a higher proportion of responders had a forage analytical report and conducted one if it was not provided by the seller (Uotila *et al.* 2012) compared to the results showed by Moore-Colyer *et al.* (2023) in a UK study. Additionally, responders in the Finnish survey (Uotila *et al.* 2012) had a higher interpretation and understanding level of the forage analysis. The target group were stable owners and forage producers, which may differ from when

targeting horse owners and -keepers. Additionally, cultural differences in forage analysis may exist between regions. The marketing for forage analysis may also differ between regions. The forage analysis were utilised by responders in this survey for calculating and balancing diets, whereas Kenny and Smarsh (2024) survey indicated responders more frequently use of the forage analysis when a horse has a feed-related problem.

When conducting surveys, the responders individual experience and personal perceptions may affect the responders' interpretation of the questions. This could present an inaccurate image of *e.g.* educational groups or attitudes. There were multiple response alternatives to several questions, and some offered an alternative where responders could compose their own responses. Consequently, some of the responses were brief and vague, making them difficult to understand. Therefore, this may have influenced the report's conclusions.

5.2 Responders use of the forage analysis

The results of the survey may not reflect on the entire population of horse owners and -keepers in Sweden, as they were not collected from all of them. To gain a better understanding of who were and were not conducting an analysis, it is first necessary to identify a subpopulation.

5.2.1 Subpopulation

The survey results indicated that the majority of the respondents had over 10 years of experience with horses. Similar results were reported in other similar surveys, where 71% (Mastellar *et al*. 2018) and 70% (Kenny & Smarsh 2024) had over 10 years of experience. Thise surveys' result was similar with the findings from the Swedish Board of Agriculture (2018) survey. Around half of the responders in this survey had a horse-related education and 60% of the responders had no horse-related education in Swedish Board of Agriculture (2018) survey. Equine-related education was not included as background information in other studies within the area (Uotila *et al.* 2012; Mastellar *et al.* 2018; Kenny & Smarsh 2024). The responders' education was examined in a comparable study by Murray *et al*. (2015); however, it did not cover any horse-related subjects.

This subpopulation was further identified by the fact that the majority of responders in this report had one or two horses under their care. Over half of the responders had four (Murray *et al.* 2015) or one to five (Mastellar *et al.* 2018) horses under their care. The data presented in this study's subpopulation, which consisted of 81% leisure and 38% training and competing horses, is comparable to the results of the Swedish Board of Agriculture (2018) report. The average Swedish horse keeper is a leisure rider, and one out of every three individuals competed (Swedish Board of Agriculture 2018). In contrast to other studies, Kenny and Smarsh (2024) identified 76% of the responders having leisure horses,

while Murray *et al*. (2015), Mastellar *et al.* (2018) and Moore-Colyer *et al.* (2023) had approximately 50% of the responders as having horses for leisure or pleasure. The second largest group in these studies were training and competition horses, similar to the finding in this report.

This survey was distinguished from other studies in the area by fact that 80% of the responders had a forage analytical report. This fact should be considered when continuing the discussion in this report, as the challenges are viewed from the perspective of the responders who have a forage analytical report. Compared to the result from similar subpopulations, 62% of responders reported never having a forage analysis (Kenny & Smarsh 2024), while 28% (Masteller *et al*. 2018) and 11% (Moore-Colyer *et al.* 2023) had a forage analytical report.

5.2.2 Who sends the sample for analysis?

According to the responders in this subpopulation, purchasing forage was more common than cultivating and harvesting it on their own. Half of the responders harvested their own forage, and it was seen to be a decreased trend between 2010 and 2016 (Swedish Board of Agriculture 2018). It is possible that the reduction has persisted as the report from the Swedish Board of Agriculture (2018) is a few years old. The results of this study, which indicated that 87% of the responders purchased forage and 20% cultivated their own, were similar with the proportions reported by Kenny and Smarsh (2024).

