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Prevalence of gastrointestinal, liver and claw disorders in veal calves fed large amounts of solid feed through a cross-sectional study

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ABSTRACT

The impact of the current practice of feeding veal calves with large amounts of solid feed (SF) on the prevalence of specific disorders on rumen, abomasum, liver and claws was investigated through a *post-mortem* inspection at the abattoir. Forty-one batches ("batch" referred to a group of calves of the same breed, coming from the same farm and belonging to the same slaughter group) of crossbred male calves from dairy breed were randomly inspected at 213.6 days old. On average 16.0 rumens, 15.6 abomasa, 15.1 livers, and 30.5 hind claws were checked per batch. Rumens were evaluated for the presence of hyperkeratosis and plaques; abomasa for the presence of lesions in the pyloric area; livers for the presence of lipidosis, abscess or fibrous adherence; and claws for the presence of sole hemorrhages. More than 60% of rumens per batch had signs of hyperkeratosis and plaques, and 80 to 100% of abomasa per batch showed at least 1 lesion in the pyloric area. On average 24% of livers per batch were diseased and about 65% of claws per batch had sole hemorrhages. Affected abomasa were positively correlated to rumens with plaques. Claws with sole hemorrhages tended to be positively correlated to rumens with hyperkeratosis. Calves of inspected batches were fed 311 ± 31 kg DM/cycle of milk-replacer and 158 ± 44 kg DM/cycle of SF containing more than 85% of corn grain. Based on the recorded prevalence of alterations, this feeding strategy should be reconsidered in order to improve veal calves' welfare.

1. Introduction

The European Council Directive 08/119/EC for calf protection (European Council, 2008) made mandatory the provision of solid feed (SF) to veal calves in combination with the liquid milk-replacer (MR) diet. According to the Directives, veal calves should receive a minimum daily dose of fibrous feeds from the 2nd week of age and its amount should increase from 50 to 250 g per day from 8 to 20 weeks of age in order to fulfill some of their physiological and behavioural requirements, such as the forestomach development and the onset of rumination. The practical implementation of these guidelines was supported by the positive outcomes of a wide scientific literature. Indeed, the supplementation of the MR diet for veal calves with SF was reported to stimulate rumen development (Suárez et al., 2006a; Suàrez et al., 2007; Brscic et al., 2011), chewing and rumination activity, as well as to reduce abnormal oral behaviours (Webb et al., 2013). These positive findings made nutritionists and farmers more confident towards the use of SF for veal calves and their level of inclusion in the calf's diet has progressively increased far above the minimum requirements, reaching as an example daily quantities of 1330 g DM/calf (Brscic et al., 2014) and of 1650 and 1920 g DM/calf (Brscic et al., 2019) at the end of the fattening cycle. Solid feeds for veal calves are mainly composed by corn grain (50–80% as fed basis) and mixtures of cereals (*i.e.* corn, barley, oat, steamed flaked corn, *etc.*) and legume seeds (lupin or pea) with a small amount of roughage and their administration in large amounts led to an increase in starch intake (Brscic et al., 2019). The outcomes of a risk factor analysis by Brscic et al. (2011) on a large and representative sample of the veal production system in the 3 main veal meat-producing countries in Europe (the Netherlands, France, and Italy), showed that the provision of large amounts of SF (from 151 to 300 kg of DM/calf) rich in cereal grain during the entire fattening promoted rumen development but it worsened the occurrences of rumen plaques and rumen papillae hyperkeratinization as well as of abomasal lesions. The present study aimed at investigating the impact of the current practice of feeding veal calves with large amounts of SF on the prevalence of rumen, abomasum, and liver disorders belonged to different batches of calves through a *post-mortem* assessment at the slaughterhouse. Based on the recognized association between high concentrate diets and the occurrence of

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subclinical laminitis and related claw disorders in dairy cows (Bergsten, 2003; Alvergnas et al., 2019), the impact of the provision of large amounts of SF on calves' claw health was also assessed. Moreover, correlations among specific disorders detected across different organs belonging to the same calf were calculated at batch level.

2. Material and methods

The prevalence of rumen mucosa, abomasum, liver and claw disorders in veal calves was assessed at the slaughterhouse through a *post-mortem* inspection setting up a cross-sectional study. Organ inspection was carried out in a commercial cattle abattoir located in Northern Italy from April 2016 until March 2017 during 13 observation days. All the inspected organs belonged to batches of veal calves randomly chosen from those arriving at the slaughterhouses regularly according to the ordinary daily planning. The term "batch" was defined as a group of calves of the same breed, coming from the same farm and belonging to the same slaughter group during loading, transport, unloading, lairage time and slaughtering phases. Each day of observation lasted almost seven hours (from 0600 h to 1300 h) with a predefined target of inspecting the first 15–16 calves per batch. Gender and breed of calves were not set *a priori*. Three trained veterinarians located in different areas of the slaughter line (dispatch, tripery, and skins areas) allowed to trace and inspect different organs belonging to the same calf. The prerequisite of the study was to use a set of quick assessment measures (1 min/organ) that could be applied without interfering with the regular working schedule of the slaughter-line. After each observation day, information about the farm of origin of each inspected batch were obtained *a-posteriori* by the slaughterhouse personnel. The corresponding farmer was then interviewed in order to collect information regarding some main features of the rearing facilities (flooring and ventilation systems) adopted in the origin farms, and regarding the total amount of MR and the type and total amount of SF fed to the inspected batches of calves during the whole fattening period.

