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A Preliminary Study on Feeding Straw to Horses and Its Effects on Equine Chewing and Consumption Rates

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Abstract

Straw as a forage source has been investigated with regards to managing obese horses. However, its effect on chewing rate (CHR) and consumption rate (CR) lacks convincing evidence to encourage its inclusion. In this 2×7-day crossover study, the CHR (chews/5 mins) and CR (kg/hour) of eight horses were analyzed for differences in response to two diets: 50% oat straw, 50% haylage (S) and 100% haylage (CON). On Day 1, CR with S was lower compared to CON ($p > 0.05$), and by Day 7, this decrease was statistically significant ($p = 0.018$). CHR was lower on S on Day 1 than CON but higher on Day 7 ($p > 0.05$). The results suggest that oat straw provided at 50% of the forage ration slows consumption and alters chewing behavior in favor of managing obese horses. Adding oat straw to the forage diet can potentially improve the welfare of horses with low-energy requirements.

Keywords

Obesity; chewing; straw; satiety; forage; consumption

1. Introduction

Equine obesity has been a significant and challenging welfare concern for decades [1]. Restricting daily dry matter (DM) intake (DMI) is the most common method to induce weight loss [2], but this may compromise the horse's well-being/welfare [3,4]. Owners often find it difficult to adhere to strict management regimes and find it hard to identify and locate lower-energy grass-based forages [5]. Additionally, a horse's need to chew [6] and inability to self-regulate forage intake [7] make obesity prevention increasingly difficult to sustain.

It is recommended that horses perform natural feeding behavior for at least eight hours daily [8], spread across several meals to ensure fasting periods do not exceed four hours [9]. When periods without forage exceed six hours, it poses a significant risk to the development of EGUS [10]. Therefore, the forage requirement is strictly advised to reach a minimum DMI of 1.5% body weight (BW) per day to aid continuous foraging and reduce the risk of gastrointestinal disease and behavioral issues [8]. However, it can become difficult to balance continuous forage provision with energy content, even at this level of intake, as it can often exceed some horses' energy requirements. Therefore, slow feeders such as haynets and grazing muzzles are used to slow consumption and increase foraging opportunity [11,12]. Nevertheless, these may still have undesirable consequences such as musculoskeletal injury, refusal to eat, frustration due to unnatural feeding mechanisms, and increased poll pressure [6,13]. This is encouraging new research to find alternative methods that allow owners to feed more forage (i.e., 1.5-2% of BW in DM per day) to increase chewing opportunity and feeding frequency, without increasing the rate of intake or the risk of obesity.

Recent investigations indicate that the inclusion of straw as a partial hay or haylage replacement could promote equine welfare due to its high-fiber, low-calorie composition. The high neutral detergent fiber (NDF) content in straw reduces digestibility and palatability, thus may also decrease CR and CHR [14], resulting in prolonged feeding and reduced daily calorie consumption. Prolonged feeding increases chewing opportunity, which is believed to increase salivary secretion to buffer stomach acid [15] and promote satiation [16]. This may help horses feed on the same ration over a longer period, without requiring frequent top-ups, thus reducing daily calorie intake. Extended feeding periods by slowing consumption have been linked to slower passage rates and greater nutrient digestibility on straw diets [17]. Straw may also reduce insulinaemic responses, as was shown in the study by Jansson *et al.* [16] on a 50% straw and 50% haylage forage ration. However, it should be noted that replacing part of the forage diet with straw must consider additional vitamin and mineral supplementation as it is less nutritious than hay and haylage.

Presently, there is some reluctance among horse owners to include straw in rations due to a previous study associating straw with an increased risk of gastric ulcers [10]. The increased risk was associated with straw being the sole or predominant forage source, but this detail is missed by many. Conversely, recent studies found that 50% of straw-based rations did not cause gastric ulcers [16], promoted weight loss, and increased consumption time [16,18]. From these findings, Jansson *et al.* [16] proposed it is safe to feed straw, restricted to a maximum inclusion rate of 50% (as a percentage of the total daily forage ration).

