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High intake of sugars and starch, low number of meals and low roughage intake are associated with Equine Gastric Ulcer Syndrome in a Belgian cohort

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Abstract

Equine gastric ulcer syndrome (EGUS) is a pathological condition affecting the glandular and squamous regions of the stomach. It is characterized by nonspecific clinical signs, behavioural changes or can also be found without any overt clinical manifestations. Nutritional factors such as intermittent feeding, high sugars and starch intake, large amounts of straw as forage and prolonged time without access to forage have all been associated with an increased risk of equine squamous gastric disease (ESGD). The aim of this study was to investigate which nutritional practices are commonly seen in clinical ESGD cases in Belgium.

Medical records of 27 horses referred to the equine nutritional service at Ghent University (2013-2018) due to equine gastric ulcer lesions were reviewed. Twenty-one healthy horses referred for dietary evaluation during the same period were selected as control cases (CC). Dietary evaluation

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was performed on an individual basis. Forage/concentrate ratio on dry matter basis, forage content in the diet, total dietary sugar and starch intake per day and per meal were analyzed. Retrospective descriptive and statistical analyses were performed.

Significantly higher amounts of forage intake (%DM per BW) in the CC versus ESGD group were noted ($p \leq 0.05$) with average values of 1.39 (SD $\pm$ 0.27) and 1.27 (SD $\pm$ 0.70) respectively. There were no significant differences for sugar and starch intake in g/kg BW/day ($p=0.18$). However, the sugar and starch intake per meal (g/kg BW/meal) in the CC group (average value 1.06, SD $\pm$ 0.56) was significantly ($p < 0.001$) lower than in the EGUS group (average value 1.85 SD $\pm$ 0.78).

Forage intake below the recommended absolute minimum value as well as high sugar and starch intakes were most commonly associated with EGUS in the present case series. An adequate diet formulation taking into account these main nutritional factors is therefore essential to avoid gastric problems in horses.

Introduction

Equine gastric ulcer syndrome (EGUS) is a pathological condition affecting the glandular and squamous part of the equine stomach, the terminal part of the oesophagus and first part of the duodenum (Andrews et al., 1999). The prevalence of gastric ulceration is variable (Zavoshti and Andrews, 2017), but in racing horses values as high as 89% have been reported (Kingston et al., 2007). Horses suffering from EGUS tend to present with nonspecific clinical signs such as mild colic, poor appetite, weight loss, poor hair coat, crib biting, reduced performance and behavioural changes (Luthersson and Nadeau, 2013).. Several predisposing factors have been associated with the development of gastric ulcers in horses, such as age, breed, gender (Chameroy et al., 2006), alterations in the diet (Andrews, Larson and Harris 2017; Luthersson et al., 2009; Taharaguchi et al., 2004), management (Husted et al., 2008), stress, electrolyte administration (Holbrook et al., 2005) and non-steroidal anti-inflammatory drug use (Fennell and Franklin; 2009, Reed et al., 2006). Definitive diagnosis of EGUS is performed by gastroscopy (Andrews et al., 1999), after withholding feed for at least 12 hours. In 2015, EGUS was subdivided in 2 different subtypes (Sykes et al., 2015) based on the anatomical location and physiopathology of the lesions: equine squamous gastric disease (ESGG) and equine glandular gastric disease (EGGD).

While dietary changes in addition to therapeutic medication are important in the management of this syndrome, poor nutrition (lower quality feedstuffs and/or inappropriate ration formulation) can also be one of the trigger factors for EGUS (Andrews et al., 2017; Jonsson and Egenvall, 2006). More specifically, nutritional factors such as intermittent feeding (Murray, 1994) , alfalfa chaff in weaned foals (Fedtke et al., 2015; Vondran, Venner and Vervuert, 2016)), high sugar and starch intakes, high

amounts of straw in the diet and prolonged time without access to forage (Luthersson et al., 2009) have been associated with a high predisposition to EGUS. The aim of this particular study was to investigate which nutritional practices are commonly seen in clinical ESGD cases in Belgium.

