



Prevalence of gastrointestinal disorders recorded at postmortem inspection in white veal calves and associated risk factors

M. Brscic,^{*1} L. F. M. Heutinck,[†] M. Wolthuis-Fillerup,[†] N. Stockhofe,[‡] B. Engel,[§] E. K. Visser,[†] F. Gottardo,^{*} E. A. M. Bokkers,[#] B. J. Lensink,^{||} G. Cozzi,^{*} and C. G. Van Reenen[†]

^{*}Department of Animal Science, University of Padova, Viale dell'Università 16, 35020 Legnaro (PD), Italy

[†]Livestock Research, Wageningen UR, PO Box 65, 8200 AB Lelystad, the Netherlands

[‡]Central Veterinary Institute, Wageningen UR, PO Box 65, 8200 AB Lelystad, the Netherlands

[§]Biometris, Wageningen UR, PO Box 16, 6700 AH Wageningen, the Netherlands

[#]Animal Production Systems, Wageningen UR, PO Box 338, 6700 AH Wageningen, the Netherlands

^{||}Groupe ISA, 48 Boulevard Vauban, 59046 Lille Cedex, France

ABSTRACT

The study aimed at assessing the prevalence of poor rumen development, presence of rumen plaques, rumen papillae hyperkeratinization, and abomasal lesions in veal calves and to investigate risk factors for their occurrence at the farm level. Within a wide cross-sectional study, a sample of 170 veal farms representative of the European veal meat production systems was considered in the 3 major producing countries (99 in the Netherlands, 47 in France, and 24 in Italy). An average of 59 ± 10 (SD) rumens and abomasa belonging to calves from a single batch per farm were inspected at the abattoir by trained observers to assess the incidence of these gastrointestinal disorders. Potential risk factors for their occurrence related to farm management, housing, and to the feeding plan were obtained by a questionnaire submitted to the stockperson. Prevalence of poor rumen development (almost no papillae present), rumen plaques, and hyperkeratinization were 60.4, 31.4, and 6.1% of rumens, respectively, whereas abomasal lesions in the pyloric area were recorded in 74.1% of abomasa. Independent variables related to the feeding system confirmed to be the main risk factors for the occurrence of gastrointestinal disorders in veal calves. However, additional risk sources for each given problem were identified among housing and management variables. The provision of a low amount of solid feed (≤ 50 kg of dry matter/head per cycle) was a relevant risk for rumen underdevelopment. Rumen wall alterations (plaques and hyperkeratinization) and abomasal lesions were instead associated with the administration of large quantities of solids (151–300 kg of dry matter/head per cycle) in calves receiving milk replacer during the entire fattening cycle. Among the types of solid

feed, cereal grain acted as a preventive measure for low rumen development, whereas it was a risk factor for the occurrence of rumen plaques, papillae hyperkeratinization, and abomasal lesions. Some housing and management options adopted to improve veal calf welfare (i.e., higher space allowance and use of heating) were associated with lower risk for gastrointestinal disorders.

Key words: veal calf, gastrointestinal disorder, risk factor, welfare

INTRODUCTION

Worldwide, surplus male dairy calves are mainly used for veal production in specialized fattening units under intensive rearing conditions. Europe raises about 6 million calves per year for veal meat production and France, the Netherlands, and Italy are the main producing countries with a yearly production of 1.6, 1.2, and 0.9 million calves, respectively (EUROSTAT, 2007). Veal calf rearing systems are similar and very standardized across European Union countries. Nowadays, about 90% of the veal calves are housed in small pens and this housing system is mainly adopted in the Netherlands and Italy. The remaining farms house calves in larger groups of 30 to 60 animals and this housing solution is more frequent in France. Calves in small groups receive the milk replacer in individual buckets or in a common trough, whereas milk delivery in large groups is carried out through computer-controlled automatic milk delivery devices (AMD).

White veal calf production has been strongly criticized for poor animal welfare (Broom, 1991). To fulfill the physiological and behavioral demands of the calf, a specific European legislation for their protection set a ban on the individual cage and added the provision of solid feed in addition to the all-liquid diet (European Council, 1991, 1997; directives 91/629/EC and 97/2/EC). Relevant improvements of calf behavior and productive performance were achieved by the veal

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¹Corresponding author: marta.brscic@unipd.it

producers after the introduction of the group housing (Andrighetto et al., 1999; Babu et al., 2004). Moreover, the compulsory provision of increasing amounts of solid feed in addition to the all-liquid diet reduced abnormal oral behaviors (Mattiello et al., 2002; Di Giancamillo et al., 2003) and promoted rumen development (Morisse et al., 2000; Suárez et al., 2006a).

