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Association between gastrointestinal tract, claw disorders, *on-farm* mortality and feeding management in veal calves

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ABSTRACT

This study analysed potential associations between the prevalence of rumen, abomasum, liver, and claw disorders detected in 26 batches of Holstein veal calves through a *post-mortem* inspection at the slaughterhouse, and *on-farm* mortality and feeding management data. Organs of 15–16 calves per batch (16.5 rumens, 15.9 abomasa, 15.1 livers, and 31.1 claws) were inspected by 3 veterinarians in the slaughter-line. 'Batch' refers to group of calves belonging to the same farm and slaughter group. Hyperkeratosis and plaques were detected in over 60% of rumens per batch, and some cases, in all rumens. More than 85% of abomasa showed ulcerations. Sole haemorrhages were detected in 64 to 97% of claws. During fattening, calves received on average 312 kg of milk-replacer (MR) and 162 kg of solid feed (SF), composed mainly of corn grain (85–93% as-fed basis). Rumens with hyperkeratosis were positively correlated to the percentage of corn grain. Abomasa with large-sized-lesions in the pyloric area were positively correlated to the SF amount. Ulcerated abomasa were positively correlated to calves' mortality reported by farmers. Cluster analysis identified 3 feeding plans. The first, based on MR administration and moderate SF amount, produced lighter carcasses and low-developed rumens, but reduced the prevalence of rumen hyperkeratosis and sole haemorrhages; the other two, more 'aggressive' by increasing the amount of SF or both SF and MR, produced heavier carcasses but worsened rumen and claw conditions. This study suggests the existence of different feeding practices used by veal producers that should be reviewed to improve calves' welfare.

HIGHLIGHTS

- Feeding plans based on moderate amount of solid feed together with the liquid diet reduce the prevalence of rumen alterations and sole haemorrhages
- The provision of greater amount of high-grain solid feed throughout the fattening rises the prevalence of rumen hyperkeratosis and sole haemorrhages
- None of the feeding plans were capable of decreasing the occurrence of abomasal ulcerations, which were positively associated with *on-farm* mortality

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Veal calf; feeding management; rumen alteration; abomasal lesion; sole haemorrhage

Introduction

The European veal production system operates under rather standardised managerial principles as regards calves' feeding plans and housing solutions (Cozzi et al. 2009). The compliance with the Directive 08/119/EC for calf protection (European Council 2008) had made mandatory the provision of a minimum daily ration of fibrous feeds in addition to the liquid milk-replacer (MR) as well as the group-housing system for calves. These obligations have satisfied several behavioural and physiological needs of calves (Berends et al. 2012; Webb et al. 2015), but there are still concerns about specific factors, related to the feeding program in particular, that can impair calves' health and welfare. The current level of inclusion of solid feed (SF) in the veal calf's diets has by far been increased above the recommended amount of 50–250 g/calf/d set by the Directive (Brscic et al. 2014; Berends et al. 2015; Brscic et al. 2019), and it mainly consists of starch-rich mixtures of corn (more than 50% as-fed basis) and other cereal grains and legume seeds. The administration of this type of SF in large amounts was reported to be a relevant risk for the development of rumen plaques and rumen papillae hyperkeratinisation, and abomasal lesions (Brscic et al. 2011, Berends et al. 2014; Brscic et al. 2019), and its role in the

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development of specific liver and claw disorders is still poorly understood. The present study aimed therefore at assessing the potential associations between the prevalence of specific rumen, abomasum, liver, and claw disorders detected in several batches of veal calves through a *post-mortem* inspection at the slaughterhouse and calves' mortality and feeding management data obtained by farmer interview.

