ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

DOI: 10.5336/vetsci.2024-104328

Evaluating the Influence of Horse Nutrition on Greenhouse Gas Emissions in the Netherlands

Hollanda'da At Beslenmesinin Sera Gazı Emisyonları Üzerindeki Etkisinin Değerlendirilmesi

Gülşah KAYA KARASU[a]

[a]Van Hall Larenstein University of Applied Sciences, South Holland, Netherlands

This study was presented as an oral presentation at 28th Congress of the European Society of Veterinary and Comparative Nutrition (ESVCN), September 10-13, 2024, Belfast, Northern Ireland.

ABSTRACT Objective: The purpose of this study was to determine the impact of current horse feeding practices on greenhouse gas (GHG). **Material and Methods:** A cross-sectional survey was conducted to gather data from horse livery yards for warmblood horses 4-14 years owners/managers in the Netherlands in 2022. In this study, demographic information, feeding specifics, body weight (BW) and workload were recorded. The GHG emissions from each horse's diet were calculated using the Ecoinvent v3.6-cut-off database. The collected data were calculated using Systat 16.0 (SPSS, Chicago, IL). Normally distributed data were presented as mean±standard deviation. **Results:** The study included 180 warmblood geldings ranging in age from 4 to 14. The estimated mean BW of the horses was 540.2±104.2 kg. The majority of horses were fed grass hay (92%), with some offered lucerne (26%), and haylage (24%). The mean forage intake was 7.4±6.2 kg/d (as fed). The majority of the horses were fed concentrate feeds (90%). Supplements were commonly used (84%). The mean concentrate intake was 4±2.2 kg/d and supplement intake was 90.24±96.2 g/d. The global warming potential (GWP) from feeding compromises 3.70±1.74 $CO2$ eq from forage 1.90±2.0 CO^2 eq from concentrates, 0.32±1.80 CO^2 eq from supplements and 0.06±0.12 CO^2 eq from packaging. **Conclusion:** Equine forage feeding had the highest GHG impact in terms of GWP compared to other feed sources, most likely due to the hay production process; additional research is needed to confirm this assessment. A limitation of this study was the use of comparisons with other animal feeding sectors to conceptualize an emissions scale.

Keywords: Horse; feeding; sustainability; greenhouse gas emissions; global warming potential

ÖZET Amaç: Bu çalışmanın amacı, mevcut at besleme uygulamalarının sera gazı [greenhouse gas (GHG)] üzerindeki etkisini belirlemektir. **Gereç ve Yöntemler:** 2022 yılında Hollanda'da 4-14 yaş arası sıcakkanlı atların sahipleri/yöneticileri için yapılan kesitsel bir anketle veriler toplandı. Çalışmada demografik bilgiler, beslenme detayları, vücut ağırlığı (VA) ve çalışma yükü bilgileri toplandı. Her atın diyetinden kaynaklanan GHG emisyonları Ecoinvent v3.6-Cut-Off veri tabanı kullanılarak hesaplandı. Tanımlayıcı veriler Systat 16.0 (SPSS, Chicago, IL) kullanılarak hesaplandı. Normal dağılıma sahip veriler ortalama±standart sapma olarak sunulmuştur. **Bulgular:** Çalışmaya 4-14 yaş arası toplam 180 sıcakkanlı kısrak dâhil edilmiştir. Atların tahmini ortalama VA'sı 540,2±104,2 kg olarak belirlenmiştir. Atların çoğunluğu çayır otu (%92), bazıları ise yonca (%26) ve silaj (%24) ile beslenmiştir. Ortalama kaba yem alımı 7,4±6,2 kg/gün (verilen şekilde) olarak belirlenmiştir. Atların çoğunluğu yoğun yemlerle beslenmiştir (%90). Takviyeler yaygın olarak kullanılmıştır (%84). Ortalama yoğun yem alımı 4±2,2 kg/gün ve takviye alımı 90,24±96,2 g/gün olarak belirlenmiştir. Beslemeden kaynaklanan küresel ısınma potansiyeli [global warming potential (GWP)], kaba yemlerden 3,70±1,74 CO^2 eq, yoğun yemlerden 1,90±2,0 $CO2$ eq, takviyelerden 0,32±1,80 CO^2 eq ve ambalajdan 0,06±0,12 CO^2 eq olarak hesaplanmıştır. **Sonuç:** At kaba yem beslemesi, büyük olasılıkla saman üretim süreci nedeniyle GWP açısından en yüksek GHG etkisine sahiptir; bu değerlendirmeyi doğrulamak için ek araştırmalara ihtiyaç vardır. Bu çalışmanın bir sınırlaması, emisyon ölçeğini kavramsallaştırmak için diğer sektörlerle yapılan karşılaştırmaların kullanılmasıdır.