There are also concerns about the risk of colic when horses are fed straw, predominantly in those with poor dentition or due to straw's poor hygiene quality. Poor hygiene quality is believed to increase digestive demand on the large intestine; however, it has only been anecdotally mentioned as a risk factor for feeding straw, with few studies evaluating this directly [19–21]. Additionally, the coarse texture of straw making it difficult to break down for horses with poor dentition has deemed it an unsuitable food source for many horses; Hammar [22] and Ralston *et al.* [23] have shown associations between poor dentition and poor digestibility, and consequently colic, but this has not been studied using straw forage. Thus far, most concerns regarding colic when feeding straw forage are assumptions based on situations where the forage was either introduced too quickly or the diet consisted of more than 50% straw. Studies [17] and [24], and more recently, [18] and [16] did not report incidences of colic during or after their studies, despite feeding straw diets up to 50% inclusion. In these studies, the inclusion rate was restricted to 50%, the forage was introduced slowly, and horses with dentition issues were excluded.

Existing research on straw forage is still limited, and inconsistencies in methods and variables have resulted in confusing and conflicting outcomes and communications about the safety and efficacy of feeding straw. Further investigation into how straw affects feeding behavior will provide greater insight into its suitability as a forage source for equines. The aim of the study was to evaluate how replacing 50% of the haylage ration with oat straw affects CHR and CR. It was hypothesized that the inclusion of straw would decrease CHR and increase the time spent foraging, thereby reducing CR.

2. Materials and Methods

2.1. Ethical Approval

To comply with the ARU Writtle ethical guidelines, an animal welfare monitoring protocol was established. Any horse used for the study was not to be subjected to pain and must be free of illness or pain (including colic and gastric ulcers) and up to date with dental examinations before commencing the investigation. Any horse refusing to eat during the study or showing sudden changes in behavior or stress had to be removed. All horses had to remain on the same daily routine to avoid additional stress factors. The ethical approval was granted under the number 1426.

2.2. Animals, Diets, and Experimental Design

Eight horses (age 14.88 ± 6.24 years old; weight 602.75 ± 53.49 kg; height 161.28 ± 8.31 cm) free from gastric ulcers, dental issues, colic, and other gastrointestinal diseases for the last 12 months were used for the study. The sample size was calculated using a formula (E = number of horses × number of groups - 2) to determine the maximum and minimum number of horses that could be recruited to ensure the study remains ethical. Eight horses were considered an appropriate sample size.

Prior to the study, all horses had been at the current premises for at least one year. All horses were only accustomed to a haylage diet. They had not been fed or bedded on straw before the study. Horses were housed in their usual single 3m × 3m stalls with rubber matting and shavings bedding overnight (17:00-11:00). Management routines remained unchanged from routines before the study period, and horses received daily group turnout for three to six hours (11:00-17:00) in bark paddocks. Water was provided ad libitum (AL). No additional feed or forage was available during turnout. The study diets were provided at the horses' usual feeding times, twice daily at 8:30 and 16:30 from haynets (4.5 cm openings), and once data collection was completed, they still had access to the remaining ration left in the haynet or were topped up if needed to fulfill their daily DM requirements. All horses were habituated to eating from the haynets used in the study. Due to the nature of a university yard setting, all attempts were made to ensure feeding times and data collection remained during hours when environmental disturbances were minimal. The study was performed as a 2×7-day crossover study with an initial acclimation period of two days **(Figure 1)** consisting of 75% haylage and 25% oat straw, to facilitate a smooth introduction of the study diet [16]. The choice of straw was informed by typical practice and availability. In the UK, oat straw is more widely available and more frequently used in horse feeds, like chaffs, in comparison to barley or wheat straw. It is also considered easier to handle and more digestible for horses, potentially making it a more suitable forage substitute. Horses were randomly divided into Group A (n = 4 horses) and Group B (n = 4 horses) using a computer-based random order generator. Each group received both study diets in different periods with each individual horse serving as the experimental unit. Diets fulfilled an average daily DMI of 1.71% (S) and 1.35% (CON) BW. The difference in DMI was due to the higher DM content in the oat straw and lower DM content in the haylage. As horses were required to be fed the same total daily forage quantities in the study diets that they received prior to the study, the rations could not be adjusted to be iso-caloric. The haylage and straw used during the study underwent wet chemistry and NIRS analysis [25] to determine their composition (Table 1), as done in previous studies [16–18,24,26]. When preparing the forage rations, each haynet containing S was weighed regularly using a portable scale to ensure thorough mixing and an equal divide of the straw and haylage proportions of the ration.