Material and methods

A *post-mortem* inspection of veal calves' rumen, abomasum, liver, and claws was carried out in a commercial cattle slaughterhouse located in Northern Italy during 9 inspection days. The inspected calves belonged to 26 different batches of Holstein male calves randomly chosen from those regularly arriving at the abattoir. The term 'batch' refers to a specific group of calves of the same breed, belonging to the same slaughter group (loading, transport, unloading, lairage time and slaughtering phases) that came from the same farm (Magrin et al. 2020). The protocol of the study aimed at inspecting rumen, abomasum, liver, and claws of the hind limbs of the first 15–16 calves of each batch by 3 trained veterinarians located in different areas of the slaughter-line. A prerequisite of the assessment was to use a set of quick measures (1 min/organ) that could be applied without interfering with the regular working of the slaughter-line (Magrin et al. 2018).

Organs' inspection

The organs' assessments performed *post-mortem* in this study did not require the approval of the animal welfare committee.

Rumens and abomasa were examined in the tripery after their opening and rinsing in tap water. Rumen mucosa development was graded according to the 4-point scale described in detail by Brscic et al. (2011). The presence of hyperkeratosis of the rumen papillae, plaques on the rumen wall, and redness of rumen mucosa was recorded as binary measures (yes/no) whenever they occurred. The same veterinarian also inspected the abomasa evaluating 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 area. Lesions in the pyloric area 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 $>1\,cm^2$ (Brscic et al. 2011, Brscic et al. 2019).

Livers' assessment was performed in the dispatch area by a second veterinarian recording the occurrence of any kind of liver disease (lipidosis, abscesses, or fibrous adherences) as binary (yes/no).

Claws' collection and inspection are described in detail by Magrin et al. (2018). Hocks and claws of the hind limbs were collected, and the trimming of the sole horn with an electric grinder was performed by a third veterinarian who then evaluated the specific claw disorders. The presence of at least one sole haemorrhage was recorded as binary (yes/no).

On-farm *mortality and feeding management data*

At the end of each inspection day, the slaughterhouse personnel provided information about the farm of origin of each inspected batch of calves. Individual carcass weights and days of fattening of inspected calves were obtained from the slaughterhouse records. The stockman of each inspected batch was then interviewed to collect information about calves' feeding management and mortality. Data about the total amount of MR powder and SF provided to calves during the fattening were recorded along with the percentage of skimmed milk powder in the MR, the percentage of corn grain included in the SF, the number of milk and solid meals' per week, and the time of SF distribution after the milk meal. The percentage of dead calves per cycle of each inspected batch was obtained from farm health sheets.

Statistical analysis

Batch was the experimental unit either for data recorded at slaughter inspection or for those obtained from farmers' interview and slaughter records. In particular, data from *post-mortem* inspection were expressed as percentages of organs affected by a given disorder over the total number of examined organs per batch. All the information regarding mortality, feeding management, days of fattening, and carcass weights were collected *a-posteriori* per each batch and considered as continuous variables. Preliminary descriptive statistics (mean, median, SD, minimum, and maximum) were calculated at batch level either on data recorded at slaughter inspection or on those obtained from farmers' interview and slaughter records using a Proc UNIVARIATE (SAS 9.3; SAS Institute Inc.). Regarding the normality and

Table 1. Descriptive statistics of rumen, abomasa, liver, and claw disorders detected in 26 batches of veal calves during a *post-mortem* inspection at slaughter.

	Mean	SD	Min	Max
Low rumen development, % rumens	11.9	13.4	0.00	60.0
Moderate rumen development, % rumens	42.6	17.2	6.67	73.3
Hyperkeratosis, % rumens	60.1	18.4	29.0	93.3
Plaques, % rumens	68.7	22.6	20.0	100
Redness of mucosa, % rumens	24.2	21.9	0.00	80.0
Abomasal lesions, % abomasa				
On torus pylorus	86.1	11.3	50.0	100
At least 1 in the pyloric area	91.9	9.13	61.1	100
Small lesion	62.1	13.7	27.8	93.8
Medium lesion	72.9	14.9	40.0	93.3
Large lesion	80.5	12.0	53.3	100
Hepatic diseases, % livers	17.3	13.0	6.67	41.7
Sole haemorrhages, % claws	64.1	25.9	7.50	96.7

homoscedasticity of the errors, the hypotheses of the linear model were graphically assessed on the studentized residuals.