Anahtar Kelimeler: At; besleme; sürdürülebilirlik; sera gazı emisyonları; küresel ısınma potansiyeli

Correspondence: Gülşah KAYA KARASU
Van Hall Larenstein University of Applied Sciences, South Holland, Netherlands
E-mail: gulsah.kayakarasu@hvhl.nl

Peer review under responsibility of Turkiye Klinikleri Journal of Veterinary Sciences.

Received: 07 Jun 2024 ***Received in revised form:*** 11 Oct 2024 ***Accepted:*** 11 Oct 2024 ***Available online***: 08 Nov 2024

In 2015, the United Nations adopted a set of Sustainable Development Goals (SDG) that imagined a future (2030) without poverty and hunger, and safe from the worst effects of climate change and loss of biodiversity.[1] Sustainability is prominent discussion topic across all industries, including the equine sector. This topic has increased in prevalence within society, as the need to better protect our planet increases. In recent years there has been increasing focus on the contribution of the agriculture industry to the production of greenhouse gases (GHG: including methane CH_4, hydrogen H_2, carbon dioxide CO_2) rather than just nutrient leaching. Globally the livestock industries, including horses, account for approximately 18% to 20% of global GHG emissions.[2] The equine sector can be considered as more of a slow adapter in comparison to alternative sectors. This means the industry takes less initiative when new concepts arise. As a result, other comparable sectors such as mainstream livestock agriculture, are considerably more advanced in the areas of sustainable management of their animals and business.

However, where there is an absence, lies an opportunity. According to Hoffman et al. less than 50% of horse owners knew the daily water and hay requirements for a horse, and 69% lacked knowledge about the proper use of concentrates in a diet.[3] If such a high percentage of owners lack equine nutritional knowledge base, it could be likely they know a considerably less amount about sustainably feeding their horses.

There is a general impression that the livestock industry has done extensive research into the impact feeding, land, and manure management has on the planet, yet the equine sector has not accessed this issue. Each of these management aspects utilize our planet resources, therefore it is important as a sector to treat these resources with respect and cause minimal negative impact. To achieve this, it is required to first assess the current impact. A recent study outlines the five main green assets of equines in a European context.[4] They breakdown green assets into equine grazing, domestic biodiversity, land use, tourism, and equine work.[8] These assets are vital to highlight as they indicate the positive environmental impacts horses can have such as grazing behavior causing increased heterogeneity plant cover, equine breeds adapted to utilizing poor and sensitive (not suitable for machinery) grasslands, vital working animals that aid in a multitude of tasks globally, and equine tourism being a sustainable form of leisure.[4]

Global warming has driven awareness of sustainability over the last decades.[5] Even though, concerns about environmental impacts have increased transition towards sustainable production remains a long-term goal globally and across all sectors. GHG emission is associated with atmospheric concentration of carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and carbon tetrachloride. Agricultural practices contribute significant amount of GHG to atmosphere. Global warming is one of the main concerns nowadays and decreasing global warming potential (GWP) requires commitment from all industries.

Horses are a great asset; however, it is vital we manage them in a way that their positive impacts outweigh any negative impacts, therefore making them more of an investment rather than a hindrance on or path to a more sustainable world. When we take a horse away from its natural vast landscape and confine them in a way we do with domestic horses, it is our responsibility to limit the impacts of having these animals in an unnatural smaller space. Sustainability is critical to the equine industry's survival, with equines emitting 1.1 million tonnes of GHG emissions per year, accounting for 0.6% of total global emissions from large herbivores.[6] The purpose of this study is to determine the impact of current horse feeding practices on GHG in the Netherlands.