Materials and Methods

Data from medical records of horses referred to the nutritional service (Ghent University) between 2013 and 2018 due to equine gastric ulcer lesions were collected and reviewed. Details regarding endoscopic diagnosis and location of lesions were obtained from the medical reports of the referring veterinarians. Cases from both the equine hospital at Ghent University and from private veterinarians were considered. Reviewed data included clinical history and diagnosis (from the referring veterinary report), and dietary background collected in a standard questionnaire used by the nutritional service. This questionnaire focuses on the animal's feeding regime and diet composition and also includes age, sex, breed, body weight (BW), 9-scale body condition score (BCS) (Henneke et al., 1983), management of the horse, training regime, latest dental check-up, current medication and anthelmintic status. In a next step, the diet was evaluated on an individual basis. Forage/concentrate ratio on dry matter basis (DMB), forage content in the diet (% forage DMB) related to the current body weight (BW), estimated total dietary sugar and starch intake per kg BW per day and estimated total dietary sugar and starch intake per kg BW per meal were analyzed. For forage, reference tables/values from the equine nutrition book in Belgium and The Netherlands (Veevoederbureau, 2013) were used. For commercial products, label information and nutritional data collected by communication with companies were used to perform the evaluation.

Healthy horses referred for dietary evaluation during the same period (2013-2018) as the ESGD group were selected as control cases (CC). As the same nutritional questionnaire was used, the same dietary evaluation was performed for both groups.

Retrospective descriptive and statistical analyses were performed. A Shapiro-Wilk test was used to evaluate normality of the data. If a significant deviation from normality was found, a Mann-Witney U test was used to compare the groups. Data is reported as mean and standard deviation or median and interquartile range, when appropriate. All analyses were performed with SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). The significance threshold was set at $p \leq 0.05$.

Results

Twenty-seven cases with endoscopic diagnosis of ESGD were included in the study and a total of 21 cases were used as a control group.

An individual dietary evaluation was performed for each horse. The median age in the ESGD group was 11 years (range of 2 – 22), with 54% of the horses being geldings, 40% mares and 6% stallions. Regarding the BCS in this group, 36% of the horses had an ideal BCS (4-5/9), 15% had a high BCS (6-7/9) and 49% of the horses were underweight (BCS 2-3/9). The median age of horses in the control group was 10 years (range 2-25), with 43 % of them being geldings and the same percentage being mares, while the remaining 13% were stallions. Body condition score evaluation showed 10% of cases were underweight (BCS 3/9), 71% had an ideal condition (BCS 4-5/9) and 19% of the control group were overweight/ obese (7-8/9).

Evaluation of forage/concentrate ratio (DM-basis) revealed an inverted ratio with higher concentrates than forage in 21% of cases in the ESGD group. In 86% of the cases, a forage intake lower than 1.5% of dry matter/ kg body weight (DM/BW) was found in the current diet, and in 48% of the cases this was even lower than 1% DM/BW. In the control group, however, there were no horses with a forage intake lower than 1% forage DM/BW. 81% of the horses had a forage intake between 1 and 1.5% and the remaining 19% had a forage intake higher than 1.5% DM/BW. A statistically significant difference was found when both groups were compared ($p = 0.05$). Higher amounts of forage intake (%DM per BW) were seen in the control versus ESGD group (graph 1) with average values of $1.39 (SD \pm 0.27)$ and $1.27 (SD \pm 0.70)$ respectively.