The relationship between all variables was assessed at batch level using Spearman's rank correlation (PROC CORR of SAS 9.3) that allowed to evaluate possible redundant variables for the following k-means clustering approach. A k-means cluster analysis (PROC CLUSTER of SAS 9.3) was performed to group those batches of calves (each batch was treated as a single unit) progressively and iteratively based on their similarity in *post-mortem* inspection data and *on-farm* mortality and feeding management data. This approach aims to partition a dataset into k district, diverse clusters, so that the variables within each cluster are similar to each other. It was run with 2, 3, 4, and 5 clusters, replacing the missing values (7) with their nearest neighbour. The most appropriate group model was chosen considering at least 4 batches of calves per each cluster and reaching the higher reduction of intraclass variation (in percentage terms) explained by the model. Leave one out cross-validation of the clustering criterion (PROC DISCRIM of SAS 9.3) was conducted, and the confusion matrix was generated. Reliability indexes (sensitivity, specificity, accuracy, precision, and Matthews correlation coefficient) were calculated as in Bisutti et al. (2019). A factorial discriminant analysis was used to compute 2 main canonical variables (F1 and F2) for plotting the clusters and to calculate the total-sample correlations between canonical and original variables. The loadings of the 26 batches of veal calves were illustrated in the F1 $\times$ F2 Euclidean space.

A one-way ANOVA for normally distributed variables and a Kruskal–Wallis test for non-normally distributed ones were performed to test the clustering effect. The threshold level of statistical significance was set at $p < .05$.

Results

Descriptive statistics of the prevalence of disorders recorded at slaughter during *post-mortem* inspection on rumens, abomasa, livers, and claws of 26 different batches of veal calves are reported in Table 1. On average, 16.5 ± 3.8 rumens, 15.9 ± 2.4 abomasa, 15.1 ± 3.3 livers, and 31.1 ± 4.4 claws were inspected per batch. Almost 12% and 43% of inspected rumens per batch were low- and moderate-developed, respectively. Hyperkeratosis and plaques were detected in over 60% of inspected rumens per batch, and for some batches, in almost all rumens. Signs of redness of mucosa were recorded on average in 24% of rumens per batch, varying wildly among batches, from 0 to 80% of inspected rumens. More than 85% of inspected abomasa per batch showed lesions on torus pylorus and/or in the pyloric area. Of the total abomasa affected per batch in the pyloric area, 73% to 81% had medium-sized and large-sized ulcers, respectively. Some hepatic diseases were recorded on average in 17% of inspected livers per batch, affecting in some cases up to 42% of livers. Sole haemorrhages were detected on average in 64% of inspected claws per batch, and in some batches, the prevalence of affected claws was almost 100%.

Descriptive statistics about calves' mortality and feeding management collected *a-posteriori* through farmers' interview, and about fattening cycle duration and carcass weights gathered from slaughter records are shown in Table 2. The amount of MR provided to calves during the entire fattening was on average 312 kg, reaching up to 365 kg in some batches, and it was always delivered in 2 daily meals for the whole week. The percentage of skimmed milk powder in the MR varied from 18.5 to 55.0%. Calves of all farms always received the SF twice a day for the whole week, 30 to 120 min after the distribution of the MR. The total amount of SF delivered during the entire fattening was on average 162 kg, reaching up to 240 kg in some batches. Corn grain accounted for 85 to 93% of the complete SF formulation. Farmers reported an average mortality rate of 2.74%. The duration of the fattening cycle was on average 185 days. Calves reached an average carcass weight of 165 kg, which varied widely from 125 to 233 kg.