2.1. Post-mortem rumens and abomasa inspection

At the abattoir, rumens and abomasa were examined by a trained veterinarian in the tripery. Rumens were evaluated after their opening and rinsing in water. Rumen mucosa development was graded according to the 4-point scale described in detail by Brscic et al. (2011), from a low-developed rumen (score 1) (Fig. S1) having almost no papillae in the atrium and in the ventral and dorsal rumen to a fully-developed rumen (score 4) having numerous papillae in the ventral and dorsal rumen and with leaflet shaped papillae in the atrium. The presence of hyperkeratosis of the rumen papillae, of plaques on the rumen wall and of redness of rumen mucosa were recorded as binary measures (yes/no) whenever they occurred, regardless of the extension of the area involved by the disease (Fig. S1). As described by Brscic et al. (2011), hyperkeratinization is characterized by thickened and hardened papillae, both visually and tactually. Plaques on the rumen wall appeared as groups of papillae adherent to each other and fixed by a sticky mass of feed, hair, and cell debris (Suárez et al., 2006a; Brscic et al., 2011). Redness of rumen mucosa was identified when papillae appeared reddish. Regarding abomasa inspection, the same veterinarian evaluated as binary (yes/no) the presence of any kind of lesions on the mucosa of the torus pylorus after cutting it longitudinally, and of the pyloric region where they were prevalent according to previous studies (Brscic et al., 2011; Brscic et al., 2019). Consistent with the above cited studies, lesions in the pyloric region were counted from 0 (no lesions) to a censored maximum of 4 (presence of 4 or more lesions) within 3 size classes: small lesions with a diameter < 0.5 cm^2, medium lesions with a size between 0.5 and 1 cm^2, and large lesions > 1 cm^2 (Fig. S2).

2.2. Post-mortem livers inspection

The assessment of livers was performed directly in the slaughter-line in the dispatch area by a second veterinarian before the routine veterinary inspector who verified their suitability for sale on the market. Any kind of liver diseases (lipidosis, abscesses or fibrous adherences) was recorded as binary (yes/no) whenever they occurred.

2.3. Post-mortem claws inspection

The same procedures of claw collection and inspection described by Magrin et al. (2018) for finishing beef cattle were used also for veal calves. In particular, one assessor collected the anatomical part between hock and claw of the hind limbs from the calves. A third veterinarian, specialized hoof trimmer, performed the trimming of the sole horn with an electric grinder and evaluated the claw health conditions by looking for the specific claw disorders described in the International Committee for Animal Recording Claw Health Atlas (Egger-Danner et al., 2015). Among all disorders included in the cited protocol, sole hemorrhages were the only ones detected by the veterinarian with a batch prevalence $> 1\%$, and they were recorded as binary (yes/no), regardless of the number or of the extension of the sole involved by the hemorrhage (Fig. S3).

2.4. Statistical analysis

All data gathered during *post-mortem* inspection were expressed as percentages of organs affected by a given disorder (*i.e.* % rumens with hyperkeratosis, % abomasa with lesions on torus pylorus, or % claws with at least 1 sole hemorrhage) over the total number of examined organs per batch. General descriptive statistics (mean, median, SD, minimum and maximum) were calculated at batch level for all variables using a Proc UNIVARIATE (SAS 9.3; SAS Institute Inc.). Moreover, the percentages of organs affected by some specific disorders were graphically represented per each batch inspected in order to investigate the variability among batches. The relationship between the prevalence of specific disorders detected on the same organ or among different organs was assessed at batch level using Spearman's rank correlation (PROC CORR of SAS 9.3).

3. Results

A total of 41 batches of veal calves coming from 28 farms were inspected at the slaughterhouse. All calves inspected were crossbred males from dairy breed (prevalently Holstein), either national or imported from Eastern European countries. Rumen, abomasa and claw inspection was performed in all batches and liver inspection in 38 batches only (missing data from 3 batches for the lack of the second veterinarian during one observation day).

According to data gathered *a-posteriori* by farmers' interview, all batches of calves inspected at the slaughterhouse were intensively reared indoors in closed barns provided with automatic ventilation systems, and housed in multiple pens of 4 to 5 calves each on fully slatted wooden floor.

With regards to the feeding systems, all farms of origin adopted feeding plans that combined increasing amounts of MR and SF throughout the fattening cycle. Both MR and SF were delivered in two daily meals, in the morning and in the evening. The total amount of MR provided to calves during the entire fattening was on average 311 $\pm$ 30.8 kg DM/calf. The total amount of SF was on average 158 $\pm$ 44.3 kg DM/calf per cycle. Farmers declared that the SF ingredient composition mostly consisted of corn grain plus corn grain-based commercial mixtures (*i.e.* composed mainly by corn grain, barley, flaked corn, oat, lupin bean, corn gluten, and soybean proteins, or mainly by corn grain, corn gluten, and wheat straw; or mainly by corn silage and corn grain) that overall approximately contained more than 85% of corn grain and other

cereals, and less than 10% of straw. Calves were slaughtered at 213.6 ± 10.6 days of age after a fattening period of 183 ± 18.5 days.