Nearly half of the responders received an analytical report from the forage seller, in contrast to results presented by Moore-Colyer *et al.* (2023) where 26% of the responders received a forage analytical report with the purchased forage. In a survey from the United Kingdom, 4% of the responders conducted forage analyses if they purchased forage without an analysis (Moore-Colyer *et al*. 2023), in a survey from Finland, 16% did so (Uotila *et al.* 2012). Therefore, it seemed to be more likely to conduct a forage analysis in Sweden and Finland if the forage seller is not providing an analytical report than in the United Kingdom.

The majority of the responders did not have all the variables included in the forage analytical report. Selenium concentration in forage is not of any high interest in Sweden due to the soil's selenium deficiency and the fact that forages from northern Europe typically contain little to no selenium (Zhao and Müller, 2015). The number of responders with a sugar analysis in this report were interesting. Sugar concentration in forage is not important for healthy horses; however, it may be crucial for horses with impaired glucose metabolism (Müller 2017). It was more common to analyse sugar concentrations in forage than micromineral concentrations in the current study. It might affect more horses, as minerals are essential for all horses, while sugar is of interest only for horses with impaired glucose metabolism. This could be a result of guidelines and information

clearly defining the potential problems associated with excessive sugar concentration.

In comparison to this study, the results of a study conducted in United Kingdom indicated that 75% of the responders had both DCP and WSC analysis (Moore-Colyer *et al*. 2023). It appeared more common in the former study to have both WSC and DCP concentrations analysed. One potential explanation can be that WSC analysis is marketed differently, making more horse owners and -keepers to conduct one. It is also possible that the subpopulations differ between the surveys due to the fact that the distribution method can influence who responds to it. More research with the laboratories may provide a deeper understanding of the variables that are analysed most frequently.

5.2.3 How a forage analysis is used

The question of how horse owners and -keepers were utilizing the forage analysis can be addressed by combining knowledge of the subpopulation and the individual who conduct the forage sampling. The analytical report was most frequently used by the responders to estimate or calculate a balanced diet. How the responders utilised the forage analytical report was not influenced by education level; however, there was an association between the education level and the tools used to interpret the analysis.

When interpreting the analysis, the feed ration program was the most frequently used tool. Responders who had a university education within the equine area appear to have been more comfortable with utilizing a program, as fewer used advisors and friends as tools. Additionally, the analysis was interpreted more easily by the same educational group than other educational groups. These findings indicated that a university education within the equine area can be beneficial for understanding and interpreting the forage analytical report. Nevertheless, the data from this survey and from the Swedish Board of Agriculture (2018) indicated that not all horse owners and -keeper have a horse-related education. Moreover, both reports indicated that less than 10% of the responders had a horse-related university education. This could suggest that a higher level of education may facilitate interpretation and the utilization of the analysis.

Twelve per cent of the responders in Kenny and Smarsh (2024) study utilised the forage analysis when there was a problem, whereas only 1% did so in this survey. The findings suggested that the forage analytical report was more frequently used in Kenny and Smarsh (2024) survey due to nutritional-related health issues. This may suggest that the analysis was primarily used in Sweden to prevent feed-related health issues, whereas in the other study, it was used as a tool when the horse had already contracted a feed-related health issue.

5.3 Challenges and possible changes

5.3.1 Knowledge gaps

Numerous studies are discussing the significance of forage and the central role of forage analysis to maintain health and performance of the horse (Saastamoinen & Hellämäki 2012; Harris & Dunnett 2016; Richards *et al.* 2021). In this study 80% of responders stated nutrition as important. This is lower compared to data presented by Murray *et al.* (2015), where 95% stated nutrition as important.

In a comparable study, 38% of the responders stated forage analysis as crucial (Kenny & Smarsh 2024). Although the responders were not specifically asked about their perceptions of the importance of a forage analysis, they provided responses that showed some attitudes such as “forage analysis is unnecessary”, and Moore-Colyer *et al.* (2023) made a similar finding. Forage is the most crucial component of the horse's feed ration, and the risk of over- or underfeeding is high with unknown nutritional values. In addition, forage analysis can be a useful tool for determining whether the forage is appropriate for the horse, as some responders have mentioned. Therefore, it may be interesting to evaluate why some horse owners consider the forage analysis unnecessary.