Results of the Spearman rank correlations between batch-level prevalence of specific disorders and information gathered *a-posteriori* from farmers' interview and slaughter records are reported in Table 3. Mean fattening days were not included in the cluster analysis being highly correlated to the MR and SF

Table 2. Descriptive statistics of data about feeding management and mortality obtained by farmer interview, and about duration of the fattening cycle and carcass weight gathered from slaughter records of 26 batches of veal calves inspected.

	Mean	SD	Min	Max
Feeding management				
Liquid milk-replacer diet				
Quantity of milk-replacer, kg/calf/cycle	312	29.9	258	365
Skimmed milk powder, %	32.1	18.5	0.00	55.0
Solid feed diet				
Quantity of solid feed, kg/calf/cycle	162	38.3	90.0	240
Corn grain, %	85.4	16.2	15.0	93.0
Time of solid feed distribution after milk-replacer, min	44.0	23.7	30.0	120
Mortality, % of calves	2.74	2.52	0.00	12.0
Fattening days[1]	185	16.7	154	213
Carcass weight, kg	165	26.6	125	233

[1]Variables not included in the subsequent cluster analysis.

quantities provided per cycle ($r = 0.70$ and 0.52, respectively; $p < .01$).

The clustering process identified 3 groups of batches (Table 4), which explained 70% of the total variance. The batches of calves belonging to Cluster 1 (C1) received the lowest amount of SF and had the lightest carcass weights at the slaughter. These calves showed a higher prevalence of low-developed rumens, and a lower prevalence of hyperkeratosis and redness of mucosa, and claw sole haemorrhages than calves of Clusters 2 (C2) and Cluster 3 (C3). The batches of calves belonging to C2 reached a higher carcass weights than C1 due to the higher amount of SF provided throughout the cycle. At slaughter inspection, C2 calves had a low prevalence of low-developed rumens and high prevalence of rumen hyperkeratosis and redness of mucosa, and claw sole haemorrhages than C1 calves. Calves of C3 were fed the highest amounts of both MR and SF, having similar prevalence of gastrointestinal, liver, and claw disorders than C2 calves. The prevalence of plaques on the rumen wall and of abomasal lesions was similar among all clusters (Table 4).

The outcomes of cluster analysis cross-validation showed satisfactory results with a low percentage (25%) of misclassified observations in C3 only. Sensitivity, specificity, accuracy, precision, and Matthews correlation coefficient were always above 92% for C1 and all equal to 100% for C2. Cluster 3 showed reliability indexes always above 96%, except for sensitivity and Matthews correlation coefficient values that were 75% and 83%, respectively.

The factorial discriminant analysis showed a first canonical variable (F1) accounting for 52% of the total variability and a second canonical variable (F2) accounting for the remaining 48% (Figure 1(a)). The F1 was mainly correlated with MR quantity provided per cycle (0.73) and with the mean carcass weight (0.64). The F2 was mainly correlated with the prevalence of rumens with hyperkeratosis (0.66), and of those with redness of mucosa (0.59), with the prevalence of claws with at least 1 sole haemorrhage (0.61), and with SF quantity provided per cycle (0.64). Canonical coefficients of the 26 batches of veal calves were plotted on the factors space and 95% confidence ellipses for the 3 clusters were displayed in Figure 1(b).

Discussion

Despite being similar for breed and gender, the 26 batches of veal calves inspected in the study were allotted to 3 different clusters as evidence of the potential existence of different feeding practices used by the veal producers to reach the suitable finishing status of the animals required by the market, with a different impact on calves' health status. The plot of the loadings of the batches of calves in the factors space (Figure 1(b)) allows us to describe the 3 clusters according to their different feeding plans and how these feeding strategies affected the prevalence of rumen wall disorders, abomasal lesions, and claw health. Farms of C1 used a feeding program with a moderate amount of SF in addition to the liquid diet, as compared to C2 and C3 farms. This feeding strategy that produced lighter carcasses, limited rumen development but reduced the occurrence of lesions in the rumen wall and in the claw sole. With regards to the abomasal damage, the batch-prevance of abomasa with lesion on torus pylorus or with at least one lesion in the pyloric area remained very high (more than 87%), even though there was a tendency to lower the prevalence of abomasa having small- and large-sized lesions. Farms of C2 and those of C3, in particular, adopted more 'aggressive' feeding programs, especially regarding the amount of SF. If on one side resulted in heavier carcass weight, on the other it worsened the frequency of gastrointestinal and claw disorders.