The number of batches inspected at the slaughterhouse was 16, 10, and 15 at the first, second, and third assessment day, respectively. On average, 16.0 ± 3.1 rumens, 15.6 ± 2.0 abomasa, 15.1 ± 2.7 livers, and 30.5 ± 3.7 claws were evaluated per batch. Rumens with a low-developed mucosa were observed in 11% of inspected rumens per batch, reaching in some batches the maximum of 60% of inspected rumens (Table 1). The percentage of rumens observed per batch with a moderate development of the rumen mucosa was on average 50%, but it could reach up to 85% in some batches. Well-developed rumen mucosa was observed on average on 37% of inspected rumens and in some batches on a maximum of 80% of rumens. Rumens with a full development of rumen mucosa were on average 1.4%, reaching in some batches the maximum of 27% of inspected rumens. Hyperkeratosis and plaques were observed in more than 60% of inspected rumens per batch, involving in some batches all inspected rumens (100%). Almost 30% of inspected rumens per batch were observed with reddening signs on mucosa.

More than 80% of inspected abomasa per batch showed a lesion on the torus pylorus, and more than 90% of them showed at least 1 lesion in the pyloric region. In some batches, 100% of inspected abomasa were affected by an abomasal lesion on the torus pylorus or by at least 1 abomasal lesion in the pyloric region. The abomasal lesions observed in 78% of affected abomasa in the pyloric area were large-sized lesions.

Livers with some hepatic diseases (signs of lipidosis or abscesses, or fibrous adherences) were on average 24% of the total livers inspected per batch, reaching in some batches more than 90% of inspected livers. Nearly 65% of inspected claws per batch were affected at least by 1 sole hemorrhage, involving in some batches almost all inspected claws (97%) (Table 1).

Prevalence of rumens with specific disorders per batch inspected are shown in Fig. 1. Prevalence of abomasa having lesions on torus pylorus and in the pyloric area at batch level is shown in Fig. 2. Prevalence of pathological livers and claws per each batch monitored are shown in Figs. 3 and 4, respectively.

Results of the Spearman rank correlations among specific disorders detected on rumen, abomasa, liver, and claws at batch level are reported in Table 2. The percentage of rumens with hyperkeratosis and redness of mucosa was negatively correlated to the percentage of rumens with low-developed mucosa. The percentage of rumens with hyperkeratosis was positively correlated to the percentage of well-developed rumens. Regarding abomasal lesions, the percentage of abomasa with lesions on the torus pylorus was positively correlated to the percentage of rumens with plaques. The percentage of abomasa having large-sized lesions was negatively correlated to the percentage of rumens with moderate-developed mucosa, but positively to the percentage of those with well- and fully-developed mucosa and with redness of mucosa. The percentage of claws with sole hemorrhages was positively correlated to the percentage of rumens with well-developed mucosa, but negatively correlated to the percentage of rumens with plaques, and to the percentage of pathological livers.

Table 1
Prevalence of rumen, abomasa, liver, and claws disorders detected in 41 batches of veal calves during a *post-mortem* inspection carried out at the slaughterhouse.

	Mean	SD	Minimum	Maximum
Rumen development class, % of rumens				
Low	11.1	14.4	0.0	60.0
Moderate	50.5	21.1	6.67	84.6
Well	36.9	20.5	0.0	80.0
Full	1.44	4.57	0.0	26.7
Hyperkeratosis, % of rumens	60.1	22.6	0.0	93.3
Plaques with hairs, % of rumens	68.2	21.6	20.0	100
Redness of mucosa, % of rumens	27.9	23.8	0.0	80.0
Abomasal lesion, % of abomasa				
Presence on torus pylorus	84.7	15.1	33.3	100
Presence of at least 1 in pyloric region	92.0	9.02	61.1	100
Small lesions	65.7	17.1	27.8	100
Medium lesions	73.4	15.1	40.0	100
Large lesions	77.5	14.8	40.0	100
Lipidosis, abscesses, or fibrous adherence, % of livers	23.6	24.7	0.0	93.3
Presence of at least 1 sole hemorrhage, % of claws	64.9	22.4	7.50	96.7

4. Discussion

The veal production chain is recognized as being one of the most standardized cattle rearing system over the years (Cozzi et al., 2009), which operates under rather rigorous criteria regarding calf management and housing structures. Looking at the information obtained *a-posteriori* by the farmers, the types of flooring and ventilation systems adopted for the batches of calves inspected were exactly the same in all farms of origin. This high level of standardization of the rearing facilities adopted by veal farmers proven even today is the reason why we mainly attributed the occurrence of specific gastrointestinal, liver, and claw disorders registered at slaughter to the current feeding practice rather than to some housing or environmental aspects. Specifically, calves' feeding plans and SF types adopted by different commercial farms are very closely controlled by few integrators/owners to which farms belonged through agistment contracts, and this is evident from the limited variability in values of the total amounts of MR and SF provided during the cycle and of the SF composition obtained *a-posteriori* from our sample of batches of calves inspected in the current study.

Due to the high amount of SF provided during the fattening cycle, the prevalence of calves observed with well-developed rumens was expected to increase compared to the past. In fact, in the present study 38% of rumens were found with well- or fully-developed mucosa compared to just 11% of rumens found by Brscic et al. (2011) at European level. All the SF provided to calves of the inspected batches were rich in starch and prompted the development of rumen papillae, likely through a higher production of butyrate and propionate (Berends et al., 2014; Suarez-Mena et al., 2016). However, along with the rumen mucosa development, SF strongly increased the occurrences of signs of redness, rumen plaques and hyperkeratosis that were observed in almost all rumens inspected. Previous studies associated these rumen mucosa alterations to the feeding of large quantities of cereal grains and small amounts of coarse roughage sources, because this feed combination speeds up the rumen fermentation rates with a consequent drop in ruminal pH, and minimizes the buffering capacity and the abrasive effect on the rumen wall (Suárez et al., 2006b; Suàrez et al., 2007; Brscic et al., 2011). Hyperkeratinization of rumen papillae, redness of rumen mucosa and plaque formation are considered among the first and the foremost macroscopic pathological variations in the rumen epithelium (Brscic et al., 2011; Vestergaard et al., 2013).