MATERIAL AND METHODS

A cross-sectional online survey conducted via Survey Monkey (2022) was used to gathered data from horse owners/managers in the Netherlands, recruited through social media in 2022. The study collected demographic information, feeding specifics (forage, complementary feed, and supplements, packaging), body weight (BW) and workload. Each horse's diet was analyzed in relation to their estimated daily nutritional intakes for the total diet (forage, concentrates and supplements) and requirements. The nutrient intake for energy, starch, sugar, crude fat, crude protein (CP), lysine, copper, manganese, zinc, and cobalt were calculated, an estimate of workload was also calculated, and these data were used to compare the estimated intake with the estimated horse requirements using National Research Council (NRC) recommendations.[7] Pasture dry matter (DM) intake was estimated at 1.2 g DM/kg$^{0.75}$ for a 500 kg horse.[7] Individual feed products were assessed for their impact on GHG parameters including acidification, eutrophication, GWP, freshwater ecotoxicity, and terrestrial ecotoxicity. The feeding categories were further subdivided into forage, concentrates, and supplements, with ingredients measured per DM kilogram. The GHG emissions from each horse's diet were calculated using the Ecoinvent v3.6 cut-off database.[8] Each horse was analyzed in relation to their daily environmental impact. An environmental impact analysis was conducted with the support of Ecochain Mobius, an analysis program that quantifies the environmental impact. The data base used was Ecoinvent v3.6, Cut-Off which contains more than 2,200 new and 2,500 updated datasets related to agriculture, building and construction materials, chemicals, electricity, fishing, metals, refineries, textiles, tourism, transport, waste treatment and recycling, and water supply.[8] Each horse is analyzed individually under the categories feeding (forage, concentrates, supplements, and packaging). The selected parameters were acidification, eutrophication, GWP, fresh water ecotoxicity, marine aquatic ecotoxicity, human ecotoxicity and terrestrial ecotoxicity. Firstly, feed products were individually quantified in terms of impact across the parameters, acidification, eutrophication, GWP, fresh water ecotoxicity, marine aquatic ecotoxicity, human ecotoxicity and terrestrial ecotoxicity. This was included per DM kg hay, haylage, lucerne; per kg concentrate ingredients oat, barely, maize, soybean, linseed, and wheat semolina as they presented as the most common feed ingredients; per kg feed for four common feed brands; per kg packaging type and per container packaging type. For feeding, the category was divided into forage, concentrates and supplements. Each horse's daily forage consumption was entered as DM kg. Each kg of concentrate feed product was also entered and classified into its top three ingredients in equal amounts. Similarly with feed supplements, each kg per product was entered and classified into its top two ingredients with equal amounts. Each survey respondent provided the packaging material per product/forage. For haylage plastic wrap was added with 0.005 kg plastic per kg DM forage. Feed bag and supplement plastic container weights were standardized based on weighing a standard 25 kg feed bag and 1 kg supplement container. Feed bags were estimated to weigh 25 g in paper. Supplements containers were estimated to weigh 100 g in plastic. To get the per day usage of each product packaging the values were divided by 365. Impact references from data base were individually allocated to each product/ingredient which are outlined in the annex.[2]

DATA ANALYSIS

Data were initially examined using descriptive statistic and plots. Normal distribution and homogeneity of the data were evaluated by Kolmogorov-Smirnov tests Normally distributed data were presented as mean±standard deviation, whereas skewed data were presented as median and range. Data were examined using SPSS 20.0 (IBM, 2021, USA).

RESULTS

DEMOGRAPHICS

The study included 180 warmblood geldings ranging in age from 4 to 14. The median age of the horses was 10 years old. The estimated mean BW of the horses was 540.2±104.2 kg. The median BW of the horses was 520 kg. The horses all had a body condition score of 5/9 and were livery yard horses

FORAGE, CONCENTRATE AND SUPPLEMENT INTAKE

The majority of the horses (80%) had access to pasture, 80 with a median grazing time of 8 hours per day (range 1 to 24 hours). A small proportion, approximately 8%, had no turnout, while 12% were turned out in sand paddocks. The mean forage intake was 7.4±6.2 kg/d (as fed). The majority of the horses were fed concentrate feeds (90%). Supplements were also commonly used (84%). The mean forage intake was 9±6.2 kg/d for hay, 5±4.4 kg/d for haylage, and 4±2.6 kg/d for lucerne. Grass (meadow) hay (92%) was the most common conserved forage offered to horses, followed by lucerne (26%) and grass haylage (24%). Often combinations of conserved forage were offered, 10% of the horses were fed both haylage and hay, and 20% of the horses were fed alfalfa with another type of forage (either hay or haylage). Alfalfa hay was never offered as the only conserved forage, and only 12% of horses were fed haylage as a sole forage source.