Table 3. Correlations between specific disorders detected on rumen, abomasa, liver, and claws detected in 26 batches of veal calves during a *post-mortem* inspection at slaughter, and information gathered *a-posteriori* from farmers' interview and slaughter records.

	quantity of MR, kg/calf	skimmed milk powder, % MR	quantity of SF, kg/calf	corn grain, % SF	time of SF distribution after MR, min	carcass weight, kg	fattening days	mortality, % calves
Rumens								
Low-developed	−0.06	0.00	−0.37	−0.25	−0.04	−0.30	0.12	−0.01
	ns	ns	†	ns	ns	ns	ns	ns
Moderate-developed	0.00	0.06	−0.34	−0.18	0.06	−0.43	0.20	0.26
	ns	ns	†	ns	ns	*	ns	ns
Hyperkeratosis	−0.33	0.08	0.22	0.46	0.01	0.47	−0.30	−0.36
	†	ns	ns	*	ns	*	ns	†
Plaques	0.26	0.05	0.36	−0.23	0.29	0.10	0.22	0.14
	ns	ns	†	ns	ns	ns	ns	ns
Redness of mucosa	0.17	−0.03	0.65	0.17	0.23	0.18	0.16	−0.13
	ns	ns	***	ns	ns	ns	ns	ns
Abomasa								
Lesion on torus pylorus	0.24	0.19	0.27	0.16	0.28	0.07	0.29	0.04
	ns	ns	ns	ns	ns	ns	ns	ns
Lesion in pyloric area	0.01	−0.50	0.03	−0.13	−0.20	−0.10	0.22	0.41
	ns	*	ns	ns	ns	ns	ns	*
Small lesion	0.14	−0.25	0.17	−0.10	0.31	−0.12	0.21	0.27
	ns	ns	ns	ns	ns	ns	ns	ns
Medium lesion	0.31	−0.47	0.26	−0.02	0.01	−0.23	0.45	0.31
	ns	*	ns	ns	ns	ns	*	ns
Large lesion	0.06	−0.32	0.39	−0.11	0.11	0.06	0.06	−0.09
	ns	ns	*	ns	ns	ns	ns	ns
Livers								
Hepatic disease	0.14	−0.32	−0.16	−0.37	−0.40	−0.10	0.10	0.24
	ns	ns	ns	†	*	ns	ns	ns
Claws								
Sole haemorrhages	0.00	−0.10	0.10	0.00	−0.03	0.32	0.14	−0.15
	ns	ns	ns	ns	ns	ns	ns	ns

MR: liquid milk-replacer; SF: solid feed.
ns $p > .10$; † $p < .10$; *$p < .05$; ***$p < .001$.

Table 4. Clusters of veal calves' batches based on *post-mortem* inspection data and information collected *a-posteriori* about calves' mortality, feeding management, fattening cycle duration, and carcass weights.

