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, Mogg, & Perkins, 2007). Horses suffering from EGUS tend to present with non-specific clinical signs such as mild colic, poor appetite, weight loss, poor hair coat, cribbing, and abnormal behaviour (Andrews, 1999). Ulcers are classically found in the glandular and squamous regions of the stomach (Andrews, 1999). EGUS can present without any overt clinical manifestations (Andrews, 1999). 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 was performed on an individual basis. Forage/concentrate ratio on dry matter basis, forage content in the diet, total dietary sugars and starch intake per day and per meal were analysed. Retrospective descriptive and statistical analyses were performed. Significantly, higher amounts of forage intake (%DM per BW) in the CC vs. ESGD group were noted ($p \leq .05$) with average values of 1.39 (SD ± 0.27) and 1.27 (SD ± 0.70) respectively. There were no significant differences for sugars and starch intake in g/kg BW/day ($p = .18$). However, the sugars and starch intake per meal (g/kg BW/meal) in the CC group (average value 1.06, SD ± 0.56) was significantly ($p < .001$) lower than in the EGUS group (average value 1.85 SD ± 0.78). Forage intake below the recommended absolute minimum value as well as high sugars and starch intake 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.
bilitating, reduced performance and behavioural changes (Luthersson & Nadeau, 2013). Several pre-disposing 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, & Harris, 2017; Luthersson, Nielsen, Harris, & Parkin, 2009; Taharaguchi et al., 2004), management (Husted, Sanchez, Olsen, Baptiste, & Merritt, 2008), stress, electrolyte administration (Holbrook, Simmons, Payton, & MacAllister, 2005) and non-steroidal anti-inflammatory drug use (Fennell & Franklin, 2009; Reed, Messer, Tessman, & Keegan, 2006). Definitive diagnosis of EGUS is performed by gastroscopy (Andrews et al., 1999), after withholding feed for at least 12 hr. In 2015, EGUS was subdivided into two different subtypes (Sykes, Hewetson, Hepburn, Luthersson, & Tamzali, 2015) based on the anatomical location and physiopathology of the lesions: squamous gastric disease (ESGG) and 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 & Egenwall, 2006). More specifically, nutritional factors such as intermittent feeding (Murray, 1994), alfalfa chaff in weaned foals (Fedtke, Pfaff, Volquardsen, Venner, & Vervuert, 2015; Vondran, Venner, & Vervuert, 2016), high sugars and starch intake, high amounts of straw in the diet and prolonged time without access to forage (Luthersson, Nielsen, et al., 2009) have been associated with a high pre-disposition to EGUS. The aim of this particular study was to investigate which nutritional practices are commonly seen in clinical ESGD cases in Belgium.

2 | 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 the 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, Potter, Kreider, & Yeates, 1983), management of the horse, training regime, latest dental check-up, current medication and antihelmintic 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 sugars and starch intake per kg BW per day and estimated total dietary sugars and starch intake per kg BW per meal were analysed. 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–Whitney 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 $p \leq .05$.

3 | 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. About 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 ($p = .05$). Higher amounts of forage intake (%DM per BW) were seen in the control vs. ESGD group (Graph 1) with average values of 1.39 (SD ± 0.27) and 1.27 (SD ± 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 sugars and starch provision was higher than 2g/kg BW per meal. Only 17% of all horses presented with EGUS had a sugars and starch intake below 1g/kg BW/meal. The estimated sugars and starch intake (g/kg BW/meal) in the control group was significantly ($p < .001$) lower than in the EGUS group (Graph 2). The percentage of control horses with a sugars 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 sugars and starch intake in g/kg BW/day between groups ($p = .18$) (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 ± 0.3) meals per day.

To perform a visual evaluation, a biplot (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. Sugars and starch intake higher than 3g/kg BW/meal can be observed in four horses with gastric lesions, and 12 cases had forages intakes lower than 1% DMB/BW in the same group. Surprisingly, three horses suffering from EGUS lesions and with sugars and starch intake 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 & 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 hr access to timothy hay had a pH of 3.1 compared with 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

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**GRAPH 2** Comparison of the sugar content per meal between the two groups. Caption: *** $p$-value < .001. CC, Case control group; EGUS, Equine gastric ulcer syndrome group

**GRAPH 3** Comparison of the sugar content per day between the two groups. Caption: BW, body weight; CC, Case control group; EGUS, Equine gastric ulcer syndrome group

**GRAPH 4** Case distribution of the two groups using the variables sugars and starch per meal and forage content per day. Caption: BW, body weight; CC, Case Control group; DM, dry matter; EGUS, Equine gastric ulcer syndrome group
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 recommended 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 400–480 g saliva per 100 g DM consumed (Meyer, Coenen, & Gurer, 1985). However, when concentrate is fed, the amount of saliva produced is significantly lower (206 g saliva per 100 g dry matter) (Meyer et al., 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, Aitchison, & Colquhoun, 1985). Without sufficient saliva production and buffering effect, damage and lesions to the gastric mucosa may occur (Luthersson & Nadeau, 2013). Additionally, provision of only a small number of meals per day and periods longer than 6hs without food access increases the likelihood of gastric ulceration (Luthersson, Nielsen, 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 hr.

In the present study, a low forage intake was significantly associated with EGUS lesions compared with 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 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 were a 2.6 times increased likelihood of developing EGUS in horses receiving more than 1g/kg BW/meal of starch (Luthersson, Nielsen, et al., 2009). This is in line with the results found in the current study where EGUS was significantly associated (p < .05) with higher sugars and starch intake (g/kg BW/meal). In the same paper, Luthersson (Luthersson, Nielsen, 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 = .135) with EGUS compared with 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 gastrointestinal 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 & 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 & 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, Buchanan, Smith, Elliott, & Saxton, 2006). Moreover, high-starch diets are normally associated with lower fibre intakes and less salivary secretion (Luthersson & 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, Nielsen, 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 pre-disposition 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 with 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 et al., 2017). In horses, the size of the pellets itself could also play a role, as was demonstrated by Bochnia (Bochnia, Goetz, Wensch-Dorendorf, Kamphues, & Zeyner, 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 into two pathologies, EGGD and ESGD, it would also be interesting to investigate the correlation between the anatomical area of the lesions and the associated nutritional pre-disposing factors. However, this was not possible in this study due to the lack of cases with EGGD.

5 | 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.

6 | CONCLUSION

Forage intake below the recommended absolute minimum value of 1% DM forage per IBW per day, as well as high sugars and starch intake (> 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 sugars and starch intake per meal.

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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**How to cite this article:** Galinelli N, Wambacq W, Broeckx BJG, Hesta M. 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. *J Anim Physiol Anim Nutr*. 2019;00:1–6. https://doi.org/10.1111/jpn.13215