In 82% of clinical ESGD cases, the diet provided had an estimation of more than 2g of sugars and starch/kg BW per day, and in 41.5 % of the diets the sugar and starch provision was higher than 2g/kg BW per meal. Only 17% of all horses presented with EGUS had a sugar and starch intake below 1g/kg BW/meal. The estimated sugar and starch intake (g/kg BW/meal) in the control group was significantly ($p < 0.001$) lower than in the EGUS group (graph 2). The percentage of control horses with a sugar and starch intake below 1g/kg BW/meal was 57%. While 29% of the controls were above 1g/kg BW/meal and below 1.5 g/kg BW/meal, only 14% of the same group had an estimated sugars and starch intake higher than 2 g/kg BW/meal. However, there were no statistically significant differences found when comparing sugar and starch intakes in g/kg BW/day between groups ($p = 0.18$) (graph 3). The number of meals per day may also play a role: while in the ESGD group all horses received 2 meals a day, the horses in the control group received on average $3 (SD \pm 0.3)$ meals per day.

To perform a visual evaluation, a bi-plot (graph 4) was created. Nutritional composition differences of the diets in the groups can be observed. While the diets for the CC group are more clustered, those in the other group are more scattered over on the graph. Sugar and starch intakes higher than 3g/kg BW/meal can be observed in 4 horses with gastric lesions and 12 cases had forage intakes lower than 1% DMB/BW in the same group. Surprisingly, 3 horses suffering from EGUS lesions and with sugar and starch intakes higher than 1g/kg BW/meal also had a high amount of forage in their diet (>2% DM forage/ IBW/day).

Discussion

It is well known that a prolonged mucosal exposure to a low pH environment (driven by high amounts of hydrochloric acid and volatile fatty acids) is the most common cause of gastric ulceration in the squamous mucosa (Andrews et al., 2017). As horses have a continuous gastric acid secretion (Luthersson and Nadeau, 2013), without a proper feeding management (empty stomach for longer time), the stomach pH drops reaching strong acid values. This was shown in a study where equines with 24 hours access to timothy hay had a pH of 3.1 compared to fasted horses where the pH was as low as 1.5 (Murray and Schusser, 1993). Lack of forage intake is also linked with the “splash effect” (Lorenzo-Figueras and Merritt, 2002), commonly observed during training when acid fluid is freely available in the stomach and comes into contact with the non-glandular mucosa. It was demonstrated that forage content in the stomach may buffer a part of the free gastric juice preventing the “splash effect”. Based on those two observations, it has been recommend to ensure a minimum amount (1.5% daily forage DM/BW) (Sykes et al., 2015) of forage in the stomach and to provide small meals as frequently as possible. Nonetheless, there is lack of strong evidence showing that free access to fibrous feed or frequent forage feeding reduces the risk of gastric ulceration (Sykes et al., 2015).

When eating forage, horses produce 400-480g saliva per 100g DM consumed (Meyer, Coenen and Gurer, 1985). However, when concentrate is fed, the amount of saliva produced is significantly lower (206 g saliva per 100g dry matter) (Meyer, Coenen and Gurer, 1985). Saliva has a buffering effect due to its composition (i.e. mainly potassium, chloride and bicarbonate) and may consequently impact the stomach pH (Eckersall, Aitchisson and Colquhoun, 1985). Without sufficient saliva production and buffering effect, damage and lesions to the gastric mucosa may occur (Luthersson and Nadeau, 2013). Additionally, provision of only a small number of meals per day and periods longer than 6hs without food access increase the likelihood of gastric ulceration (Luthersson et al., 2009). In this study, information about the exact time when meals were offered was unfortunately not available in

the case's history. However, considering that the EGUS cases were fed 2 meals per day, it can be assumed the time between meals was longer than 6 hours.