Most of the horses (94%) were provided concentrate feeds, with 52% being fed two or more types. The mean concentrate intake was 4±2.2 kg/d. The estimated quantities of forages and concentrates offered are provided in Table 1. The median number of concentrates fed was 2 (range 1 to 4). Few of the horses (10%, n=18) were fed a diet that contained grain. The most common unprocessed grains offered in descending order were oats (n=9), barley (n=6), soybean meal (n=2) and maize (n=1).

The mean supplement intake was 90.24±96.2 g/d. The most commonly used supplements were multivitamins, muscle supports, and gastrointestinal protectives. Joint supplements and herbal supplements were also used.

The data presented in Table 1 summarizes the average daily consumption of various types of forages and concentrates by a sample of 180 horses. The mean intake of hay was 9 kg per day with a standard deviation of 6.2 kg. Haylage consumption averaged 5.0 kg per day, with a standard deviation of 4.4 kg, while alfalfa intake was 4 kg per day with a standard deviation of 2.6 kg. The overall mean intake of total forage was 7.4 kg per day, with a standard deviation of 6.2 kg. Additionally, the mean intake of total concentrates was 4 kg per day, with a standard deviation of 2.2 kg.

TABLE 1: The mean amount of forages consumed as fed basis with horses (kg/day) (n=180).

Feeds	All horses intake ($\bar{X}$±SD)
Hay	9±6.2
Haylage	5.0±4.4
Alfalafa	4±2.6
Total forage intake	7.4±6.2
Total concentrate intake	4±2.2

SD: Standard deviation.

NUTRIENT ANALYSIS

Using the estimated quantities from the concentrates and forages offered and estimated pasture consumption the majority of the horses (84%) were offered metabolizable energy (ME) in their predicted daily requirement, with a mean energy intake of 120.2±41.1 MJ ME/d. Only 5% of horses were estimated to be offered less than their recommended energy levels and 11% had more than their requirements. The estimated CP intake of most of the horses (92%) was greater than 110% of the NRC recommendations, while 2% of the horses had an estimated CP intake of below 90% of the NRC recommendations.[7] The average daily intake of CP was approximately 2.2 times the typical CP requirement of 820.2±220.2 grams per horse per day. The mean CP intake (including pasture) was 3.8±2.2 g/kg BW. Mean crude fiber intake was 6.8±2.5 g/kg BW, and crude fat intake was 0.9±0.4 g/kg BW, both being within NRC recommendations.[7] However, average starch intake was 2.6±0.4 g/kg BW, and sugar intake was 1.8±1.2 g/kg BW, both of which were high compared to the recommendations.[9]

GWP ANALYSIS

Table 2 provides calculated references from the database for the environmental impacts, specifically GWP, eutrophication, and acidification values, of various forage types, common concentrate ingredients, and feed packaging materials used for horse feed.[8]

The total emissions from the horse population, quantified on a per horse per day basis, encompassing GWP, eutrophication, and acidification, are presented in Table 3. The mean GWP per horse per day was 5.88±2.90 kg CO_2 eq, the mean eutrophication potential was 0.50±0.12 kg PO_4^{3-} eq, and the mean acidification potential is 0.06±0.04 kg SO_2 eq. Further breakdown of the GWP per horse per day

TABLE 2: Environmental impact values for forage types, common concentrate ingredients, and feed packaging.