Despite these recent advances in veal production, calf welfare is still compromised by gastrointestinal disorders such as rumen mucosa alterations and abomasal lesions (Cozzi et al., 2002a; Bähler et al., 2010). Hyperkeratinization, also called rumen parakeratosis, is one of these mucosa alterations in calves. It occurs when epithelial squamous cells develop a hardened keratin layer due to the diet's inability to continuously remove degenerating epithelial cells (Hinders and Owen, 1965). Parakeratosis creates a physical barrier, restricting absorptive surface area and VFA absorption, reducing epithelial blood flow and rumen motility, and causing papillae degeneration and sloughing (Beharka et al., 1998). Parakeratosis is often associated with concentrate diets with small particle size and low abrasive value (Greenwood et al., 1997), increased VFA production, decreased rumen buffering capacity, and subsequently decreased rumen pH (Anderson et al., 1982). A calf with parakeratosis might, therefore, be more easily subject to potential (sub)acidosis, which is detrimental to its welfare. Next to rumen parakeratosis, rumen plaques can be found in a certain number of cases, which means that feed particles become impacted in between the ruminal papillae (Suárez et al., 2006b). Although the exact consequences on the calf's health are still unknown, it can be imagined that the absorptive capacity of the rumen papillae is limited in the case of rumen plaques, with a possible accumulation of VFA in the rumen. Poor rumen development and the impaired integrity of rumen and abomasal mucosa are supposed to cause economic losses by decreasing VFA absorption and feed conversion efficiency. Abomasal lesions may also develop into perforating ulcers, which are one of the main causes of death in veal calves (Bähler et al., 2010).

The etiology of most of these disorders has been mainly related to the calf feeding plan and feed characteristics, as summarized in Figure 1. According to Suárez et al. (2006b) the incidence of rumen plaques was increased by the provision of concentrate diets in addition to the milk replacer. Abomasal lesions were suggested to be associated with the overloading of the stomach by the high volumes of milk replacer delivered in a small number of meals per day (Bokkers and Koene, 2001; Veissier et al., 2001), as well as to the mechanical damage caused by roughage with high fiber content (Wiepkema et al., 1987; Morisse et al., 2000).

However, other predisposing factors or causative stressors have also been reported as potential risk factors for the occurrence of this problem. Recent findings from Bähler et al. (2010) suggested that the high prevalence of abomasal lesions may be associated with risk factors such as the frequency of cleaning or the type of ventilation (manual versus mechanical) of the housing facility.

No on-field investigations have assessed how the prevalence of gastrointestinal disorders, such as low rumen development, rumen mucosa alterations, and abomasal lesions are affected by the different management factors of modern veal calf husbandry. Therefore, a large-scale risk factor analysis is needed to quantify the prevalence of these disorders as well as to identify their predisposing causes. These 2 goals were targeted in this research through a cross-sectional study on a large sample of veal calf farms in Europe.

MATERIALS AND METHODS

Farm Sample

A comprehensive cross-sectional study was carried out, in part, within the Welfare Quality project, with the joint involvement of research groups from the 3 main white veal meat-producing countries in Europe (the Netherlands, France, and Italy). Across the 3 countries, a sample of 170 veal calf farms was chosen to reflect the proportions of the prevailing rearing systems operating in Europe in terms of type of housing (small or large groups) and milk delivery strategies (bucket, trough, automatic feeding device). The sample consisted of 148 farms housing calves in small groups (92 farms in the Netherlands, 35 farms in France, and 21 farms in Italy), equipped either with individual buckets or a common trough for milk delivery. The remaining 22 farms (7 farms in the Netherlands, 12 farms in France, and 3 farms in Italy) housed animals in large groups adopting AMD. The sample within each country considered farms located in the main regions where veal calves are reared and it was selected among farms belonging to integrators/owners willing to participate in the study. A single batch of calves was considered for each farm, and the tested batches were evenly distributed across all 4 seasons.

A randomized group of calves belonging to the same batch per farm was followed at the slaughterhouse at the end of the fattening cycle. Inspected calves were a random subsample of the batch slaughtered on 1 d, considering that 1 entire batch of veal calves could be slaughtered on several days and in different slaughterhouses.

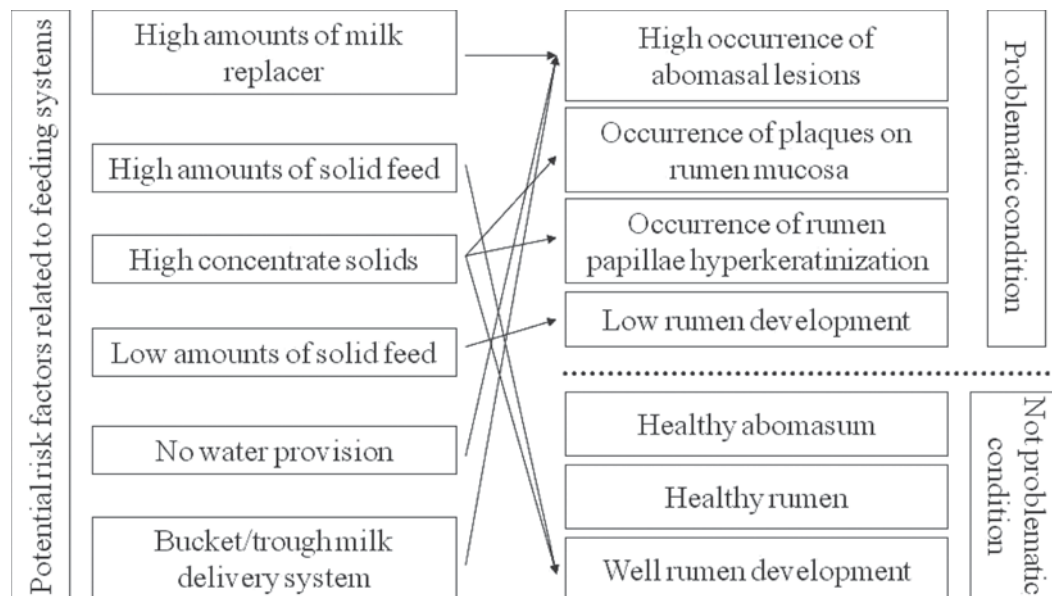


Figure 1. Schematic association between problematic or nonproblematic conditions of the digestive system of preweaned calves and effects related to the feeding strategies described in the literature (Wiepkema et al., 1987; Suárez et al., 2006b; Bähler et al., 2010) that were considered as the starting point for the hypothesis formulation and risk factors investigation in the present study.