In the present study, a low forage intake was significantly associated with EGUS lesions compared to the control group. This low forage intake might have led to a reduction in saliva production on the one hand and free gastric juice coming into contact with the squamous gastric mucosa during exercise on the other hand. Another reason to recommend providing ad-libitum forage to EGUS horses is the fact that stomach pH was higher than 4 in horses with pasture turn out for a large part of the day (Husted et al., 2008), which again was due to the influence of continuous saliva flow and presence of grass in to the stomach. However, based on the results of three horses that were fed an amount of forage higher than 2% DMB/BW, a high DMB/BW alone might not be sufficiently protective when the sugars and starch intake is higher than 1g/kg BW/meal. This could potentially be due to the influence of other factors such as low number of meals, too much time between meals and the forage feeding methods used (slow feeders, hay-net or roughage provided directly on the floor). However, it has also been reported that there was a 2.6 times increased likelihood of developing EGUS in horses receiving more than 1g/kg BW/meal of starch (Luthersson et al., 2009). This is in line with the results found in the current study where EGUS was significantly associated ($p < 0.05$) with higher sugar and starch intakes (g/kg BW/meal). In the same paper, Luthersson (Luthersson et al., 2009) reported that exceeding intakes of 2g of sugar and starch per kg BW per day also made the likelihood of EGUS twice as high. However, in the present study, higher dietary intakes of sugar and starch per day were not associated ($p = 0.135$) with EGUS compared to the control group. Another study by Taharaguchi (Taharaguchi et al., 2004) reported more prevalent and more severe squamous gastric ulcer lesions in dams when increased amounts of concentrates were fed. Fermentation of sugars and starch by microbiota residing in the gastro intestinal tract generates lactate and volatile fatty acids (VFA). Within the gastric microbial population, large concentrations of anaerobic bacteria have been found, represented by Firmicutes and Proteobacteria as main phyla (Julliand and Grimm, 2019). Remarkably, while the concentration of cellulolytic bacteria is negligible, lactate utilizing bacteria can reach up to 10 million colony forming units per ml in the stomach content. This translates in a strong impact on starch digestion and generation of lactate reaching a concentration of 8mmol/L after a meal (Julliand and Grimm, 2016; 2019). As a consequence, high concentration of sugars and starch have been shown to reduce the integrity of the mucosa and affect its bioelectric properties (Andrews et al., 2008; Andrews et al., 2006). Moreover, high-starch diets are normally associated with lower fibre intakes and less salivary secretion (Luthersson and Nadeau, 2013). All the above mentioned factors contributed in the current study to a higher likelihood of developing EGUS lesions. Nevertheless, these results highlight the need to limit the amount of sugar

and starch per meal and to adapt the number of meals to the amount of concentrates / sugars and starch being fed per day.

Another factor associated with gastric ulcer lesions is a high amount of straw in the diet. When horses were fed straw as the only forage source, a 4.5 fold higher likelihood of gastric lesions was reported (Luthersson et al., 2009). In the current study, all horses with EGUS received only hay and haylage as forage sources. However, it was not specified if they were able to eat straw from the bedding. There is no evidence suggesting that small amounts of straw cause of gastric ulcerations. Nevertheless, this could potentially be another factor increasing the predisposition to EGUS.

Particle size of the pelleted food was not determined in the present study. However, it was proven in pigs (Ayles, Friendship and Ball, 1996; Hedde et al., 1985) that a particle size smaller than 0.4 mm was a trigger factor for gastric ulceration (Cappai, Picciau and Pinna, 2013) and that adding a small amount of long fibre had a protective effect. In contrast with these results, Vondran (Vondran et al., 2016) demonstrated that in horses a large amount of alfalfa chaff could produce gastric lesions in the glandular region due to mechanical damage. In the same study, weanling foals fed alfalfa in a pellet form showed lower lesion scores in the gastric mucosal compared to those fed alfalfa chaff, suggesting a protective effect of the pelleted formulation. It has been suggested that calcium and protein content, both high in alfalfa, produce a buffer effect in the stomach resulting in a protective effect on the squamous mucosa (Andrews, Larsson and Harris, 2017). In horses, the size of the pellets itself could also play a role, as was demonstrated by Bochnia (Bochnia et al., 2017). In this study larger pellets had a higher hardness degree and, as a consequence, mastication induced the higher saliva production. Nevertheless, more research is necessary to determine the link between particle and pellet size and gastric lesions in the horse.