2.3. Measurements

On Day 1 and Day 7 of each period, the BW, CHR, and CR were measured. BW was measured using a Horseweigh weighbridge before feeding at 7:30 at the beginning and end of P1 and the end of P2. The author (NM) was responsible and aware of the group allocation and conduct of the experiment and the data analysis, and therefore could not be blinded to the treatments.

2.4. Chewing Rate

Chewing was measured by visual observation of horses eating according to established methods previously described [6,27,28]. The methods described in these studies all consisted of manually counting chews for 1-to-10-minute intervals. Mueller *et al.* [27] also measured chewing rate at the start and end of a one-hour eating bout, which was not done in the other two studies. An attempt was made to replicate this in the present study by randomizing the order of counting chews.

In the present study, four horses were filmed for five minutes each between 8:30 and 9:30. The remaining four horses were filmed between 9:30 and 10:30. This was done to allow horses to become accustomed to the forage rations as it was anticipated that chewing frequency could be greater when forage was first presented after the overnight period where a period without forage is likely to have occurred. The order of filming horses eating the forage was randomized using a computer-based random order generator, with each horse being filmed at a different time for each data collection day. Filming took place outside of the stables to reduce disturbance.

CHR (chews/min) was counted while watching the replay of the videos for each individual horse using a Hand Tally Digital Click Counter (FEBSNOW). One chew was counted as either one leftward or rightward circular jaw movement, depending on individual chew laterality [29]. One chew corresponded to one click on the counter. Jaw movements associated with searching for forage, drinking, crib biting, and turning haynets around were not counted as chews [30]. When horses showed such behaviors for more than two seconds, the video recording was stopped and resumed when the horse returned to eating. Chews were counted for one minute and then the counter was reset before resuming counting at two minutes for another minute. This was repeated for a total of five minutes for each horse. Each minute of chewing was counted three times, and an average was taken to reduce human error during counting.

2.5. Consumption Rate

Consumption was measured using techniques described by Ellis *et al.* [6] and Glunk *et al.* [11]. Both studies removed the haynets from the stables before weighing, which was replicated in the present study. However, unlike the aforementioned studies, it was not feasible to repeat this process in the evening or measure CR for longer than two hours in the present study, but the horses were still fed the study diet rations throughout the night.

In the present study, all haynets were weighed before administering to the horses. As soon as all horses received their forage rations at 8:30, a one-hour timer was started. The CR was measured by removing all haynets from stables after one hour (at 9:30 exactly) to be weighed. This prevented some horses from receiving additional time to consume their forage. Before weighing the forage rations, the scale was calibrated using an object of known weight (1kg Equiblox Hi-Fiber block) to ensure accurate weighing of the forage. After recording weights, the haynets were put back in stables, another one-hour timer was started, and the process was repeated for the second hour.

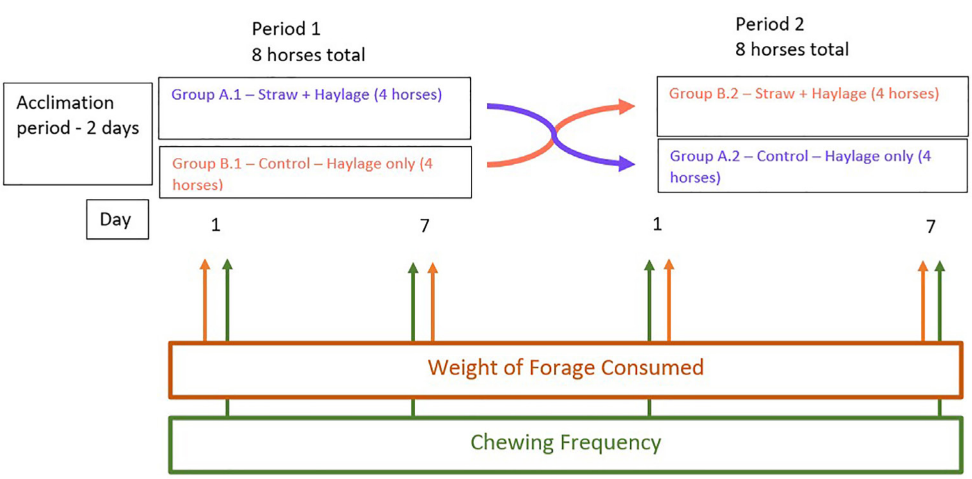

Figure 1: Illustration of the crossover study design (four horses in Groups A and B, respectively, that shifted diets from Period 1 (P1) to Period 2 (P2)). Days for data collection in each period are indicated by arrows and numbers. Periods followed each other with no washout period.