	Cluster			
	1	2	3	Significance
Batches, n	13	9	4	
Feeding management				
Quantity of MR[1], kg/calf/cycle	309.0 ± 6.0^{b}	294.1 ± 7.2^{b}	358.8 ± 11^{a}	***
Skimmed milk powder[2], % MR	30.2 ± 18	28.1 ± 20	47.5 ± 2.9	ns
Quantity of SF[1], kg/calf/cycle	139.1 ± 7.2^{c}	172.5 ± 9.1^{b}	218.8 ± 13^{a}	***
Corn grain[2], % SF	86.7 ± 5.7	80.0 ± 25	91.6 ± 0.5	ns
Time of SF distribution after MR[2], min	35.0 ± 8.7	53.3 ± 25	52.5 ± 45	ns
Mortality[2], % calves	3.66 ± 3.2	1.97 ± 0.8	1.44 ± 1.0	ns
Fattening days[1,3]	185.8 ± 4.7	180.0 ± 5.6	193.0 ± 8.4	ns
Carcass weight[1], kg	152.7 ± 4.8^{b}	162.7 ± 6.2^{a}	210.6 ± 8.7^{a}	***
Slaughter inspection data				
Low development[2], % rumens	18.1 ± 16^{a}	4.40 ± 5.6^{b}	8.33 ± 10^{ab}	*
Moderate development[1], % rumens	50.4 ± 4.4^{x}	34.9 ± 5.3^{y}	34.6 ± 7.9^{y}	†
Hyperkeratosis[1], % rumens	48.6 ± 4.0^{b}	75.1 ± 4.8^{a}	63.8 ± 7.1^{ab}	**
Plaques[1], % rumens	73.7 ± 6.2	58.6 ± 7.4	75.0 ± 11	ns
Redness of mucosa[1], % rumens	11.7 ± 5.2^{b}	37.0 ± 6.2^{a}	36.0 ± 9.3^{a}	**
Lesion on torus pylorus[2], % abomasa	87.4 ± 10	81.8 ± 14	91.5 ± 6.7	ns
Lesion in pyloric area[2], % abomasa	90.6 ± 12	94.0 ± 5.5	91.8 ± 2.8	ns
Small lesion[1], % abomasa	57.0 ± 3.5^{y}	70.3 ± 4.2^{x}	59.9 ± 6.4^{xy}	†
Medium lesion[1], % abomasa	70.0 ± 4.2	75.6 ± 5.1	76.3 ± 7.6	ns
large lesion[1], % abomasa	75.3 ± 3.1^{y}	86.7 ± 3.7^{x}	83.4 ± 5.6^{xy}	†
Hepatic diseases[2], % livers	22.1 ± 14	9.61 ± 8.2	20.0 ± 11	ns
Sole haemorrhages[1], % claws	49.0 ± 5.9^{b}	82.1 ± 7.2^{a}	72.5 ± 11^{a}	**

MR: milk-replacer; SF: solid feed.
[a,b]Values within a row with different superscripts differ ($p < .05$).
[x,y]Values within a row with different superscripts differ ($p < .10$).
[1]One-way ANOVA (normally distributed data), data are reported as LSmeans ± SE.
[2]Kruskall Wallis test (non-parametric data), data are reported as means ± SD.
[3]Variables not included in the cluster analysis.
ns $p > .10$; † $p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