As EGUS is divided in 2 pathologies, EGGD and ESGD, it would also be interesting to investigate the correlation between the anatomical area of the lesions and the associated nutritional predisposing factors. However, this was not possible in this study due to the lack of cases with EGGD.

Limitations

Due to the retrospective nature of the study, data regarding the daily food intake was evaluated according to the information provided by owners in the questionnaire and communications. Despite the control group being clinically healthy, horses in this group were not controlled by gastroscopy and therefore subclinical lesions could have been missed. As lesions in the EGUS cases were described but not graded in the veterinary reports, the correlation between lesion severity and nutritional parameters could not be investigated.

Conclusion:

Forage intake below the recommended absolute minimum value of 1 % DM forage per IBW per day, as well as high sugar and starch intakes (> 2 g/kg/meal) were most commonly associated with ESGD in the present case series. It is also important to note that, in certain cases, a high provision of forage (more than 2%DM/IBW) alone was not sufficient to prevent ESGD when combined with high sugar and starch intakes per meal.

Bibliography

- Chameroy, A. K., Nadeau, J., Bushmich, S., E. Dinger, J., A. Hoagland, T., & Saxton, A. (2006). Prevalence of non-glandular gastric ulcers in horses involved in a University Riding program (Vol. 26).
- Andrews, F., Bernard, W., Byars, D., Cohen, N. D., Divers, T., MacAllister, C., Vatistas, N. (1999). Recommendations for the diagnosis and treatment of equine gastric ulcer syndrome (EGUS). *Equine Vet. Educ.*, Volume 11(Issue 5), 262-272.
- Andrews, F. M., Buchanan, B. R., Elliot, S. B., Jassim, R. A. M. A., McGowan, C. M., & Saxton, A. M. (2008). In vitro effects of hydrochloric and lactic acids on bioelectric properties of equine gastric squamous mucosa. *Equine Vet J*, 40(4), 301-305. doi: doi:10.2746/042516408X293565
- Andrews, F. M., Buchanan, B. R., Smith, S. H., Elliott, S. B., & Saxton, A. M. (2006). In vitro effects of hydrochloric acid and various concentrations of acetic, propionic, butyric, or valeric acids on bioelectric properties of equine gastric squamous mucosa. *American Journal of Veterinary Research*, 67(11), 1873-1882. doi: 10.2460/ajvr.67.11.1873
- Andrews, F. M., Larson, C., & Harris, P. (2017). Nutritional management of gastric ulceration. *Equine Veterinary Education*, 29(1), 45-55. doi: 10.1111/eve.12495
- Bochnia, M., Goetz, F., Wensch-Dorendorf, M., Kamphues, M., & Zeyner, A. (2017 20 - 23 Sept.). Physical properties of pelleted feeds and different meal sizes influence feed intake patterns in horses. Paper presented at the Proc. of the European Society and Veterinary Nutrition, Cirencester, UK.
- Eckersall, P. D., Aitchison, T., & Colquhoun, K. M. (1985). Equine whole saliva: variability of some major constituents. *Equine Vet J*, 17(5), 391-393.
- Fedtke, A., Pfaff, M., Volquardsen, J., Venner, M., & Vervuert, I. (2015). Effects of alfalfa chaff on gastric mucosa in weanling foals. *Pferdeheilkunde*, 6, 596-602.

253 Fennell, L. C., & Franklin, R. (2009). Do nonsteroidal anti-inflammatory drugs administered at
 254 therapeutic dosages induce gastric ulcers in horses? *Equine Veterinary Education*, 21(12), 660-662.

255 Holbrook, T. C., Simmons, R. D., Payton, M. E., & MacAllister, C. G. (2005). Effect of repeated oral
 256 administration of hypertonic electrolyte solution on equine gastric mucosa. *Equine Vet J*, 37(6), 501-
 257 504.