Farm Environment and Management Data

Specific data regarding veal calves management, housing, and resources were gathered from an interview with the stockperson carried out on each farm. Data concerning the amounts of milk powder and prevalent type and quantity of solid feed delivered to calves throughout the fattening cycle were also provided by the farm manager. Duration of the rearing cycle was calculated as the difference between the week of slaughter and the week of arrival of the considered batch at the fattening unit.

Postmortem Inspection

At the abattoir, rumens and abomasa were examined by trained observers. Rumens were evaluated after opening and rinsing the organs in water. Rumen development was graded according to the following scale: score 1 = low-developed rumen having almost no papillae in the atrium and in the ventral and dorsal rumen; score 2 = rumen with moderate development having few papillae in the ventral and dorsal rumen and the rumen wall still visible; score 3 = well-developed rumen having a moderate number of papillae in the ventral and dorsal rumen, and rumen wall still visible but with numerous papillae in the atrium; and score 4 = fully developed rumen having numerous papillae in the ventral and dorsal rumen and with leaflet shaped papillae in the atrium.

The presence of plaques on the rumen wall or papillary epithelial hyperkeratinization were also recorded as a binary measure (yes/no). Rumen plaques consist of multiple patches on the mucosa with coalescing and adhering papillae covered by a sticky mass of feed, hair, and cell debris (Suárez et al., 2006b). Hyperkeratinization is characterized by papillae of thicker and harder texture. Visually, a hyperkeratinized epithelium looks like thickened and clustered papillae of a more rounded shape and its tissue is harder at physical contact.

Abomasa were evaluated in the last 15 cm of the pyloric area after opening it by a longitudinal cut. Presence of any kind of lesion at the mucosa (from erosion to open ulcer) was recorded as a binary measure at the pyloric area level and at the torus pylorus level. In accordance with the Welfare Quality Consortium protocol for veal calves (Welfare Quality Consortium, 2009), lesions in the pyloric area were counted from 0 = absence of lesions to a censored maximum of 4 = presence of 4 or more lesions within each of the following 3 size classes: 1 = lesions with a diameter $<0.5 \text{ cm}^2$, 2 = lesions with a size between 0.5 and 1 cm^2 , and 3 = lesions $>1 \text{ cm}^2$.

Data Processing and Statistical Analysis

Raw data gathered during postmortem inspection were expressed as percentages of organs with a given score (e.g., % rumens with score 1) or with a given problem (e.g., % abomasa with at least one lesion on

torus pylorus) over the total number of examined organs per farm. Moreover, a mean score was calculated per farm for both rumen development (mean of the scores attributed to all of the observed rumens) and abomasal lesions. To estimate the overall damage at the abomasums, a weighted lesions mean score was calculated as follows: [(number of lesions of size 1×1) + (number of lesions size 2×2) + (number of lesions size 3×3)] and it ranged from 0 for no lesions to a censored maximum of 24.

Data were statistically analyzed using GenStat (GenStat Committee, 2000), with farm as the experimental unit. Descriptive analyses were carried out on both response and explanatory variables. The response variable was one of the gastrointestinal disorders, whereas the explanatory variables were the potential risk factors obtained from the farmer interviews. The distribution of farms for each continuous risk factor (e.g., covariable, such as farm size or total amount of solid feed) included in the data set was displayed with the use of histograms. Subsequently, all covariables were transformed into class variables with a maximum of 4 classes. In the case of normally distributed covariables, thresholds for classes were chosen mainly according to location parameters such as lower quartile, median, and upper quartile. For nonnormally distributed covariables, thresholds were arbitrarily chosen in such a way that sufficient numbers of farms were present in each class. In the case of the covariable space allowance, a cut-off point equal to the minimum legal requirement of 1.8 m^2 (for calves with a body weight over 220 kg) could be conveniently applied. Thus, all potential risk factors were defined as discrete (class) variables. An overview of potential risk factors and corresponding levels is given in Table 1.

Risk factor analysis was carried out in a stepwise way. Each gastrointestinal disorder was analyzed separately and, consistent with a threshold suggested by Gillman et al. (2009), risk factor analysis was carried out only for problems that showed an average prevalence $>5\%$. When the inspection of the same organ (rumen and abomasum) considered different classes of evaluation (e.g., rumen development) and the calculation of a mean score (e.g., rumen development and abomasal lesions), risk analysis was performed on the response variable most correlated with the others for the same organ (Spearman rank correlations) or to the most relevant according to the literature. Poor rumen development (score 1) was included in the risk analysis because it is reported in the literature as associated with poor calf welfare and it was highly negatively correlated with well-developed rumen ($r = -0.80$, $P < 0.001$) and full rumen development ($r = -0.75$, $P <$