Table 1: Dry Matter (DM), energy, and nutrient content of the haylage and oat straw forages used in the study diet.

Dietary component	Haylage	Oat straw
Dry matter (%)	59.20	90.60
Crude protein (%)	13.20	3.60
Water-soluble carbohydrate (%)	5.10	2.18
Starch (%)	-	1.2
Neutral detergent fiber (g/kg)	56.60	59.60
Acid detergent fiber (g/kg)	33.70	34.70
Digestible energy (MJ/kg)	9.3	9.4
Metabolizable energy (MJ/kg)	8.1	6.5

2.6. Statistical Analysis

Data was first transferred to Microsoft Excel to produce descriptive statistics and subsequently analyzed by IBM SPSS Statistics (version 28, 2021) following data collection. Feed intake measurements included total chews in five minutes and consumption (weight in kg) of forage consumed per hour, both of which were analyzed as rates. All horses in Group A and Group B were subjected to both diets and the aim was to compare the diets. The data was split into Day 1 and Day 7, representing the first day and last day of administering the diet. For Day 1, CHR was calculated by averaging the number of chews/5 mins for each horse in Period 1, Group B and Period 2, Group A (for CON diet) and Period 2, Group B and Period 1, Group A (for S diet). The same was repeated using a separate dataset for Day 7. This process was repeated for CR. Period 1 and Period 2 only represented the duration of diet administration and illustrated the switching of diets between Group A and Group B.

The horses were included in the study if they continued to consume their forage for the total duration of the study. If horses showed negative health signs such as colic symptoms or refusal to eat, they were removed from the study and their data was excluded from analysis. As all eight horses did not show these behaviors, they were included in the analysis. A normality test (Shapiro-Wilk) was run to determine whether the data was parametrically or non-parametrically distributed. Parametrically distributed data was analyzed using a paired samples t-test. Non-parametrically distributed data was analyzed using Wilcoxon's Signed Rank test. A Pearson's Correlation test was run to determine the correlation coefficient between CR and CHR due to parametrically distributed data. For this test, chewing was extrapolated to a rate of chews/hour for a correct comparison. Statistical significance was assumed when $p < 0.05$.

3. Results

Data are represented as mean ± standard deviation unless otherwise stated. There were no outliers in any of the data, as assessed by visual inspection of boxplots. None of the horses were excluded from the data analysis. Shapiro-Wilk normality tests were used for all variables.

3.1. Chewing Rate

On Day 1, horses on CON had a higher chewing rate (317.25 ± 27.65 chews/5 mins; range: 285–353) than horses on S (308.63 ± 20.80 chews/5 mins; range: 274–341). This increase in CHR was not statistically significant, t(7) = -0.868, p = 0.414. On Day 7, horses on S had a higher CHR (322.38 ± 33.39 chews/5 mins; range: 264–367) than horses on CON (317.25 ± 31.78 chews/5 mins; range: 287–381), but this was not statistically significant, t(7) = 0.282, p = 0.786 **(Figure 2)**.

3.2. Consumption Rate

On Day 1, horses on CON consumed their forage ration faster (1.72 ± 0.59 kg/hour; range: 0.50–2.50) than horses on S (1.53 ± 0.45 kg/hour; range: 0.75–2.25); although, statistically this was only a trend, t(7) = -0.917, p = 0.390. On Day 7, CON elicited a statistically significant median increase in CR (Median = 1.65 kg/hour; range: 1–3) compared to S (Median = 1.00 kg/hour; range: 0.50–1.50), z = 2.371, p = 0.018. For comparison to Day 1, CR was plotted on the graph as a mean instead of a median **(Figure 3)**.