The results of this study indicated that 54% of the responders thought it was “easy” to interpret the analysis, while only 32% stated it was “easy” to create a balanced feed ration using the forage analytical report. Additionally, a request for additional information and education was stated by responders in order to utilise the analysis. This is supported by the findings by Jansson *et al*. (2012b), who reported that horse owners require information and education to utilise forages correctly in their horses’ diets. The statement is also supported by the findings of Hoffman *et al.* (2009), which demonstrated that horse owners utilise information from multiple sources to create a feed ration. A lack of using scientifically based sources was reported by Murray *et al.* (2015), and Mastellar *et al.* (2018) identified a knowledge gap in general horse nutrition among survey respondents. The results of this survey may suggest that horse owners and -keepers may lack vital knowledge to calculate a balanced feed ration for the horse, even if they acknowledge the importance of the forages and its nutritive values.

The nutritional variables of a forage analytical report are all fundamental to meet the requirement for maintaining health and performance in horses. The three most important variables that the responders in the Finnish survey identified were DCP, sugar and DM (Uotila *et al.* 2012). The three most important variables that the responders in this subpopulation identified were DCP, ME and the DCP/MJ ME ratio. This could indicate that the responders are aware of the critical role that obesity and underweight play. Obesity and underweight are potential health consequences when over- or underfeeding these variables, which in turn can increase the risk of other health issues. This may also be a result from feed ration

programs highlighting these values, and it is easy to gather information regarding them.

Another interesting finding was the absence of a sugar concentration in the analysis for 40% of the responders who stated sugar concentration as “important.” Sugar concentration is important for horses with impaired glucose metabolism; however, there is a lack of understanding regarding the specific sugars that contribute to insulin responses in both healthy and impaired glucose metabolism horses (Müller 2017). It is possible that owners and -keepers of horses with metabolic diseases are more interested in the forage analysis; however, this was not examined in this survey. For further research, it may be beneficial to examine data from laboratories to determine the actual usage of the different types of analyses.

A lack of knowledge was seen, particularly regarding mineral elements. In comparison to basic forage analysis, a smaller number of responders analysed concentration of mineral elements, especially microminerals. Additionally, the fact that a smaller number of responders thought that minerals were important may suggest a limited understanding of minerals. The mineral content in forages in Sweden and Norway differed, particularly for calcium, potassium, iron and manganese (Zhao & Müller 2015), and this should be taken into account when determining the feed ration. Two potential changes for reducing the knowledge gap are to highlight the reasons for the inclusion of mineral concentrations in a forage analysis, and to incorporate both macro- and micromineral analysis into the basic analysis. This may have increased the awareness of horse owners and -keepers regarding the variations in mineral element concentrations in forages and the consequences of an excess or deficiency of mineral elements in the equine diet. The statement was reinforced by emphasising the importance of routine analysis of minerals as the concentrations may vary considerably as reported by Zhao and Müller (2015). This was also supported by the findings by Ringmark (2017) and Richards *et al.* (2021), who both recommended analysis of all variables in forages and that the analysis should be mandatory when selling forages.

5.3.2 Interpretation level

The interpretation level of the analysis may be seen as a challenge; while 54% of the responders thought it was “easy”, only 32% thought it was “easy” to create a balanced feed ration for the horse. Education and years of experience were identified as factors affecting the responders experience in how difficult it was to interpret a forage analysis. The majority of responders who had a horse-related university education thought it was “easy”, while less than half of the responders who did not had a horse-related education thought it was “easy” to interpret the analysis. Although one study did not reach the same conclusion, it is possible that

the reason was that the focus was on general education rather than horse-related education (Moore-Colyer *et al.* 2023). It is possible that certain responders find the forage analysis too difficult to interpret and use as a tool. If the objective is to enable horse owners and -keepers to utilise the forage analytical report, it should not be necessary to have a horse-related education at the university level.