0.001), as well as with the mean score ($r = -0.99$, $P < 0.001$). Similarly, the percentage of abomasa with lesions in the pyloric area was highly positively correlated with the occurrence of lesions on the torus pylorus ($r = 0.62$, $P < 0.001$) and with the mean score ($r = 0.86$, $P < 0.001$). First, a univariate analysis was performed to study the effect on the dependent variable (Y) of each single factor separately using a generalized linear model. A 2-way ANOVA was then carried out to test for each pair of risk factors the significance of main effects and their interaction as well as to evaluate potential multicollinearity between risk factors through the inspection of the distribution of farms across combinations of risk factors, and the calculation of the variance inflation factor. High variance inflation factors for the dummy variables for discrete risk factors may point to multicollinearity, and partial confounding between risk factors was also automatically signaled. Following univariate analyses, only potential risk factors associated with the dependent variable ($P < 0.10$) were offered to bi- or multivariate models. Selection of risk factors was performed both by stepwise forward and stepwise backward selection. The criterion in backward and forward selection was the adjusted coefficient of determination (R^2). On the union of final models of both selection procedures, best subset selection was performed and significance tests for the effects of the selected risk factors were evaluated. Only risk factors that added significance ($P < 0.05$) to the model were retained. Risk factors that were (partially) confounded were not simultaneously maintained in the same model. No interactions between risk factors were considered.

For the analysis of prevalence (i.e., percentages per farm, or batch), logistic regression models were used, specifying a binomial variance function with a multiplicative dispersion parameter. Estimation was by quasi likelihood. The dispersion parameter in the variance was estimated from the data (McCullagh and Nelder, 1983). For each risk factor retained in a final model, odds ratios (OR) as well as 95% confidence intervals were obtained.

RESULTS

Farm Environment and Management Data

Reflecting the European veal calf production, the majority of farms included in the sample raised white veal in small groups with less than 16 calves/pen. Farms adopting large groups housed 26 to 50 calves/pen. Calves were predominantly males; 70% of the batches included less than 5% of females. Holstein was the prevalent breed of calves, and raised in 66.5% of the

farms. Pure dual-purpose breed calves were raised in 16.5% of the farms, whereas 17% of the farms fattened crosses between different dairy and beef breeds.

Considering the calf feeding plan, 3 levels were distinguished for the total amount of milk-replacer powder administered throughout the fattening cycle. Twenty percent of farms provided 280 to 330 kg of milk-replacer powder/calf during fattening; 51% of farms provided 331 to 380 kg/calf, and 29% of farms provided >380 kg/calf. Four levels were set for the total amount of solid feed delivered during the fattening cycle. Seventeen percent of farms provided a minimum amount of solid feed (≤ 50 kg of DM/calf); 23% provided 51 to 100 kg of DM/calf; 48% provided 101 to 150 kg of DM/calf, whereas the remaining 12% of farms provided 151

to 300 kg of DM/calf. Drinking water was provided ad libitum in 27% of farms, it was restricted in 54% of farms, and it was not available for calves at any stage of the rearing cycle in 19% of farms. Calves were slaughtered within 30 wk of fattening in the large majority of farms.

Prevalence of Gastrointestinal Disorders Recorded During Postmortem Inspection

On average, 59 ± 10 rumens and abomasa were inspected per farm. Regarding rumen development, a high prevalence of rumens with score 1 occurred, whereas the lowest percentage was scored 4 (Table 2). Rumen plaques were observed in 31% of inspected rumens and

Table 1. List of the tested potential risk factors for the occurrence of gastrointestinal disorders in veal calves

Item	Level
Potential risk factors related to production and housing system	
Housing system during fattening	Small (≤ 15 calves/pen) large group (> 15 calves/pen)
Farm size	≤ 300 301–600 601–1,200 $> 1,200$ total number of calves
Space allowance	≤ 1.8 > 1.8 m ² /calf
Type of floor	Slatted wooden floor concrete rubber or straw
Estimated luminosity of the barn	Light half-light dark
Presence of a specific sickbay	No yes
Environmental enrichment	No yes
Access to outdoor alley	No yes
Separated lying area	No yes partly (during a period or for part of calves)
Renovation of the barn	≤ 4 5–8 > 8 yr
Floor age	≤ 4 5–8 > 8 yr
Ventilation	Natural ventilation equipment both
Ridge (exit of air from roof)	No yes both
Manure	Under the calves scraped outside
Potential risk factors related to batch characteristics	
Quality of the batch at arrival	Good average bad
Season at housing	Spring summer autumn winter
Calves origin	National foreign more countries
Prevalent breed	Holstein dual-purpose breed crossbred
Percentage of females	0 1–5 $> 5\%$
Estimated weight at arrival	≤ 43 44–47 48–51 > 51 kg
Average hemoglobin level at 3 and 13 wk of rearing	≤ 5.7 5.8–6.2 > 6.2 mmol/L
Average number of calves/pen	≤ 6 7–9 10–15 > 15
Duration of fattening cycle	< 24 24–30 > 30 wk
Potential risk factors related to management and farmer experience	
Prophylaxis treatment	No yes
Use of individual baby boxes	No yes
Duration of baby boxes use	0 1–4 5–6 > 6 wk
Use of heating	No yes
Sorting/regrouping practice	No yes
Cleaning for all-in/all-out	Everything partial brush only no cleaning
Frequency of visits by technician	Weekly every 2 wk
Frequency of visits by veterinarian/fattening cycle	< 3 ≥ 3
Frequency of visits by farmer/d	≤ 2 > 2
Years of farmers' experience	≤ 5 6–15 16–25 > 25 yr
Years of adoption of the existing rearing system	≤ 2 3–10 > 10 yr
Potential risk factors related to feeding system	
Type of milk delivery system	Bucket trough automatic milk delivery device (AMD)
Total amount of milk-replacer powder	280–330 331–380 > 380 kg/calf per fattening cycle
Calves always received ≥ 14 liquid meals/wk	No yes
Prevalent type of solid feed	Maize silage pellets or mixture cereal grain ¹ treated maize ²
Total amount of solid feed	≤ 50 51–100 101–150 151–300 kg of DM/calf per fattening cycle
Water provision	Ad libitum limited no water

¹Barley or maize.