4. Discussion

4.1. Chewing Rate

This is the first study, to the authors' knowledge, to examine CHR on a 50% straw forage diet. The results indicate that CHR may be affected by the inclusion of oat straw due to the numerical differences between Day 1 and Day 7 on S, while CHR on CON remained constant. There are a few possible explanations for these findings, one being the novelty of the straw forage. Horses avoid unpalatable, indigestible, or poisonous plants and rely on olfaction to explore new scents and select suitable plants before ingestion **[31]**. Stachurska *et al.* **[32]** found that novel feeds were smelled for longer and more frequently rejected by horses. In the present study, oat straw probably had a novel odor as horses were not accustomed to eating it before the study. This may explain why horses were observed to spend less time chewing and more time searching for the more palatable haylage. Van den Berg and Hinch **[33]** suggested it takes three to four days to reduce variability in a horse's reaction to novel feeds. This could explain why CHR on S increased on Day 7, as oat straw was no longer a novelty.

Six horses were also observed to engage in more exploratory behaviors when straw was fed. These included flipping the haynet around, taking more pauses between feeding, and increasing periods of smelling the ration. They were performed intermittently, and no chewing occurred during this time. This may have been performed in search of the more palatable haylage, as a form of mental stimulation, or due to frustration. Several studies suggested that straw can provide mental stimulation as increased exploratory behaviors can indicate a motivation to search for alternative resources **[34–36]**. This may also be interpreted as frustration because of a reduction in diet palatability. However, this is less likely as the horses did not exhibit other behaviors indicative of frustration (i.e., muscle tension, aggression, displacement, stereotypies) **[37]**. Even if an increase in exploratory behaviors, rather than the composition of the straw itself, is the main cause of the decreased CHR, this effect is still beneficial as it slows intake and increases mental stimulation by allowing the horse to sort through the forage, mimicking what they do in the wild or in pasture. This indicates straw can elicit beneficial effects beyond just feeding and may be a source of enrichment.

Hunger level is another factor that could have promoted a higher CHR on S on Day 7. CHR was determined from the first five minutes of forage consumption in the morning when horses are likely to be hungrier. Other studies agree with this hypothesis, stating that increased hunger is one plausible reason for a higher CHR [28,38].

Due to the short-term study, an increase in search behaviors and hunger levels on S are the most plausible explanations for the lower CHR on Day 1 and higher CHR on Day 7. The existing literature suggests that CHR decreases with increasing NDF content as a greater masticatory effort is required to break down food particles [28,38,39], although the present study could not establish whether NDF content had an influence on CHR. Accordingly, further exploration of chewing in relation to straw composition is essential. While it is hypothesized that a decreased CHR is desirable to prolong feeding and increase saliva production, thus reducing the risk of EGUS, there is no concrete evidence of such benefits occurring in response to chewing, thus warranting additional investigation. However, the standardization of the units of measurement for CHR is fundamental for fair comparisons between different studies and to improve understanding of how different forages and feeding methods impact CHR. Chews/min or chews/5 mins might be the most realistic unit to report rates if the aim is to facilitate easy implementation of measuring feeding behavior into the horse owner's routine.

4.2. Consumption Rate

The findings on CR are arguably the most important as they suggest S had the greatest effect on CR and that statistically significant differences could be observed within a week. The lower CR on S could be due to the lower palatability and digestibility of oat straw, increased gut fill, and more demanding mastication. This may have created a sensation of fullness, thus reducing their appetite and making it difficult for horses to consume their forage rapidly. These results and hypotheses are consistent with several investigations on straw-based diets [16,18,24,26,40] although the study's short duration means other factors that influence CR may have had a more pronounced effect than oat straw composition.

An increase in search behaviors in response to a novel forage, as mentioned previously, reduces the time spent consuming forage, which may partially explain the lower CR [32]. However, such behaviors relating to novelty are likely to have ceased after 30 minutes so would have had less of an impact, especially by Day 7 as the straw was no longer novel. Nevertheless, horses may still sort forage based on palatability.