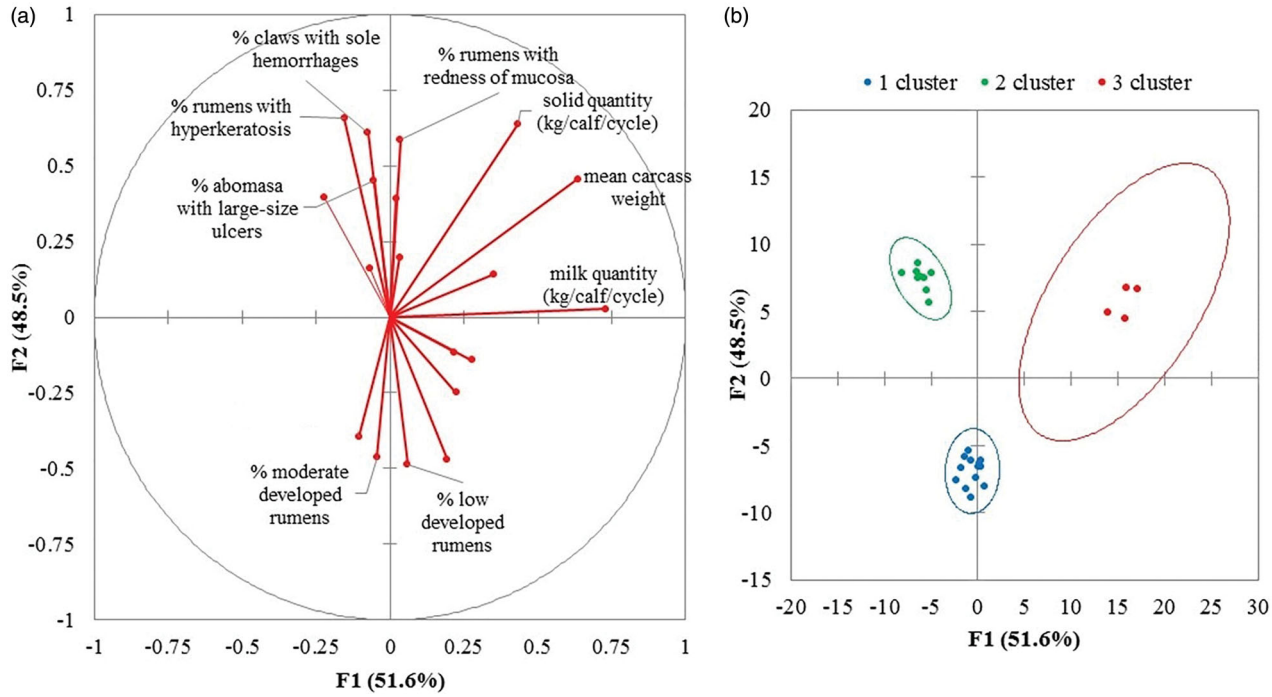

Figure 1. Canonical coefficients between original variables and the two main canonical variables (a) and loadings of the 26 veal calves' batches grouped by the cluster analysis according to the two canonical variables F2 and F1 (b).

Consistent with the literature (Berends et al. 2014; Brscic et al. 2019), the current study confirmed the use of corn grain as the main ingredient included in solid feed mixtures for veal calves. According to the information reported by the farmers of this study, corn grain ranged from 85 to 93% in the complete SF formulation, and the load of starch induced by the intake of this type of solids was certainly involved in the magnitude of calf's gastrointestinal and claw disorders observed *post-mortem*. According to previous researchers (Suárez et al. 2006; Brscic et al. 2011; 2019), the administration of great amounts of cereal grains to veal calves increases the risk of the development of rumen papillae hyperkeratinisation and plaques, likely as results of an excessive lactate/propionate concentration in the rumen (Bertram et al. 2009) and the concurrent lack of the abrasive effect of roughage sources (Suàrez et al. 2007). At this regard, a study by Prevedello et al. (2012) showed a higher occurrence of rumen papillae hyperkeratosis and rumen plaques in veal calves that received more than 170 kg of corn grain as SF during the fattening period compared to that of calves fed a similar amount of SF in which 20% (as-fed basis) of grain was replaced by a roughage source. In the present study, calves with rumen hyperkeratosis and redness of mucosa were observed in almost all batches, but the occurrence of these alterations was exacerbated in C2 and C3 where the total consumption of high-grain SF during the whole fattening was above 170 kg/calf.

Although there are several hypotheses on the aetiology of abomasal lesions in veal calves (Bus et al. 2019), also their high prevalence recorded in this study might be mainly related to the amount and the type of solid feeding provided to calves. Support to this assumption comes from previous studies showing that the consumption of large amounts of corn grain alone (Prevedello et al. 2012) or of 80:20 of concentrate and roughage diets (as-fed basis) (Berends et al. 2014) by veal calves worsen their abomasal damage. In the current research, all batches of calves inspected had indeed more than 86% of abomasa affected by ulcers on torus pylorus or in the pyloric region. However, according to clustering and Spearman rank correlations results, the occurrences and severity of abomasal ulcers seemed to be further aggravated as the amount of SF provided throughout the fattening increased (C2 and C3).