Particularly alarming was the high prevalence of abomasal lesions on torus pylorus and in the pyloric area that in some batches was observed on all inspected calves. According to a recent review on the abomasal damage, the current prevalence at slaughter ranges from 70 to 93% of all animals affected (Bus et al., 2019). The prevalence recorded in this study was, indeed, similar to that recorded over the last 20 years (Mattiello et al., 2002; Brscic et al., 2011, 2019). Controversial hypotheses exist on the relation between the distribution of large amount of SF and the abomasal damage. Some researchers suggested the administration of increasing amounts of concentrate or hay in the veal calf diet as a way to prevent abomasal damage through an earlier stimulation of the rumen development and fermentation activity (Berends et al., 2012; Webb et al., 2015). According to this theory, a well-developed rumen mucosa would decrease the passage of unfermented feed particles into the abomasum, protecting its mucosa against ulcer formations (Bus et al., 2019). In contrast, large amounts of SF, both roughages or concentrates, were reported to increase the prevalence and the size of ulcers on the

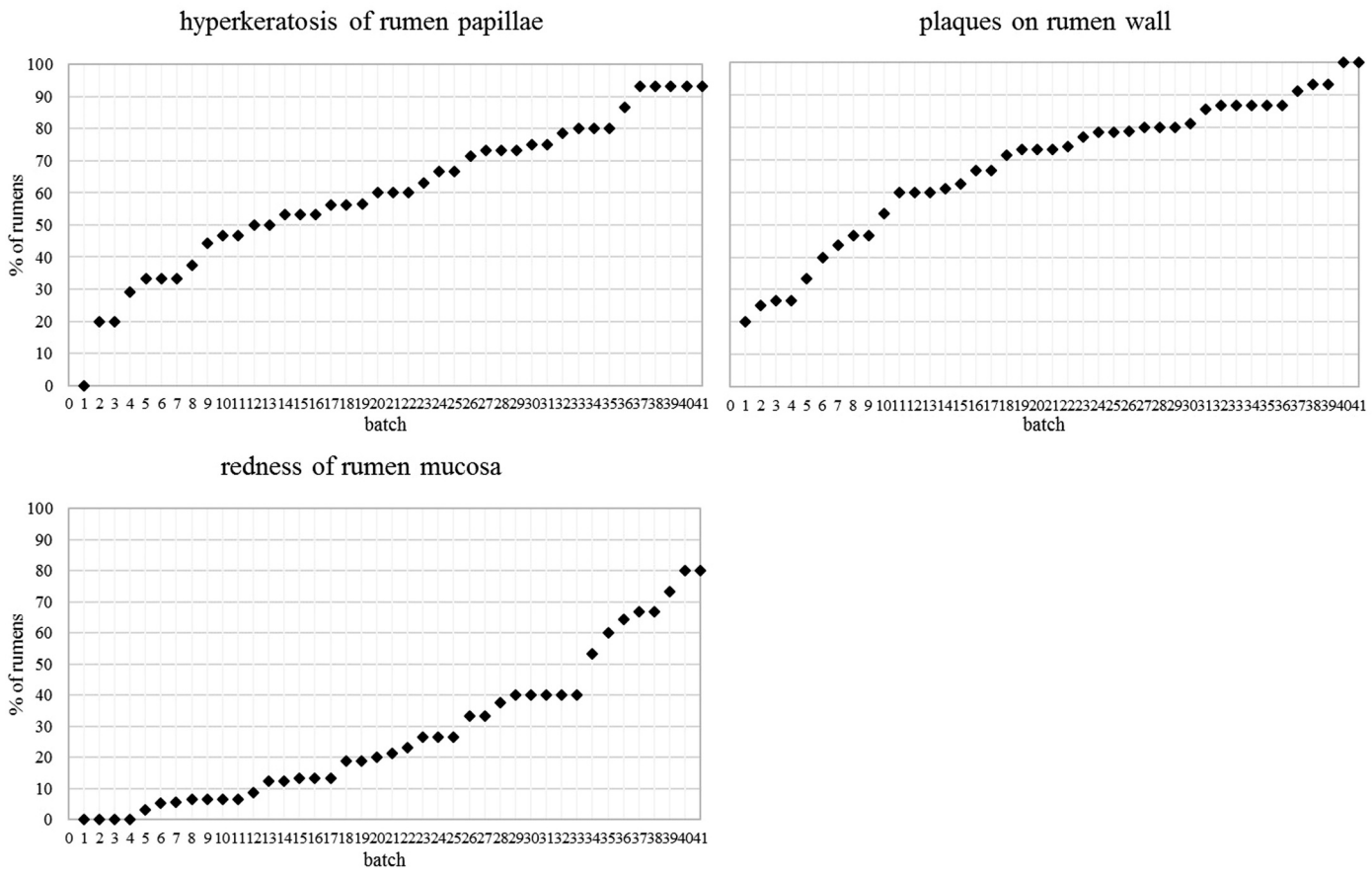

Fig. 1. Prevalence of rumens with hyperkeratosis, plaques, and redness of mucosa at batch level ($n = 41$) in increasing order (1 ◆ corresponds to 1 batch).