²Rolled or flaked maize.

Table 2. Descriptive statistics of data obtained during inspection carried out at the slaughterhouse on rumens and abomasa

Item	Mean	SD	Minimum	Maximum
Rumen development class, % of rumens				
1: Low	60.4	32.25	0.0	100.0
2: Moderate	28.6	20.71	0.0	83.3
3: Well	9.9	17.63	0.0	76.9
4: Full	1.1	4.54	0.0	50.0
Rumen development mean score ¹	1.5	0.52	1.0	3.43
Rumen plaques, % of rumens	31.3	26.16	0.0	100.0
Rumen hyperkeratinization, % of rumens	6.1	8.15	0.0	46.7
Abomasal lesion, % of abomasa				
Presence in pyloric region	74.1	13.20	31.7	100.0
Presence on torus	76.9	12.60	25.0	100.0
Abomasal lesions mean score ²	4.3	3.24	1.0	19.8

¹Score calculated as mean of the scores of all of the rumens observed per batch.

²Score weighed according to the number of lesions (from 0 to maximum of 4, censored) and size category (1 = <0.5 cm²; 2 = 0.5–1 cm²; 3 = >1 cm²) calculated as [(n of lesions size 1 × 1) + (n of lesions size 2 × 2) + (n of lesions size 3 × 3)].

the prevalence of rumens with papillae hyperkeratosis was 6.1% (Table 2).

More than 70% of the observed abomasa showed at least one lesion in the pyloric area and a similar result was found for the torus pylorus, reaching in some batches the maximum of 100% of the inspected organs (Table 2).

Risk Factor Analysis for Low Rumen Development

Because low rumen development (score 1) was described in the literature as a relevant problem for conventional veal calves, risk factor analysis was restricted to this variable. The first one-way logistic regression analysis showed that potential risk factors were linked particularly to feeding and housing factors (Table 3). The OR for poor rumen development was almost 15 in farms delivering low amounts of solid feed (≤ 50 kg of DM/calf per cycle) compared with those in which high quantities were supplied (151–300 kg of DM/calf per cycle). This variable alone explained almost 30% of the variance related to this problem. In farms where maize silage or pellets/mixture were used as the prevalent types of solid feed, compared with the use of cereal grain, the risk of low rumen development increased with an OR of 4.2 and 4.4, respectively. Considering the milk delivery system, the pairwise comparison between bucket and trough was not relevant, whereas the risk of low rumen development increased when these systems were compared with AMD. The absence of a dedicated sickbay in comparison with the presence of a sickbay, and the wooden slatted floor in comparison with the concrete floor also showed OR over 1 (Table 3).

Due to multicollinearity, the total amount and type of solid feed were not simultaneously included in the final multivariate regression model reported in Table

3. Looking at pairwise comparisons among the adopted classes for factors such as the total amount of milk powder and the water provision, OR for low rumen development were always below 1, meaning that these classes diminished the risk for its occurrence. The risk of poor rumen development increased in farms with small group housing when compared with that in large groups. Regarding the season effect, farms in which animals were housed during the summer showed the lowest incidence of poor rumen development, whereas spring increased the risk compared with that in autumn and in summer in particular.

Risk Factor Analysis for Occurrence of Rumen Plaques and Hyperkeratosis

Significant risks for rumen plaques obtained from the one-way logistic regression analysis are shown in Table 4. Feeding low quantities of solid feed (≤ 50 kg of DM/calf) decreased the risk of rumen plaques, whereas the provision of low amounts of milk powder (280–330 kg/calf) increased it more than 10 times. Calves that did not receive at least 2 milk meals per day (feed restriction for 1 d/wk) showed a higher risk of plaques on the rumen wall compared with calves that were weekly fed 14 liquid meals or more. Farms that reared national calves increased the risk of developing rumen plaques compared with those that fattened animals imported from more countries. The OR for rumen plaques was above 1 in farms that did not use heating as well as in those not equipped with individual boxes to separate the penmates during the first 8 wk of the rearing cycle. Pens with a wooden slatted floor and the absence of a sickbay were instead protective factors.

The multivariate risk factor model showed an association between occurrence of rumen plaques and

Table 3. One-way logistic regression analysis and multivariate regression model for low rumen development in veal calves