Research has indicated that responders lack confidence in their interpretation abilities of forage analytical reports (Mastellar *et al.* 2018; Kenny & Smarsh 2024). While it appears that forage analytical reports were more frequently utilised in the current study, the level of confidence in interpretation was not much higher than reported by Mastellar *et al.* (2018) or Kenny & Smarsh (2024). A barrier that has been observed by Mastellar *et al.* (2018) may also have been present in this study, as the cost and time required to interpret the forage analysis were not considered to be worthwhile. According to a survey conducted in Finland, approximately 75% of the responders were capable of understanding and interpreting the forage analysis, and 50% would conduct one if it were more affordable (Uotila *et al*. 2012). In that scenario, a more affordable analysis could have been beneficial, as it would have been utilised by more stable owners. However, in the subpopulation in the current study, the decreasing cost may not have resulted in an increase in usage, as the horse owners and -keepers were unable to interpret the forage analysis.

Advisors and feed ration programs are already available, and this study demonstrated that horse owners and -keepers were not entirely satisfied with the current market. Responders desired both better advisory services, free from collaboration with a specific feed company, and a better feed ration calculation program. Furthermore, the advisory service and feed ration calculation program may be of interest for further investigation to evaluate what is on the market and identify areas that require improvements. Additionally, it is intriguing to investigate whether the horse owners and -keepers are unable to utilise the feed ration calculation programs available on the market due to the lack of knowledge or time to locate them. The survey findings indicated that over one-third of the responders used multiple tools to interpret the analysis. This has the potential to result in misunderstandings and the use of non-scientifically based sources, as Hoffman *et al.* (2009) and Murray *et al.* (2015) discovered when investigating the knowledge of responders and their feeding management.

In the current survey, numerous suggestions were received regarding the changes that responders would like to see, many of which focused on encouraging more horse owners and -keepers to conduct forage analyses. Nevertheless, the knowledge and interpretation level pose a challenge. Consequently, a more affordable, mandatory analysis may encourage a greater number of horse owners and -keepers to conduct an analysis with more variables. However, this may not be the biggest issue. Instead, it has the potential to increase the price of forage, as

producers may increase the prices in response to an analysis, and the level of interpretation may remain low. Recommendations and guidelines with the forage analytical report were frequently requested. Although a brief Google search may provide some knowledge and guidelines, the probability of receiving non-scientific based information may be reduced by having analytical companies provide the information. Nevertheless, it will still require time to gather the information and interpret the analysis.

5.3.3 A secured analysis

To create a balanced feed ration for each individual horse, a reliable forage analysis is essential. This report suggested that the responders did not always believe in the analysis. One primary reason responders gave for not conducting an analysis was the difficulty in obtaining a representative sample, and they were uncertain about the representativeness of the submitted samples. Responders also stated that the values were not always accurate, as each bale has a unique nutritional composition, and it was difficult to obtain a sample from each bale. It is not uncommon to purchase small batches of forage, and it may not necessarily originate from the same location (Richards *et al.* 2021). When purchasing multiple batches, it is recommended to conduct a forage analysis on each batch. The nutritional quality of the forage is influenced by various factors (Fulgueira *et al*. 2007; Zhao & Müller 2015). Additionally, the forage producer could have multiple batches due to the fact that they may have different fields, or the harvest was halted for a few days due to weather conditions. Consequently, it may be necessary to conduct multiple analyses to ensure that a representative sample is obtained for each batch.