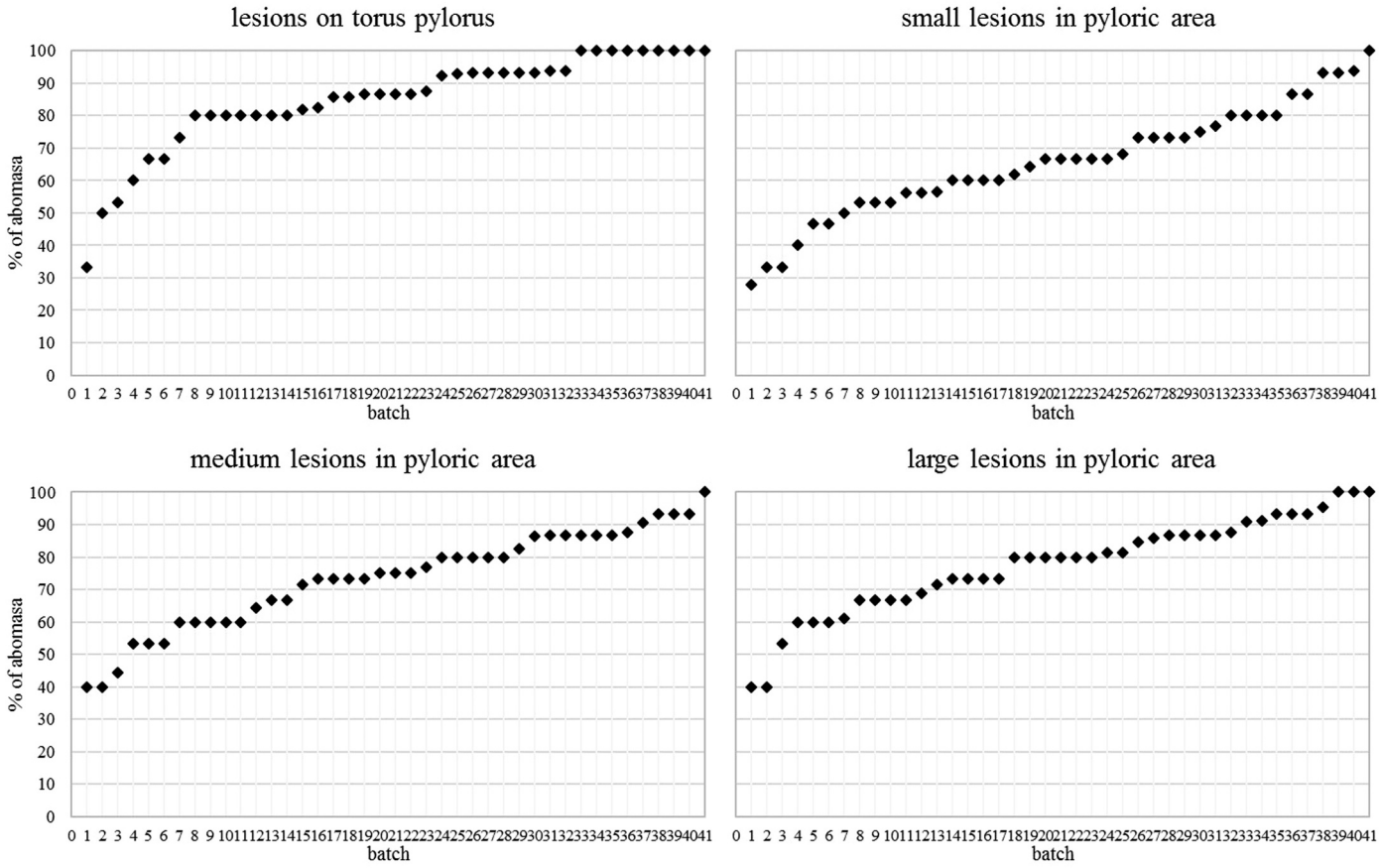

Fig. 2. Prevalence of abomasa having lesions on torus pylorus and small-sized, medium-sized, and large-sized lesions in the pyloric area at batch level ($n = 41$) in increasing order (1 ◆ corresponds to 1 batch).

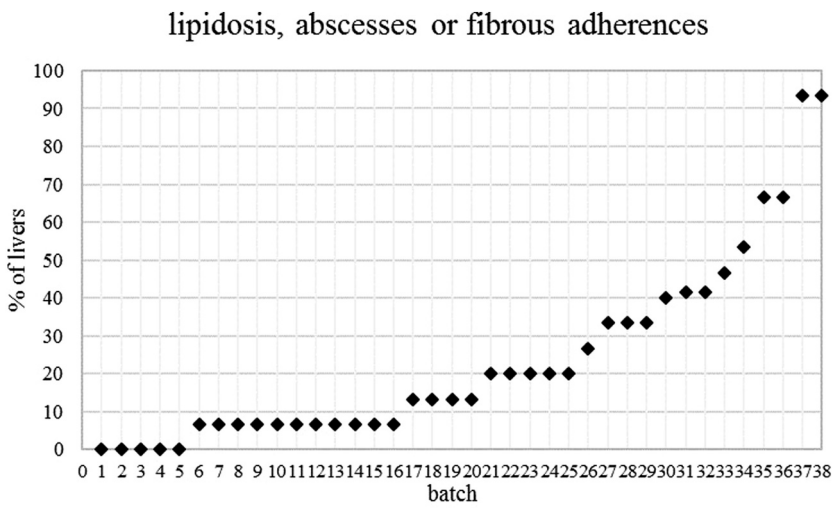

Fig. 3. Prevalence of livers with some hepatic diseases (lipidosis, abscesses, or fibrous adherences) at batch level ($n = 38$) in increasing order (1 ◆ corresponds to 1 batch).