Risk factor	Level of comparison I	Level of comparison II	Odds ratio	95% CI	t-value of pairwise comparison
One-way logistic regression analysis ¹					
Total amount of solid feed, kg of DM/calf per fattening cycle	≤50	151–300	14.75	5.34–40.70	0.001
Prevalent type of solid feed	Maize silage	Cereal grain ³	4.21	2.27–7.80	0.001
	Pellets or mixture	Cereal grain	4.43	2.38–8.27	0.001
Milk delivery system	Bucket	AMD ⁴	2.48	1.18–5.22	0.017
	Trough	AMD	2.05	1.06–3.99	0.035
Presence of a specific sickbay	No	Yes	1.95	1.26–3.03	0.003
Type of floor	Wooden slats	Concrete	3.43	1.85–6.36	0.001
Multivariate regression model ²					
Total amount of milk powder, kg/calf per fattening cycle	280–330	331–380	0.29	0.14–0.58	0.001
	280–330	>380	0.14	0.06–0.30	0.001
	331–380	>380	0.48	0.29–0.80	0.006
Water provision	Ad libitum	Limited	0.31	0.17–0.56	0.001
	Ad libitum	No water	0.10	0.04–0.22	0.001
	Limited	No water	0.31	0.15–0.65	0.002
Housing system during fattening	Small	Large	2.74	1.10–6.82	0.033
Season at housing	Spring	Summer	14.90	6.58–33.73	0.001
	Spring	Autumn	2.80	1.44–5.45	0.003
	Spring	Winter	0.94	0.46–1.90	0.863
	Summer	Autumn	0.19	0.09–0.37	0.001
	Summer	Winter	0.06	0.03–0.13	0.001
	Autumn	Winter	0.34	0.18–0.61	0.001

¹Single risk factors in the one-way logistic regression analysis were significant at $P < 0.05$.

²All risk factors in the multivariate regression model were significant at $P < 0.05$ except for Housing system during fattening, which was not significant at $P = 0.076$. Adjusted $R^2 = 47.94\%$.

³Barley or maize.

⁴Automatic milk delivery device.

type of solid feed, water provision, and space allowance (Table 4). According to OR, feeding cereal grain as the prevalent solid feed increased the risk of rumen plaques. Maize silage acted as a preventive factor when compared with pellets/mixture or cereal grain. Pairwise comparisons among the classes of water provision showed that ad libitum supply was a risk factor for rumen plaques. A space allowance ≤ 1.8 m²/calf doubled the risk for rumen plaques compared with that of larger individual space availability.

One-way logistic regression analysis showed that bucket feeding compared with the use of a common trough decreased the risk of rumen papillae hyperkeratinization (Table 5). A further preventive measure was the administration of a total amount of solid feed ≤ 50 kg of DM/calf compared with greater amounts (151–300 kg of DM/calf). Holstein calves had a lower risk of developing hyperkeratinization of the papillae compared with that of crossbred animals, whereas a space allowance ≤ 1.8 m²/calf increased such risk (Table 5).

The final multivariate risk factor model for the occurrence of rumen hyperkeratosis considered prevalent type of solid feed and the presence of a dedicated sickbay (Table 5). Feeding cereal grain highly increased the risk of rumen papillae hyperkeratinization. Furthermore, the absence of a dedicated sickbay represented a risk.

Risk Factor Analysis for Occurrence of Abomasal Lesions in the Pyloric Area

Risk factors for occurrence of lesions in the pyloric area of veal calf abomasa were mainly linked to feeding strategies and water provision (Table 6). The provision of amounts of milk powder ranging from 280 to 330 kg/calf increased the risk of abomasal lesions compared with that from higher amounts, whereas an opposite result was observed for the amounts of solid feed. The ad libitum provision of drinking water increased the risk of abomasal lesions when compared with that from the absence of drinking water. No use of heating seemed to be an additional risk factor, whereas a lower frequency of visits by the veterinarian was a preventive measure.

The final multivariate regression model for abomasal lesions in the pyloric area showed that the prevalent type of solid feed and the season at housing were the most relevant factors explaining about 41% of the total variance related to this problem (Table 6). Pairwise comparisons among classes of solid feeds showed the highest risk of lesions in the pyloric area when calves were fed cereal grain. The risk of having at least one lesion on the pylorus was lower for calves housed during the spring, whereas it was higher for those housed during the summer and autumn compared with that during the winter.

Table 4. One-way logistic regression analysis and multivariate regression model for the incidence of rumen plaques in veal calves

Risk factor	Level of comparison I	Level of comparison II	Odds ratio	95% CI	t-value of pairwise comparison
One-way logistic regression analysis ¹					
Total amount of solid feed, kg of DM/calf per fattening cycle	≤50	151–300	0.13	0.06–0.25	0.001
Total amount of milk powder, kg/calf per fattening cycle	280–330	>380	10.59	5.85–19.17	0.001
Calves always received ≥14 liquid meals/wk	No	Yes	1.99	1.19–3.33	0.010
Calves origin	National	From more countries	1.94	1.22–3.08	0.006
Type of floor	Wooden slats	Concrete	0.31	0.19–0.51	0.001
Presence of a specific sickbay	No	Yes	0.64	0.44–0.93	0.022
Use of heating	No	Yes	3.28	2.00–5.39	0.001
Use of baby boxes	No	Yes	1.92	1.19–3.11	0.009
Multivariate regression model ²					
Prevalent type of solid feed	Maize silage	Pellets or mixture	0.56	0.37–0.85	0.008
	Maize silage	Cereal grain ³	0.21	0.13–0.35	0.001
	Maize silage	Treated maize ⁴	0.60	0.29–1.28	0.189
	Pellets or mixture	Cereal grain	0.38	0.24–0.60	0.001
	Pellets or mixture	Treated maize	1.08	0.54–2.18	0.826
	Cereal grain	Treated maize	2.83	1.34–5.99	0.007
Water provision	Ad libitum	Limited	2.17	1.44–3.26	0.001
	Ad libitum	No water	2.58	1.57–4.25	0.001
	Limited	No water	1.19	0.73–1.95	0.483
Space allowance, m ² /calf	≤1.8	>1.8	2.08	1.40–3.10	0.001

¹Single risk factors in the one-way logistic regression analysis were significant for $P < 0.05$.