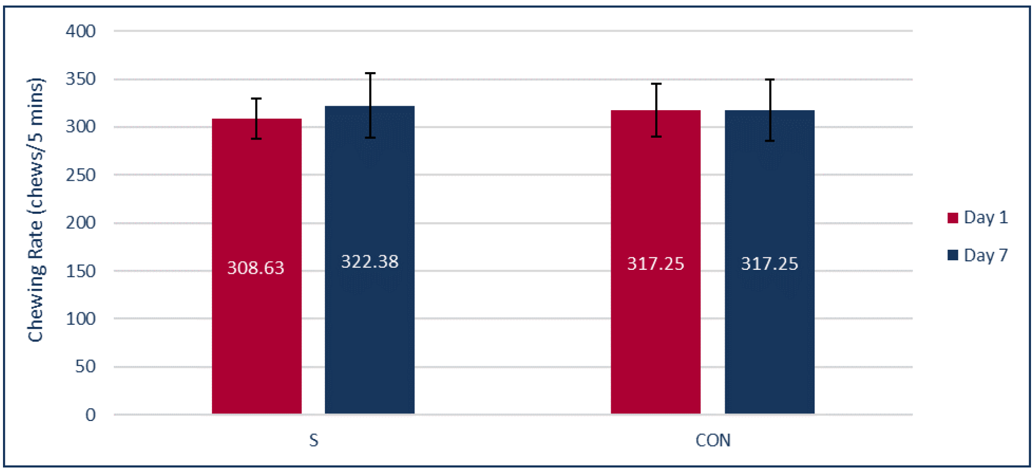

Figure 2: Mean CHR (chews/5 mins) on the S and CON diets on Day 1 and Day 7 (n = 8). Error bars show the standard deviation from the mean (p-value > 0.05).

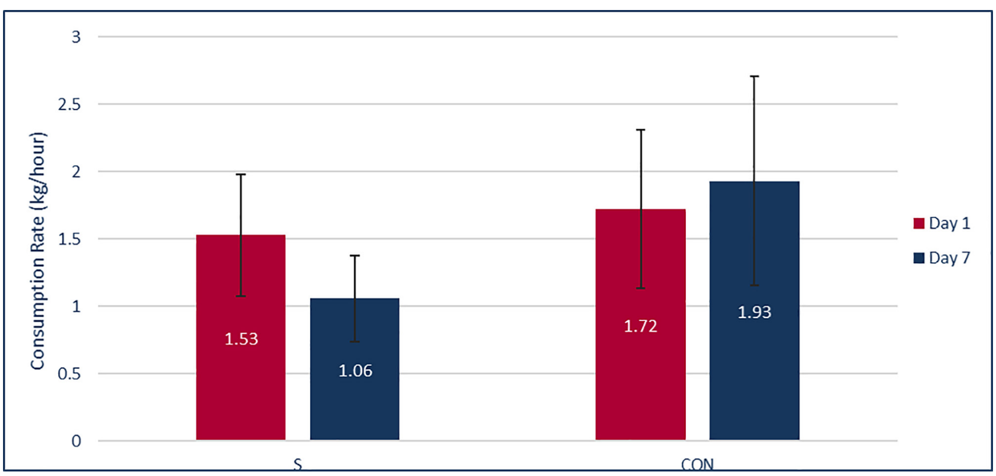

Figure 3: Mean CR (weight (kg) of forage consumed/hour) on the S and CON diets on Day 1 and Day 7 (n = 8). Error bars show the standard deviation from the mean (p-value < 0.05).

Alternatively, the S diet may have been retained inside the GIT for longer, thus decreasing ghrelin secretion, and subsequently, hunger levels, which may have increased satiety **[41]**. This decreased passage rate may have triggered a feedback loop that reduced CR in response to higher satiety levels **[42]**. Although hormonal responses to the diets are beyond the scope of the present study, there is evidence in previous research that supports this; Jansson *et al*. **[16]** found a higher serotonin production and a greater number of pauses between feeding bouts, which corresponded to a prolonged intake on the straw diet. They suggested this occurred in response to increased satiety with straw.

It is important to note that the use of haynets was a confounding factor. Haynets were used to prevent horses from separating haylage and straw, which made it difficult to isolate the effect of haynets from straw inclusion on CR. Jansson *et al*. **[16]** found that the straw diet resulted in an 80% increase in feeding time, which is comparable to feeding from haynets with small openings (3.2 cm) **[11]**. However, the haynets used in their study had 3.5 cm openings, which is smaller than the medium-sized openings (4.4 cm) in **[11]**. Therefore, the 80% increase in feeding time might not be solely due to straw inclusion. The haynets used in the present study had 4.5 cm openings so would have had a lower impact, meaning the CR obtained is more reflective of oat straw inclusion. However, more recently, Bordin *et al*. **[43]** highlighted that haynet position influences the posture and mandibular angle, which may have influenced feeding behavior differently than if the diets were fed on the floor. Thus, the size of the haynet alone is not the only influence that could have affected results, making it necessary to repeat the study while feeding on the floor to compare it against a horse's natural feeding position.