Category	Type/Ingredient	Global Warming Potential ($kg\ CO_2$ eq)	Eutrophication ($kg\ PO_4^{3-}$ eq)	Acidification ($kg\ SO_2$ eq)
Forage types (per kg DM)	Hay (86% DM)	0.46	-	-
	Haylage (60% DM) (excl. plastic)	0.33	-	-
	Haylage (60% DM) (incl. plastic*)	0.34	-	-
	Lucerne (86% DM)	0.34	-	-
Common concentrate ingredients (per kg)	Oat	0.75	0.00987	0.02
	Barley	1.05	0.00878	0.01
	Maize	0.03	0.000291	0.000124
	Soybean	3.33	0.00218	0.004
	Linseed	1.03	0.03	0.02
	Wheat semolina	0.80	0.00892	0.00695
Feed packaging	Paper feed bag (~25 g)	0.04	-	-
	Plastic supplement container (~100 g)	0.00712	-	-
	Plastic bale wrap (~1 kg)	0.80	-	-
	Paper (1 kg)	1.7	-	-
	Plastic (1 kg)	0.07	-	-

This consolidated table provides a comprehensive overview of the Global Warming Potential, Eutrophication, and Acidification values for various forage types, common concentrate ingredients, and feed packaging materials based on data from the Ecoinvent database.

TABLE 3: Overview of emissions from each parameter per horse per day.

Parameter	Unit	$\bar{X}$±SD
Global warming potential	kg CO^2 eq	5.88±2.90
Eutrophication	kg PO_4^{3-} eq	**0.50±0.12**
Acidification	kg SO^2 eq	**0.06±0.04**

SD: Standard deviation.

TABLE 4: Mean values for global warming potential per horse per day.

Category	Unit	$\bar{X}$±SD
Forage	kg CO^2 eq	3.70±1.74
Concentrates	kg CO^2 eq	1.90±2.0
Supplements	kg CO^2 eq	0.32±1.80
Packaging	kg CO^2 eq	0.06±0.12
Total feeding	kg CO^2 eq	5.98±2.90

SD: Standard deviation.

from different feed sources is detailed in Table 4. The mean GWP contributions from forage, concentrates, supplements, and packaging were 3.70±1.74 kg CO_2 eq, 1.90±2.00 kg CO_2 eq, 0.32±1.80 kg CO_2 eq, and 0.06±0.12 kg CO_2 eq, respectively. The total GWP from all feeding sources combined was 5.98±2.90 kg CO_2 eq per horse per day. These values indicate the relative contributions of different feed types and packaging materials to the overall environmental impact associated with horse feeding.

DISCUSSION

Nutrition is key aspect to the management of horses, and variations are to be expected from individual to individual. Over the population, owners fed a range for 3-8.6 kg of forage to their horses daily. Majority (77.37%) choose hay as their main forage choice, which is a common feeding practice.[3] Hay production was found to have the highest GWP value over production of haylage and lucerne excluding packaging. According to the data base, the process of hay production starts with soil cultivation and ends with harvest and storage of the hay bales at the farm gate similar to that stated for the production of haylage and Lucerne.[28] The database furthermore allowed for seeding, fertilizers, pesticides, all machinery operations (incl. corresponding machinery infrastructure and sheds). Machinery operations included soil cultivation, transport of seeds, fertilizers, and pesticides, sowing, fertilization, weed control, pest, and pathogen control, haying, baling, loading, transport to farm and discharge at roughage store. However, use of vehicles to transport service people to the production site were excluded alongside limited data regarding irrigation. In comparison to haylage/lucerne production, which is a combined impact dataset in the database, this forage source has a very the same array of processes accessed however it must be noted that the seed utilized was a timothy/red clover haylage and timothy/alfalfa lucerne, whereas no seed was specified for hay production. According to previous studies the GHG emission from lucerne silage (40.3% DM) is 1.49 kg CO_2 eq, dried lucerne (91% DM) 0.68, Grass Silage (47.4% DM) 2.40 and Grass Dried (91.8% DM) 2.01 kg CO_2 eq.[10]

It is important to note that the DM content is higher in the compared study and this study database calculated emissions based per kg DM rather than per kg product.

Moreover, a significant increase can be observed. Regarding dried lucerne, the value (0.34 kg CO^2 eq) is fractionally higher than the result of this study which could be comparable to the fractionally higher DM percentage. Lastly, with no value for haylage specifically as a forage type, it can be compared to that of lucerne silage due to the linked impact with haylage and lucerne used in the database to obtain the result. No reference was made to plastic use in silage production so the value for haylage excluding plastic is taken (0.33 kg CO^2 eq). The result is again significantly reduced in comparison.