²All risk factors in the multivariate regression model were significant at $P < 0.001$. Adjusted $R^2 = 31.51\%$.

³Barley or maize.

⁴Rolled or flaked maize.

DISCUSSION

The gastrointestinal disorders investigated in this study might negatively affect the health and welfare status of veal calves by placing the animals in a borderline condition between pathological and physiological, where a physiological status indicates a developed and

functioning rumen, an unaltered rumen mucosa, and a healthy abomasum. As expected, the occurrence of gastrointestinal disorders was mainly associated with feeding-related factors. Consistent with previous findings (Beharka et al., 1998; Cozzi et al., 2002a; Suárez et al., 2006b), the importance of supplementing veal calves with solid feed to stimulate rumen develop-

Table 5. One-way logistic regression analysis and multivariate regression model for the incidence of rumen papillae hyperkeratinization in veal calves

Risk factor	Level of comparison I	Level of comparison II	Odds ratio	95% CI	t-value of pairwise comparison
One-way logistic regression analysis ¹					
Milk delivery system	Bucket	Trough	0.32	0.18–0.57	0.001
Total amount of solid feed, kg of DM/calf per fattening cycle	≤50	151–300	0.38	0.16–0.90	0.030
Prevalent breed	Holstein	Crossbred	0.50	0.32–0.79	0.003
Space allowance, m ² /calf	≤1.8	>1.8	2.72	1.64–4.52	0.001
Multivariate regression model ²					
Prevalent type of solid feed	Maize silage	Pellets or mixture	0.82	0.53–1.26	0.372
	Maize silage	Cereal grain ³	0.40	0.25–0.63	0.001
	Maize silage	Treated maize ⁴	35.34	0.60–2,068.66	0.088
	Pellets or mixture	Cereal grain	0.49	0.31–0.76	0.002
	Pellets or mixture	Treated maize	43.03	0.73–2,520.38	0.072
	Cereal grain	Treated maize	88.53	1.51–5,196.27	0.032
Presence of a specific sickbay	No	Yes	1.66	1.12–2.44	0.012

¹Single risk factors in the one-way logistic regression analysis were significant at $P < 0.05$.

²All risk factors in the multivariate regression model were significant at $P < 0.05$. Adjusted $R^2 = 17.64\%$.

³Barley or maize.

⁴Rolled or flaked maize.

Table 6. One-way logistic regression analysis and multivariate regression model for the prevalence of abomasal lesions (at least one lesion, from superficial scar to ulcer) in the pyloric area in veal calves

Risk factor	Level of comparison I	Level of comparison II	Odds ratio	95% CI	t-value of pairwise comparison
One-way logistic regression analysis ¹					
Total amount of milk powder, kg/calf per fattening cycle	280–330	>380	2.14	1.41–3.24	0.001
Total amount of solid feed, kg of DM/calf per fattening cycle	≤50	151–300	0.35	0.22–0.57	0.001
Water provision	Ad libitum	No water	1.71	1.23–2.37	0.002
Use of heating	No	Yes	1.77	1.36–2.31	0.001
Frequency of visits by veterinarian/fattening cycle	<3	≥3	0.71	0.56–0.89	0.004
Multivariate regression model ²					
Prevalent type of solid feed					
	Maize silage	Pellets or mixture	1.00	0.80–1.24	0.990
	Maize silage	Cereal grain ³	0.63	0.47–0.86	0.003
	Maize silage	Treated maize ⁴	1.16	0.80–1.68	0.445
	Pellets or mixture	Cereal grain	0.63	0.47–0.85	0.003
	Pellets or mixture	Treated maize	1.16	0.80–1.68	0.442
	Cereal grain	Treated maize	1.83	1.20–2.80	0.006
Season at housing					
	Spring	Summer	0.69	0.53–0.90	0.008
	Spring	Autumn	0.64	0.49–0.85	0.002
	Spring	Winter	1.27	0.96–1.69	0.097
	Summer	Autumn	0.93	0.71–1.22	0.593
	Summer	Winter	1.84	1.41–2.39	0.001
	Autumn	Winter	1.98	1.49–2.61	0.001

¹Single risk factors in the one-way logistic regression analysis were significant at $P < 0.05$.

²All risk factors in the multivariate regression model were significant at $P < 0.004$. Adjusted $R^2 = 40.79\%$.

³Barley or maize.

⁴Rolled or flaked maize.

ment has been demonstrated. However, results of the present study would suggest increasing the amount of solid feed provided during the fattening cycle far above the recommended 50 to 250 g/calf per day set by the European Union regulation. Forestomach size innately increases with age, but its papillae development requires physical stimulation and VFA (mainly butyrate and propionate) from microbial fermentation of solid feedstuffs (Beharka et al., 1998). Compared with maize silage or pellets that have a relatively high content of fiber, a starchy substrate, such as cereal grain, has been shown to stimulate rumen development, likely through a higher production of butyrate and propionate (Sander et al., 1959). Results of the multivariate regression model revealed the preventive effect on low rumen development of reducing the total amount of milk replacer fed throughout fattening. This finding might still be related to the provision of solids which commonly increases in feeding plans based on a restricted amount of milk powder (Suárez et al., 2007). A gradual reduction of the milk replacer associated with availability of increasing amounts of solid feed would reflect a more natural condition for calves, promoting the changes from a preruminant into a ruminant animal. The increased risk for poor rumen development associated with the use of buckets or troughs for milk delivery compared with that from use of AMD could

again be linked to the solid feed distribution. Where milk is automatically delivered, usually solids are also distributed by computer-controlled feeders. These devices allow a more balanced intake of solid feed among all penmates, avoiding that a few dominant calves eat a large amount of solid feed as in small-group systems where feeds are delivered in common mangers. The outcomes of the multivariate regression model seem to support this hypothesis because the risk for low rumen development has been shown to be increased in calves housed in small groups.