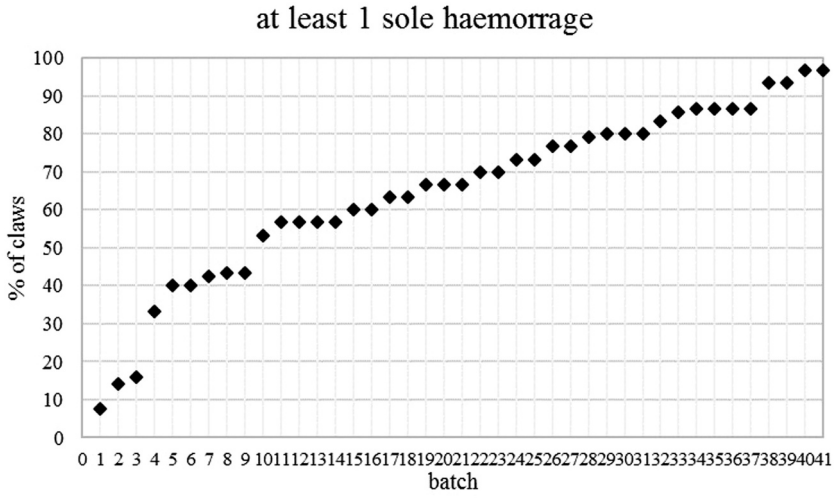

Fig. 4. Prevalence of claws with at least 1 sole hemorrhage at batch level ($n = 41$) in increasing order (1 ◆ corresponds to 1 batch).

abomasal wall (Brscic et al., 2011; Webb et al., 2013; Berends et al., 2014). The outcomes of the current study seem to support the latter hypothesis, because the provision of large amounts of SF increased the prevalence of both well- and fully developed rumens and large-sized lesions in the pyloric area, and these variables were highly associated to each other. However, the wide batch-variability of the incidence of abomasal ulcers recommends a further accurate investigation of the potential predisposing factors on the farms of origin.

Few data are available regarding the occurrence of some hepatic diseases in veal calves and they are confined specifically to liver abscesses as one of the primary cattle liver abnormalities (McKeith et al., 2012). In this study, an average of 24% of the total livers inspected per batch showed signs of some hepatic diseases but a large batch-variation was observed. In comparable intensive production systems where veal or rosé calves were fed pelleted diets based on high-starch concentrates and low amount of straw, incidences of liver abscesses of 11% and 16% were registered by Kjeldsen et al. (2002) and Vestergaard et al. (2013), respectively. Diets high in readily-fermentable carbohydrates and low in roughage make calves prone to develop ruminal acidosis and ruminitis, which might allow the translocation of bacteria and endotoxins across the ruminal epithelium to the liver inducing an inflammatory response and subsequent liver abscesses formation (Jørgensen et al., 2007; Vestergaard et al., 2013; Amachawadi and Nagaraja, 2016; Khiaosa-ard and Zebeli, 2018). However, no associations between the incidence of liver diseases and any rumen mucosa alterations were found in the current study, suggesting further researches on other possible risk factors on farm.

Regarding claw disorders, there are no direct information in literature on veal calves, but several studies on dairy cows suggested that high concentrate diets can predispose cows to sole hemorrhages on the claw (Bergsten, 2003; Sogstad et al., 2007; Alvergnas et al., 2019). The high prevalence of feet having 1 or more sole hemorrhages recorded on calves in this study might reflect earlier episodes of laminitis that is defined as a diffuse non-infectious inflammation of the laminae (corium), characterized by hyperemia and capillary lesions with a degenerative effect on the keratinization process (Bergsten and Frank, 1996; Lischer and Ossent, 2002; Bergsten, 2003). Although laminitis is a disorder of multifactorial etiology (*i.e.* metabolic, digestive, hormonal, mechanical, traumatic factors), results of this study led to consider the feeding management as a relevant predisposing factor. Ruminal acidotic conditions resulting from diets rich in highly fermentable carbohydrates have several physiological implications, among which the laminitis (Plaizier et al., 2012; Alvergnas et al., 2019). Specifically, ruminal acidosis is characterized by an excessive concentration of fatty acids, of

Table 2
Correlations among specific disorders detected on rumen, abomasa, liver, and claws belonging to 41 batches of veal calves during a *post-mortem* inspection carried out at the slaughterhouse.