The forage analysis reliability is reflecting the actual nutritional value, and depends on the sampling, as demonstrated by Fulgueira *et al*. (2007). The collector and laboratory must handle the sample carefully, as the leaf/stem ratio may impact the analytical report. This may prove to be a challenge due to the leaves tendency to break easily and fall out of the sample. Horse owners and -keepers may be hesitant to attempt to collect a sample due to the difficulties associated with the process, as there is a high likelihood of errors in numerous steps. According to the literature review, the sampling techniques differed from one another. One study suggested opening and sampling five bales of hay (Jansson *et al.* 2012a), while another suggested sampling 20 bales of hay, which could be done with the bales closed (Fulgueira *et al.* 2007). This could demonstrate that there are no standard guidelines and that the sampling methods can change based on the sampler's source of information, which could potentially impact the representativeness of the sample for the forage batch.

Another challenge that may arise from the analytical procedures implemented to determine the nutritional value of the forage. With the exception of sugar and

ammonia, NIRS has been demonstrated to reduce the analytical variation, compared to wet chemistry, by being more repeatable (Harris et al. 2018). However, it is important to remember that NIRS calibrations requires wet chemistry techniques. The subject of sugar analysis necessitates additional research due to the differences between methods and the limited repeatability within a method (Harris *et al.* 2018). In order to create feed ration for each horse, a reliable forage analysis is necessary (Harris *et al.* 2018). The result of the survey suggest that responders may occasionally have trust in the forage analysis procedure. Nevertheless, the question may arise as to whether the variation between methods and sampling techniques is significant enough to affect the horse, particularly in light of the fact that precision feeding may be challenging, as they are often fed in groups and some *ad libitum.* Additionally, these factors were stated by some responders as reasons for not performing analyses of forages.

6. Conclusions

This survey represented a subpopulation of horse owners and -keepers with over 10 years of experience, and half of the responders had a horse-related education. Most of them purchased forage and owned leisure horses. It was common to have a forage analysis and use it to estimate or calculate feed rations for the horses, and most responders used a feed ration calculation program as a tool. The challenges found in this study were similar as in studies from other countries, where the biggest difference was that having a forage analysis report was more common in the current study.

Identified challenges include a lack of understanding and confidence in interpreting a forage analysis, as well as a perception that the analysis is inaccurate. The difficulties of calculating a feed ration based on the forage analysis may indicate that horse owners and -keepers do not want to spend the money and time needed on a forage nutritive analysis. This shows that further research is required to determine potential changes that would enable horse owners and -keepers to utilise the forage nutritive analysis as a tool when composing a feed ration.

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Popular science summary

Forages are an important part of a horse’s diet, ensuring natural feeding behaviour in the horse while providing the majority of the required nutrients. It is important to know both the horse's specific needs and the specific nutrients in the forage in order to make a balanced diet. A forage analysis provides valuable insights into the particular nutrients present in the feed, making it an essential tool to ensure that the horse receives the right daily intake of nutrients. Over- or under feeding horses can lead to various health problems, including obesity, muscle deficiencies or behaviour and welfare problems.

Previous studies have found a low level of usage and knowledge of forage analysis. This study aimed to determine how Swedish horse owners and -keepers use the forage analysis in their feeding practices. Additionally, challenges in interpretations and suggestions for potential improvements to make it a standard tool were examined. An online survey was conducted together with a literature review. The survey had 505 responders, with 425 completed surveys. The responding group had mostly over 10 years of experience, caring for typically one or two horses, primarily leisure horses. Half of the responders had a horse-related education. Most of them purchased the forage and 80% of the responders had a forage analysis, either included with the forage purchase or arranged for by themselves. The most common analyses were basic and macromineral analysis, where basic analysis containing dry matter concentration, energy value and digestible crude protein concentration. The analysis was used for estimation or calculation of a feed ration, often using a feed ration program as a tool.