258 Husted, L., Sanchez, L. C., Olsen, S. N., Baptiste, K. E., & Merritt, A. M. (2008). Effect of paddock vs.
 259 stall housing on 24 hour gastric pH within the proximal and ventral equine stomach. *Equine Vet J*,
 260 40(4), 337-341. doi: 10.2746/042516408X284673

261 Jonsson, H., & Egenvall, A. (2006). Prevalence of gastric ulceration in Swedish Standardbreds in race
 262 training. *Equine Vet J*, 38(3), 209-213.

263 Julliand, V., & Grimm, P. (2016). Horse species symposium: The microbiome of the horse hindgut:
 264 History and current knowledge (Vol. 94).

265 Julliand, V., & Grimm, P. (2019, 15 - 17 February). Equine digestive microbiota: beneficial and
 266 detrimental effects of the horse? . Paper presented at the European equine health and nutrition
 267 congress, Utrecht, The Netherlands.

268 Luthersson, N., Hou Nielsen, K., Harris, P., & Parkin, T. D. H. (2009). Risk factors associated with
 269 equine gastric ulceration syndrome (EGUS) in 201 horses in Denmark. *Equine Vet J*, 41(7), 625-630.
 270 doi: 10.2746/042516409X441929

271 Luthersson, N., & Nadeau, J. A. (2013). 34 - Gastric ulceration. In R. J. Geor, P. A. Harris & M. Coenen
 272 (Eds.), *Equine Applied and Clinical Nutrition* (pp. 558-567): W.B. Saunders.

273 Luthersson, N., Nielsen, K. H., Harris, P., & Parkin, T. D. H. (2009). The prevalence and anatomical
 274 distribution of equine gastric ulceration syndrome (EGUS) in 201 horses in Denmark. *Equine Vet J*,
 275 41(7), 619-624. doi: 10.2746/042516409X441910

276 Meyer, H., Coenen, M., & Gurer, C. (1985). Investigations on saliva production and chewing effects in
 277 horses fed various feeds. *Proc. Equine Nutr. Physiol. Soc.*, 9, 38-41.

278 Murray, M. J. (1994). Equine model of inducing ulceration in alimentary squamous epithelial mucosa.
 279 *Dig Dis Sci*, 39(12), 2530-2535.

280 Reed, S. K., Messer, N. T., Tessman, R. K., & Keegan, K. G. (2006). Effects of phenylbutazone alone or
 281 in combination with flunixin meglumine on blood protein concentrations in horses. *Am J Vet Res*,
 282 67(3), 398-402. doi: 10.2460/ajvr.67.3.398

Sykes, B. W., Hewetson, M., Hepburn, R. J., Luthersson, N., & Tamzali, Y. (2015). European College of Equine Internal Medicine Consensus Statement--Equine Gastric Ulcer Syndrome in Adult Horses. *J Vet Intern Med*, 29(5), 1288-1299. doi: 10.1111/jvim.13578

Taharaguchi, S., Okai, K., Orita, Y., Asai, Y., Kuwano, M., Ueno, T., & Taniyama, H. (2004). Relation between amounts of concentrated feed given mares and gastric ulcers in foals. *J. Jpn. Vet. Med. Assoc*, 57, 366-370.

Veevoederbureau, C. (2013). CVB Tabellenboek Voeding Paarden en Pony's: Voederbehoeften en Waardering Van Voedermiddelen: Productschap Diervoeder.

Vondran, S., Venner, M., & Vervuert, I. (2016). Effects of two alfalfa preparations with different particle sizes on the gastric mucosa in weanlings: alfalfa chaff versus alfalfa pellets. *BMC Vet Res*, 12(1), 110. doi: 10.1186/s12917-016-0733-5

ANIMAL WELFARE STATEMENT

"The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. No ethical approval was required as this is a retrospective study with original research data collected from Ghent University, Equine Nutritional Service."

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