	Rumens						Abomasa					Livers	Claw
	Moderate-developed	Well-developed	Fully-developed	Hyperkeratosis	Plaques	Redness	Lesion on torus pylorus	Lesion in pyloric area	Small lesion	Medium lesion	Large lesion	Lipidosis/abscess	Sole hemorrhages
Rumens													
Low-developed	−0.09 ns	−0.47 **	−0.10 ns	−0.56 ***	0.02 ns	−0.46 **	−0.09 ns	−0.15 ns	−0.12 ns	0.10 ns	−0.12 ns	−0.19 ns	−0.19 ns
Moderate-developed		−0.74 ***	−0.48 **	−0.06 ns	−0.08 ns	−0.01 ns	0.28 †	−0.17 ns	0.08 ns	−0.15 ns	−0.42 **	0.21 ns	−0.27 †
Well-developed			0.43 **	0.41 **	0.08 ns	0.27 †	−0.12 ns	0.31 *	−0.05 ns	0.17 ns	0.51 ***	0.02 ns	0.36 *
Fully-developed				0.21 ns	−0.04 ns	0.21 ns	0.12 ns	0.22 ns	0.28 †	0.33 *	0.45 **	−0.05 ns	0.23 ns
Hyperkeratosis					0.07 ns	0.29 †	0.15 ns	0.29 †	0.10 ns	0.17 ns	0.23 ns	−0.07 ns	0.30 †
Plaques						−0.12 ns	0.39 *	−0.12 ns	−0.08 ns	0.04 ns	0.09 ns	0.07 ns	−0.34 *
Redness							0.23 ns	−0.05 ns	0.08 ns	0.06 ns	0.32 *	−0.28 †	0.30 †
Abomasa													
Lesion on torus pylorus								−0.06 ns	−0.03 ns	−0.11 ns	0.13 ns	−0.00 ns	−0.13 ns
Lesion in pyloric area									0.51 ***	0.47 **	0.40 *	0.07 ns	0.28 †
Small lesion										0.40 *	0.28 †	−0.20 ns	0.30 †
Medium lesion											0.34 *	0.06 ns	0.04 ns
Large lesion												0.02 ns	0.28 †
Livers													
Lipidosis/abscess													−0.33 *

ns $P > 0.10$; † $P < 0.10$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

lactic acid in particular, which causes the drop in rumen pH, and this condition leads to the production of some metabolites (endotoxin and/or inflammation products like histamine) that are absorbed and transported in the bloodstream to the claw tissue. These substances could directly or indirectly affect the vascularization of the claws, leading to laminitic conditions (Plaizier et al., 2012; Alvergnas et al., 2019). These assumptions were supported by the outcomes of Spearman's rank correlations that showed indeed a tendency for a positive association between claw sole hemorrhages and both rumen mucosa redness and hyperkeratosis at batch level.

5. Conclusions

The outcomes of this study suggested that the current provision of a large amounts of solid feed rich in starch sources in the feeding plans of veal calves has a negative impact on the occurrence of rumen plaques and hyperkeratosis as well as on abomasal lesions and claw sole hemorrhages, although it cannot be excluded diverse stressors other than the feeding plans. The prevalence of hepatic diseases observed at the slaughterhouse was also considerable but its wide batch-variability stimulates further detailed investigations. Positive correlations among these disorders detected on different organs led to consider the composition of solid feeding as one of their major causes. These findings suggest that the actual SF quantity provided to calves and its composition made of a dominant portion of amylaceous sources such as corn grain and of a limited amount of coarse roughage should be reconsidered in order to further improve veal calves' welfare.

Declaration of Competing Interest

None.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rvsc.2020.10.022.