However, responders faced challenges when it came to knowledge of how to interpret the analysis. Despite the crucial role nutrients play in maintaining good health, many responders regarded macro- and microminerals as less important. Even if 54% of the responders thought it was easy to interpret the forage analytical report, only 32% felt confident in calculating a balanced diet. A common request was more guidelines and recommendations, while a few expressed the analyses as unnecessary. Another difficulty responders had was ensuring the accuracy and reliability of the forage analysis. The process can be seen as difficult, as taking a representative sample of forage can be challenging. As a small sample must represent a big batch, the nutritional value is influenced by both environmental and management factors. This can therefore influence the result, leading to a questioning of the nutritional values obtained by analysis. These challenges highlight the importance of refining sampling for forage analysis. By improving the sampling and including clear guidelines, the ability to interpret the analysis, the understanding and the usage of the forage analysis could be enhanced. This could promote health and performance as well as improve the welfare in horses.

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Appendix

Survey questions and alternatives.

1. How long have you had/worked with horses?
    a. Less than one year to four years
    b. Five to 10 years
    c. 11 to 20 years
    d. More than 20 years
2. How many horses do you care for regarding feeding management?
    a. Zero horses
    b. One or two horses
    c. Three to four horses
    d. Five or more horses
3. Do you have any horse-related education?
    a. High school
    b. University education
    c. Vocational education
    d. Riding instructor education
    e. Folk high school education
    f. Single-subject courses
    g. No equestrian education
    h. Open alternative
4. Which type of horses are you responsible for?
    a. Leisure horses
    b. Working horses
    c. Training and competition horses
    d. Breeding horses
    e. Education and sales horses
    f. Riding school horses
5. How important is forages in meeting the horses nutritional needs?
    a. Very important
    b. Quite important
    c. Less important
    d. Not important at all
    e. Uncertain
6. Do you grow your own forage or purchase it?
    a. Harvest my own forage
    b. Purchases
    c. Harvest my own, but need to supplement with purchased
7. Do you have a forage analysis
    a. Yes

    b. No
8. Have you taken the analysis by yourself?
    a. Harvest and conduct my own analysis
    b. Received from the seller
    c. Conduct the analysis because the seller does not have one
    d. Do not have a forage analysis
9. What type of analysis do you have? (Choose all alternatives you have.)
    a. Basic analysis (metabolisable energy and digestible crude protein dry matter and could include ash)
    b. Macromineral analysis
    c. Micromineral analysis
    d. Sugar analysis (ESC or WSC)
    e. Selenium analysis
    f. Do not have an analysis
    g. Open alternative
10. How do you use the analysis?
    a. To estimate a feed ration
    b. To calculate a balanced feed ration
    c. Only use it when the horse has a feed-related problem
    d. Do not use the analysis
    e. Open alternative
11. Which values in a forage analysis do you think are important when making a feed ration? You can choose the alternatives for each value (DM, metabolisable energy, digestible crude protein, macrominerals, microminerals, sugar, g DCP/MJ ratio, Ca/P ratio)
    a. Important
    b. Quite important
    c. Not important
    d. Uncertain
12. What tools do you use when interpreting the forage analysis?
    a. Uses an advisor
    b. Uses a feed ration program
    c. Uses a friend
    d. Have education
    e. Have learnt from experience
    f. Do not have an analysis
    g. Open alternative
13. How easy do you think it is to create a balanced feed ration based on the analysis?
    a. Easy
    b. Okay

c. Impossible
d. Uncertain

14. Why do you not use the forage analysis?
    a. Difficult to understand
    b. It is not needed
    c. Too expensive
    d. Takes too much time
    e. The values in the analysis are not always accurate
    f. Hard to take a representative sample
    g. Too uncertain whether the sample sent in is representative
    h. There is no problem with the analysis
    i. Open alternative
15. How hard do you think it is to interpret the result from the forage analysis?
    a. Easy
    b. Okay
    c. Hard
    d. Uncertain/never done it
16. What would make it easier to use the forage analysis?
    a. Make it cheaper
    b. Have facilitated sampling
    c. Have recommendations included with the analysis
    d. More guides to interpret the analysis
    e. It is simple, and nothing needs to be changed
    f. Open alternative
17. Do you have an idea to facilitate and make it easier to use the analysis?
    a. Open alternative

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