Differentiation could be a result of more extensive data parameters used in the study by Vellinga et al., compared to the database.[8,10] However, in both there is evidence to display that hay production has a higher GWP over alternative forage sources lucerne and haylage. This could be due to the increased machinery input into production such as tossing the hay, resting for a period, returning to the field, baling, and then transporting to storage and distribution. Haylage is cut, baled, and stored/distributed in one day, therefore requiring less repeated travel to and from the production location. In addition, in this study emission was calculated based per kg DM and hay has a significant higher DM percentage over haylage. Grass silage does however have a slightly higher impact over hay, but again marginally and it is often pitted over baled so not as comparable.

Regarding concentrate feeding a wide range of concentrates were fed by respondents with oats, barely, maize, linseed, wheat semolina and soybean being common ingredients found in feed stuffs. Soybean significantly surpassed the GWP value over the alternative ingredients with a result of 3.33 kg CO^2 eq. According to Adom et al., soyabean produced 4.1 kg CO^2 eq and soybean meal produced 4.6 kg CO^2 eq.[11] This is a comparable value to the result observed in this study. Soybean is used in horse feed as a source of protein, fat, and fiber. However, it is evident through CP requirement and intake values, the population has a higher intake daily (820.2 g) than is needed in reference to the required value daily. While the study focuses mostly on traditional horse feed sources, it may be interesting to investigate alternate feed solutions that can reduce GHG emissions while still meeting horses' nutritional needs. With rising concerns about agriculture's sustainability and environmental impact, locating feed sources with lower emissions could provide considerable benefits. Feeds developed from byproducts of other agricultural operations, or those made from more sustainable crops, could be considered as potential options.

Therefore, ingredients such as soybean are not necessary to meet the protein requirement of horses considering it is already being surpassed significantly. Furthermore, increased protein results in an increased nitrogen emission from the horse. Therefore, driving the environmental impact of equine feeding up further along with the impact from utilizing an evidently earth taxing ingredient. Moreover, linseed presented as the concentrate with the second highest GWP and highest in acidification and eutrophication, making it not a very sustainable concentrate choice. Oat also produced a comparable value to eutrophication to linseed. Concerning packaging all feeds must be contained with a form of packaging or container in order to ensure it is kept fresh and free from pests. Paper is a common packaging for concentrate feeds. Per a 25 kg bag it was estimated to contain 25 g of paper resulting in 0.04 kg CO^2 eq per bag. For a 1 kg supplement pot, 100 g of plastic was estimated which resulted in 0.00712 kg CO^2 eq. Due to the nature of the products packaging is required to ensure quality and safety. Therefore, it cannot be removed for sole means of sustainability, however sustainable packaging is becoming more and more widespread. As a result, it is advisable companies invest in recycled and environmentally friendly packaging where possible, particularly as these products are in reoccurring need of purchase. Moreover, 1 kg paper had a higher GWP than 1 kg recycled plastic, making it the less sustainable option. However, it must be noted that type and source of the material will influence the emission levels. The production of paper although coming from trees, a renewable source, requires a significantly larger amount of energy than plastic production and also produces 3.5 times more GHG.[12]

Both dried hay and lucerne do not require plastic packaging to ensure it remains fresh. However, it is vital for haylage. Using a common large haylage bale of 300 kg, it is estimated that 1 kg of plastic is wrapped around the bale. The impact of 1 kg haylage wrap plastic was found to be 0.80 kg CO^2 eq. To compare forages on a larger more practical scale, rather than previous daily emissions, we can assess one 300 kg bale of hay (86% DM) and one bale of haylage (60% DM) 300 kg bale with plastic wrapping, The haybale has an emission of 118.68 kg CO^2 eq, again higher than that of a haylage bale at 60.2 kg CO^2 eq, including 1 kg plastic at 0.80 kg CO^2 eq.

CONCLUSION

Hay was found to have the highest environmental impact regarding GWP. With 77.37% of the population feeding hay as their forage of choice either alone or in pairing with haylage or lucerne, it is clear that hay is the most prominent forage fed in the Netherlands. Hay was concluded to be less sustainable due to the higher DM content and increased machinery input alongside elongated production duration. Haylage production had the lowest impact excluding plastic wrapping and equal to lucerne including. More research is required into the emissions from plastic haylage wrapping to further confirm this assessment.