References

Alvergnas, M., Strabel, T., Rzewuska, K., Sell-Kubiak, E., 2019. Claw disorders in dairy cattle: effects on production, welfare and farm economics with possible prevention methods. Livest. Sci. 222, 54–64.
Amachawadi, R.G., Nagaraja, T.G., 2016. Liver abscesses in cattle: a review of incidence in Holsteins and of bacteriology and vaccine approaches to control in feedlot cattle. J. Anim. Sci. 94, 620–1632.
Berends, H., van Reenen, C.G., Stockhofe-Zurwieden, N., Gerrits, W.J.J., 2012. Effects of early rumen development and solid feed composition on growth performance and abomasal health in veal calves. J. Dairy Sci. 95, 3190–3199.
Berends, H., Van den Borne, J.J.G.C., Mollenhorst, H., Van Reenen, C.G., Bokkers, E.A.M., Gerrits, W.J.J., 2014. Utilization of roughages and concentrates relative to that of milk replacer increases strongly with age in veal calves. J. Dairy Sci. 97, 6475–6484.
Bergsten, C., 2003. Causes, risk factors, and prevention of laminitis and related claw lesions. Acta Vet. Scand. 98, 157–166.
Bergsten, C., Frank, B., 1996. Sole haemorrhages in tied primiparous cows as an indicator of periparturient laminitis: effects of diet, flooring and season. Acta Vet. Scand. 37, 383–394.
Brscic, M., Heutinck, L.F.M., Wolthuis-Fillerup, M., Stockhofe, N., Engel, B., Visser, E.K., Gottardo, F., Bokkers, E.A.M., Lensink, B.J., Cozzi, G., Van Reenen, C.G., 2011. Prevalence of gastrointestinal disorders recorded at postmortem inspection in white veal calves and associated risk factors. J. Dairy Sci. 94, 853–863.
Brscic, M., Prevedello, P., Stefani, A.L., Cozzi, G., Gottardo, F., 2014. Effects of the provision of solid feeds enriched with protein or nonprotein nitrogen on veal calf growth, welfare, and slaughter performance. J. Dairy Sci. 97, 4649–4657.
Brscic, M., Magrin, L., Prevedello, P., Pezzuolo, A., Gottardo, F., Sartori, L., Cozzi, G., 2019. Effect of the number of daily distributions of solid feed on veal calves' health status, behaviour, and alterations of rumen and abomasa. Ital. J. Anim. Sci. 18, 226–235.
Bus, J.D., Stockhofe, N., Webb, L.E., 2019. Invited review: Abomasal damage in veal calves. J. Dairy Sci. 102, 943–960.
Cozzi, G., Brscic, M., Gottardo, F., 2009. Main critical factors affecting the welfare of beef cattle and veal calves raised under intensive rearing systems in Italy: a review. Ital. J. Anim. Sci. 8, 67–80.
Egger-Danner, C., Nielsen, P., Fiedler, A., Müller, K., Fjeldaas, T., Döpfer, D., Döpfer, V., Bergsten, C., Cramer, G., Christen, A.M., Stock, K.F., Thomas, G., Holzhauer, M., Steiner, A., Clarke, J., Capion, N., Charfeddine, N., Pryce, E., Oakes, E., Burgstaller, J., Heringstad, B., Ødegård, C., Koflr, J., 2015. ICAR Claw Health Atlas, First ed. ICAR 1–46.
European Council, 2008. Directive 2008/119/EC laying down minimum standards for the protection of calves. Off. J. Eur. Union 20, 149–155, 18 December 2008, No. L 10/7.
Jørgensen, K.F., Sehested, J., Vestergaard, M., 2007. Effect of starch level and straw intake on animal performance, rumen wall characteristics and liver abscesses in intensively fed Friesian bulls. Animal. 1, 797–803.
Khiaosa-ard, R., Zebeli, Q., 2018. Diet-induced inflammation: from gut to metabolic organs and the consequences for the health and longevity of ruminants. Res. Vet. Sci. 120, 17–27.
Kjeldsen, A.M., Bossen, D., Fisker, I., 2002. Liver abscesses in veal calves. In: Danish Cattle, Danish Agricultural Advisory Service, Skejby. Report no. 96, 75pp.
Lischer, C.J., Ossent, P., 2002. Pathogenesis of sole lesions attributed to laminitis in cattle. In: Shearer, J.K. (Ed.), Proceedings of the 12th International Symposium on Lameness in Ruminants, Orlando, Florida, pp. 82–89. January 9–13.
Magrin, L., Brscic, M., Armato, L., Contiero, B., Cozzi, G., Gottardo, F., 2018. An overview of claw disorders at slaughter in finishing beef cattle reared in intensive indoor systems through a cross-sectional study. Prev. Vet. Med. 161, 83–89.
Mattiello, S., Canali, E., Ferrante, V., Caniatti, M., Gottardo, F., Cozzi, G., Andrighetto, I., Verga, M., 2002. The provision of solid feeds to veal calves: II. Behavior, physiology and abomasal damage. J. Anim. Sci. 80, 367–375.
McKeith, R.O., Gray, G.D., Hale, D.S., Kerth, C.R., Griffi, D.B., Savell, J.W., Raines, C.R., Belk, K.E., Woerner, D.R., Tatum, J.D., Igo, J.L., VanOverbeke, D.L., Mafi, G.G., Lawrence, T.E., Delmore, R.J., Christensen, L.M., Shackleford, S.D., King, D.A., Wheeler, T.L., Meadows, L.R., O'Connor, M.E., 2012. National beef quality audit-2011: harvest-flor assessments of targeted characteristics that affect quality and value of cattle, carcasses, and byproducts. J. Anim. Sci. 90, 5135–5142.
Plaizier, J.C., Khafiour, E., Li, S., Gozho, G.N., Krause, D.O., 2012. Subacute ruminal acidosis (SARA), endotoxins and health consequences. Anim. Feed Sci. Technol. 172, 9–21.
Sogstad, Å.M., Østerås, O., Fjeldaas, T., Nafstad, O., 2007. Bovine claw and limb disorders related to culling and carcass characteristics. Livest. Sci. 106, 87–95.
Suárez, B.J., Van Reenen, C.G., Gerrits, W.J., Stockhofe, N., van Vuuren, A.M., Dijkstra, J., 2006a. Effects of supplementing concentrates differing in carbohydrate composition in veal calf diets: II. Rumen development. J. Dairy Sci. 89, 4376–4386.
Suárez, B.J., Van Reenen, C.G., Beldman, G., van Delen, J., Dijkstra, J., Gerrits, W.J.J., 2006b. Effects of supplementing concentrates differing in carbohydrate composition in veal calf diets: I. Animal performance and rumen fermentation characteristics. J. Dairy Sci. 89, 4365–4375.
Suàrez, B.J., Van Reenen, C.G., Stockhofe, N., Dijkstra, J., Gerrits, W.J.J., 2007. Effect of roughage source and roughage to concentrate ratio on animal performance and rumen development in veal calves. J. Dairy Sci. 90, 2390–2403.
Suarez-Mena, F.X., Heinrichs, A.J., Jones, C.M., Hill, T.M., Quigley, J.D., 2016. Straw particle size in calf starters: effects on digestive system development and rumen fermentation. J. Dairy Sci. 99, 341–353.
Vestergaard, M., Jarltoft, T.C., Kristensen, N.B., Børsting, C.F., 2013. Effects of rumen-escape starch and coarseness of ingredients in pelleted concentrates on performance and rumen wall characteristics of rosé veal calves. Animal. 7, 1298–1306.
Webb, L.E., Bokkers, E.A.M., Heutinck, L.F.M., Engel, B., Buist, W.G., Rodenburg, T.B., Stockhofe-Zurwieden, N., van Reenen, C.G., 2013. Effects of roughage source, amount, and particle size on behavior and gastrointestinal health of veal calves. J. Dairy Sci. 96, 7765–7776.
Webb, L.E., van Reenen, C.G., Berends, H., Engel, B., de Boer, I.J.M., Gerrits, W.J.J., Bokkers, E.A.M., 2015. The role of solid feed amount and composition and of milk replacer supply in veal calf welfare. J. Dairy Sci. 98, 5467–5481.