5. Limitations

This study has some limitations, and thus, the data presented should be considered a pilot study. The short study duration made it difficult to determine whether BW changes were reflective of a diet effect, hence why it was not a focus of the present study. A longer study duration would allow a longer adaptation to both diets to determine how BW, CHR, and CR change as horses become more accustomed to the study diets over time.

The difference of DM provided to horses is to be noted as a limitation as diets were not iso-caloric. However, as it was not in the authors' control to change diet quantity, it would be necessary to repeat this study with iso-caloric diets.

It was not feasible to conduct a longer-term study, and thus a longer acclimation and washout period had to be eliminated from the study design. While it is evident that this could have influenced results as carryover effects were not eliminated, washout periods and longer acclimation periods were also missing in similar studies **[16,18]**, indicating that more research ruling out these limitations is needed.

Measuring chewing by counting may have resulted in some human error. Initial proposals to use a rumination collar (RumiWatch) were not feasible but would have reduced human error and allowed a more extensive collection of chewing data. Establishing baseline CHR in individual horses would have been valuable to improve the interpretation of results. Notwithstanding these limitations, this study provided insight into variables that can be affected by different diets and how the inclusion of straw presents a debatable, but optimistic approach to equine obesity management.

6. Future Directions

As research continually pursues new ways to address the ongoing increase in equine obesity, the manipulation of feeding behavior by replacing half of the forage ration with straw is potentially an important focus for developing weight management strategies. Therefore, future research could benefit from using longitudinal studies and larger sample groups consisting of obese horses when investigating the effect of adding straw to the forage diet. This may reduce the influence of short-term responses, such as hunger levels and search behaviors, and therefore, more accurately describe the effect of straw on CHR and CR as a sustainable, long-term forage option. Including obese horses is necessary to evaluate the influence of straw on the target equine population. To facilitate measuring CHR more easily for longer periods and with greater accuracy, a rumination collar could be used. Moreover, as bite rate may explain the relationship between CHR and CR, it would be valuable to incorporate this into future research.

Standardizing the reporting of chewing rates in research is vital to improve our understanding of how CHR affects consumption. Such information can then be used to directly investigate the relationship between CHR, CR, and serotonin production as well as the relationship between chewing, saliva production, and the prevalence of EGUS. This can subsequently inform guidelines that assist in the formulation of suitable diets to increase satiation and manage obesity and ulcer-prone horses, therefore ultimately enhancing the welfare of a range of horses.

7. Conclusion

This study aimed to measure the impact of substituting 50% of the grass forage diet with oat straw on chewing rate and consumption rate. As emerging research suggested that oat straw may provide psychological and physiological benefits to horses, this study sought to investigate whether straw could help increase chewing and slow intake rates. This could reduce the length of time a horse is left without forage and make it a suitable partial forage replacement for horses on low-energy diets. Findings revealed that the inclusion of oat straw decreased the consumption rate more than the haylage-only diet. Its effect on chewing rate did not establish a clear trend but more evident changes occurred on the straw diet in comparison to the haylage-only diet. The findings agree with previous literature, highlighting the potential welfare benefits straw may provide to horses with lower-energy requirements, while also challenging previously unsubstantiated assumptions of its unsuitability.

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Authors' Contributions

N.L.M.: Methodology and analysis, K.W.: Conceptualization and manuscript development, B.A.W.: Conceptualization and manuscript development.

Data Availability

The data that supports the findings of this study are available from the corresponding author upon reasonable request.

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The research has not received any funding.

Conflicts of Interest

The authors declare no conflict of interest.

Ethical Approval

The authors confirm that the ethical policies of the journal, as noted on the journal's guidelines page, have been adhered to and the research received approval from the ARU Writtle ethical review committee (ethical approval number: 1426). The authors confirm they have followed EU standards for the protection of animals used for scientific purposes and feed legislation as well as the guidelines in the Declaration of Helsinki.

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