In reference to packaging, plastic showed to have a lower negative impact on sustainability than paper per kilogram. This is due to the enlarged energy requirement for production over plastic production, alongside the increase GHG emissions released from paper production. Soyabean had the highest GWP impact from the concentrate group, followed by linseed. Maize had the lowest impact and was the most sustainable concentrate choice regarding GWP. Alongside a high GWP value, linseed ranked highest in acidification and eutrophication impacts, therefore making linseed not a sustainable concentrate choice. Overall, more research is needed into the parameter's GWP, eutrophication and acidification,. Because of this a limitation of this study was comparison to other sectors to conceptualize a scale of emissions. No translator such as the carbon translator by Eco Chain is currently available for any parameters aside from GWP.

Source of Finance

This study is co-financed by the SIA Agency part of the Netherlands Organization for Scientific Research (NWO), Taskforce for Applied Research.

Proje no eklenmelidir.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

This study is entirely author's own work and no other author contribution.

REFERENCES

1. United Nations [Internet]. [Cited: February 15, 2023.]. Transforming our world: the 2030 agenda for sustainable development. Available from: https://sdgs.un.org/2030agenda
2. Velázquez AE, Salem AZM, Khusro A, Pliego AB, Rodríguez GB, Elghandour MMMY. Sustainable mitigation of fecal greenhouse gases emission from equine using safflower and fish oils in combination with live yeast culture as additives towards a cleaner ecosystem. J Clean Prod 2020;256:120460. doi: 10.1016/j.jclepro.2020.120460 .
3. Hoffman CJ, Costa LR, Freeman LM. Survey of feeding practices, supplement use, and knowledge of equine nutrition among a subpopulation of horse owners in New England. Journal of Equine Veterinary Science. 2009;29(10):719-26. https://doi.org/10.1016/j.jevs.2009.08.005
4. Rzekęć A, Vial C, Bigot G. Green assets of equines in the european context of the ecological transition of agriculture. Animals (Basel). 2020;10(1):106. PMID: 31936379; PMCID: PMC7023172.
5. Kotob F. What is sustainability? ResearchGate. 2011:1-14. https://www.researchgate.net/publication/282184670_What_Is_Sustainability
6. Elghandour MMMY, Adegbeye MJ, Barbabosa-Pilego A, Perez NR, Hernández SR, Zaragoza-Bastida A, et al. Equine contribution in methane emission and its mitigation strategies. Journal of Equine Veterinary Science. 2019;72:56-63. https://doi.org/10.1016/j.jevs.2018.10.020
7. National Research Council. Nutrient Requirements of Horses. 6th ed. Washington: National Academic Press; 2007.
8. Ecoinvent.org. [Internet]. ecoinvent v3.6. Available from: https://ecoinvent.org/the-ecoinvent-database/data-releases/ecoinvent-3-6/ (Erişim tarihi eklenmelidir.)
9. Vervuert I, Voigt K, Hollands T, Cuddeford D, Coenen M. Effect of feeding increasing quantities of starch on glycaemic and insulinaemic responses in healthy horses. The Veterinary Journal. 2009;182(1):67-72. https://doi.org/10.1016/j.tvjl.2008.04.011
10. Vellinga TV, Blonk H, Marinussen M. van Zeist WJ, de Boer IJM, Starmans D. Methodology used in FeedPrint: a tool quantifying greenhouse gas emissions of feed production and utilization. Lelystad: Wageningen UR Livestock Research; 2014.
11. Adom F, Maes A, Workman C, Clayton-Nierderman Z, Thoma G, Shonnard D. Regional carbon footprint analysis of dairy feeds for milk production in the USA. The International Journal of Life Cycle Assessment. 2012;17(5):520–34. https://doi.org/10.1007/s11367-012-0386-y
12. Emmerson Packaging. (2023). Paper Vs. Plastic Packaging. Which is More Environmentally Friendly? Emmerson Packaging. https://www.emmersonpackaging.com/paper-vsplastic/#:~:text=While%20paper%20comes%20from%20trees (Linke erişim sağlanamamaktadır, kaynağa direkt ulaşılacak link eklenmelidir)