In literature, the provision of large volumes of MR was also considered one of the most suspicious causes for abomasal damage (Brscic et al. 2011; Berends et al., 2014), through overloading of the abomasum (Bähler et al. 2010) or decreasing of lumen pH (Ahmed et al. 2002; Marshall 2009). This study did not find any direct correlation between the amount of MR and the prevalence of abomasal lesions; however, we cannot

rule out a potential synergistic effect on the stomach overload between the amount of MR and the amount of high-grain SF, when provided one right after each other in 2 meals a day. The occurrence of abomasal lesions resulted associated with the type of MR used during the fattening period. In particular, the provision of MR with an increasing percentage of skimmed milk powder reduced the occurrence of ulcers in the pyloric area. The buffering and clotting capacity of MR change according to its composition, and they could affect overload and lumen pH of the abomasum. It was demonstrated indeed that more acidified or fast-clotting capacity MR could lead to a decreased abomasal pH (Constable et al. 2005; Vajda et al. 2007). These assumptions cannot be proven in this study, and therefore, further investigations are required to clarify the relation between MR type and abomasal damage.

Swiss (Bähler et al. 2012) and Belgian studies (Pardon et al. 2012) recorded mortality rates of 0.53 and 0.11% in veal calves due to the most severe perforating forms of abomasal ulcers. Although there was no information available about the cause of death events recorded during the fattening in this study, mortality rates observed at batch level were positively correlated with the average prevalence of nonfatal abomasal damage in the pyloric area (regardless of the size or number of lesions) recorded at slaughter.

So far, the scientific literature lacks specific information regarding the effects of feeding management on veal calf's claw health. Studies on more aged cattle found that high-concentrate diets are responsible for developing several laminitis-related claw disorders, such as sole ulcers, sole haemorrhages, and white line diseases, as sequelae to ruminal acidosis (Cook et al. 2004; van Amstel and Shearer 2006). High fermentable carbohydrates are degraded mainly into lactic acid by microorganisms, which cause a drop in ruminal pH, but their excessive overload causes bacteria to release endotoxins into the bloodstream (van Amstel and Shearer 2006). These metabolites reach the microcirculation of the corium rapidly and disrupt the vascular tissue of the claw leading to lesions, among which sole haemorrhages (Bergsten and Frank 1996; Alvergnas et al. 2019). In this study, no correlations were found between any specific feeding parameter and the prevalence of claw haemorrhages. However, it can be noticed that the prevalence of claw haemorrhages was significantly higher in the two clusters (C2 and C3) that grouped farms where calves received greater amounts of high starch SF throughout the fattening.

Conclusions

The clustering process of 26 batches of calves randomly inspected at the abattoir allowed to identify the existence of different feeding practices as well as their impact on the prevalence of calves gastrointestinal and claw disorders. One out of the 3 clusters (C1) obtained by the statistical analysis grouped farms using a feeding plan based on MR administration together with moderate provision of SF. These calves had lighter carcass weights and low-developed rumens, but they showed the lowest prevalence of rumen hyperkeratosis and redness of mucosa, and sole haemorrhages. Farms of the other 2 clusters produced heavier carcass weights increasing the amount of SF alone (C2) or in combination with MR (C3). Both feeding solutions worsened the prevalence of rumen alterations and sole haemorrhages. None of the identified feeding plans were capable of decreasing the occurrence of abomasal ulcerations, which were positively associated with mortality rates reported by farmers. Aiming at improving the veal calf welfare, the outcomes of the study should inspire a deep rethinking of their current feeding strategies, particularly addressing the attention on the composition of the solid portion of the diets, which appears absolutely far from the requirements of a young ruminant.

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