It is interesting to notice that if the results for poor rumen development would recommend increasing the amount of solid feed for veal calves, those regarding the occurrence of rumen plaques and papillae hyperkeratinization suggest an opposite strategy. Moreover, whereas the prevalent provision of cereal grain promoted rumen development, it was a significant risk factor for rumen plaques and hyperkeratosis as well as for abomasal lesions. These controversial findings, with the same variable acting as preventive or predisposing factor for different disorders, demonstrate the difficulty of identifying from the present data the best feeding options capable of minimizing the prevalence of all the considered gastrointestinal disorders.

Results for plaques are consistent with the findings of Suárez et al. (2006b) who found out that supplementing

veal calves with concentrates increased the weight of the empty rumen and mucosa thickness but it enhanced the incidence of rumen plaques. The association of cereal grain and hyperkeratosis could arise either from the lack of abrasive effect of this type of feed compared with that of roughage sources (Greenwood et al., 1997; Beharka et al., 1998) or from the altered rumen fermentation profile with high propionate concentration (Hinders and Owen, 1965; Bertram et al., 2009). In both cases, a calf might be more easily subject to a potential (sub)acidosis due to the lower rumen-buffering capacity and the subsequent decrease in rumen pH (Anderson et al., 1982), with detrimental effects on its health and welfare status. The straight link between an increment of solid feed intake and the consumption of drinking water when water was provided *ad libitum* to preweaned calves (Kertz et al., 1984), could explain the results of our study, in which *ad libitum* drinking water availability acted as a risk factor for rumen plaques. No clear explanation for the association between space allowance and rumen plaques and hyperkeratosis exists except that providing calves with a larger space allowance than that set by the legal requirement (1.8 m²/calf with BW \geq 220 kg) may constitute a further strategy to limit their stress and to improve their welfare, possibly with beneficial effects on the health status of the rumen. On the one hand, our results suggest that the etiology of rumen mucosa alterations is not restricted to factors related to the feeding plan but may also involve other risk factors to which veal calves are exposed during rearing. On the other hand, they should encourage the development and application on-farm of further housing and management solutions with the aim at improving calf well-being.

In the present study, more than 74% of the inspected abomasa showed at least one lesion and this high prevalence is consistent with data of previous studies (Gottardo et al., 2002; Mattiello et al., 2002). This result appears lower than that from Welchman and Baust (1987) who reported that 97% of calves housed in individual cages and fed a traditional all-liquid diet suffered from abomasal ulcers. This might suggest that some improvements have been achieved by the actual systems of veal calf production but also that the predisposing factors for abomasal damage are still not overcome. The recent advance in veal calf management did not modify the way milk replacer is provided to veal calves throughout the entire fattening cycle, with large volumes of liquids fed usually in a few meals per day. Regardless of the type of milk replacer, this could be the main critical point for abomasal distension and its subsequent ulceration, particularly when compared with the physiological nursing behavior of the suckling calf consisting of 5 to 9 bouts/d (Day et al., 1987). Unexpectedly, in the

current study, amounts of milk powder ranging from 280 to 330 kg/calf per fattening cycle increased the risk of occurrence of abomasal lesions compared with that from greater amounts. A possible reason for this result might be linked to greater amounts of solid feed provided in farms adopting low levels of milk replacer. Under this latter feeding plan, solids may promote abomasal damage by worsening the mechanical load of the stomach. According to the literature, lesions seem to be generally associated with coarse solid feed (Cozzi et al., 2002b; Mattiello et al., 2002; Bähler et al., 2010), but the outcomes of the present risk analysis showed that cereal grain was also a risk factor. Differing from the results of Bähler et al. (2010), no associations were found between abomasal lesions and the type of milk delivery system. Free access to water was a further risk factor in veal farms, but this is in contradiction with results of Gottardo et al. (2002) who found no effect and Bähler et al. (2010) who reported an OR of 2.3 for lesions in the fundic area when no water was provided. Similar to rumen problems, results suggest that, in addition to risk factors related to feeding, housing and management factors may also play a role in the etiology of abomasal lesions.

CONCLUSIONS

This cross-sectional study was carried out on a large sample of farms in the 3 main veal meat-producing countries in Europe to gather reliable information on the prevalence of gastrointestinal disorders and the main risk factors related to their occurrence. The coming-in-force of the European regulation for calf protection has promoted relevant improvements of calf behavior and health, but the results of the current study have shown that gastrointestinal disorders are still highly prevalent. Factors related to the feeding system were confirmed to be the main risks for the occurrence of poor rumen development and of the alterations of rumen and abomasal mucosa. However, their etiology should consider other predisposing factors related to housing and management because some options adopted to improve calf welfare were associated with lower risks. Finally, controversial findings, where the same variable acted as a preventive or predisposing factor for different disorders, demonstrate the difficulty in identifying the best rearing options capable of inducing a sharp decrease in the prevalence of all of the considered gastrointestinal disorders.

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