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The provision of solid feeds to veal calves: II. Behavior, physiology, and abomasal damage^{1,2}

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ABSTRACT: The aim of this study was to evaluate the effects of the addition of two roughage sources (wheat straw and beet pulp) to the milk replacer diet of veal calves, in order to reduce stress and improve animal welfare. We allocated 138 Polish Friesian male calves to three different feeding plans: a milk replacer diet (Control), 250 g/d of wheat straw in addition to the milk replacer, or 250 g/d of dried beet pulp in addition to the milk replacer. Within each feeding treatment, 16 calves were individually housed and 30 were kept in group pens (five calves/pen). Several behavioral, physiological, and health welfare indicators were monitored throughout the fattening period, which lasted for 160 d. Abnormal oral behavior around the meals was higher in Control calves ($P < 0.01$), while its lowest level was observed in straw-fed calves. At the beginning of the trial, chewing was higher in calves receiving solid feeds ($P < 0.001$), but the difference from the Control gradually decreased and disappeared at wk 13 for calves fed beet pulp and at wk 17 for those fed wheat straw. At the end of the fattening period, no differences among treatments were found in the frequency of chewing. Regardless of the diet, self-

grooming decreased with age and no relationship was observed between this behavior and the presence of rumen hairballs. Cross-sucking was performed with low frequencies (from 4.70% at wk 2 to 1.05% at wk 23 around the meals, and even lower far from the meals) and was not affected by the provision of roughage. The time in contact with the bucket during the whole day was higher in Controls, whereas calves fed wheat straw maintained a lower level of this activity until the end of the trial ($P < 0.01$). The calves fed wheat straw spent more time in contact with the feed trough ($P < 0.001$) than those fed beet pulp and Control calves. No differences were found in cortisol curves due to the feeding treatment. In calves fed beet pulp, most hematological measures statistically differed from the other treatments, possibly in response to the higher iron intake and(or) to the higher hemoconcentration, probably due to the administration of beet pulp as dried feed. The incidence of abomasal ulcers and erosions was increased by the provision of the solid feeds, particularly by a structured fiber source such as straw. A roughage source able to satisfy calves' behavioral needs and to improve digestive processes without damaging the digestive apparatus still has to be identified.

Key Words: Abomasum, Animal Welfare, Behavior, Feeding, Hematology, Veal

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Introduction

It is known that different roughage sources can produce different effects on calves' behavior and welfare. According to Koojiman et al. (1991), abnormal oral behavior can be reduced by the administration of hay for ad libitum consumption, whereas maize silage and pelleted straw have little effect. However, very fibrous roughage sources, such as straw, have been related to the occurrence of abomasal lesions (Morisse et al., 1999, 2000).

An inadequate feeding plan may represent a source of chronic stress for the calf. Physiological indicators (e.g., cortisol levels following intravenous administration of ACTH) have been used in several domestic ani-

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mals, including cattle (Friend et al., 1987; Veissier et al., 1998; Munksgaard et al., 1999), to detect states of chronic activation of the hypothalamo-pituitary-adrenocortical (HPA) axis due to external stressors (Terlouw et al., 1997).

Chronic stress can also lead to immune depression, which can be evidenced by an alteration of hematological measures, especially by an increase of the neutrophil/lymphocyte (N:L) ratio. This ratio has also been used as a welfare indicator in several studies on veal calves (Friend et al., 1987; McFarlane et al., 1988; Stull and McDonough, 1994).

The aim of this study was to evaluate the effects of two sources of roughage (wheat straw and beet pulp), fed in addition to the milk replacer diet of veal calves, in order to reduce stress and to improve animal welfare. To this aim, we used behavioral, physiological, and health indicators.

Materials and Methods

Animals and Treatments

We used 138 Polish Friesian male calves reared in two batches (54 and 84 calves). Forty-six were fed a traditional all-liquid diet (Control), 46 received 250 g/d of wheat straw in addition to the milk replacer, and 46 received 250 g/d of beet pulp in addition to the milk replacer. Within each feeding treatment, 16 calves were individually housed and 30 were kept in group pens (five calves/pen). Within each feeding and housing system, half of the calves were provided with water, and the other half had no access to drinking water. Milk was delivered twice per day (at 0730 and 1930) and roughage was distributed immediately after the evening meal. Calves arrived at the fattening unit at the age of 1 wk and were slaughtered after 160 d. Further description of the experimental design, the housing structures, and the experimental treatments were reported by Cozzi et al. (2002).

Data Collection

Behavioral Observations. In order to monitor the development of behavior in the different feeding treatments, direct and video-recorded behavioral observations were carried out at wk 2, 7, 13, 17, and 23 of the fattening period. We performed direct observations from a high seat placed in the middle of the feeding aisle, using a scan sampling technique (a scan every 2 min; Martin and Bateson, 1993). We chose to observe the calves 1 h before and 1 h after each meal, because most oral activities in veal calves are concentrated around the meals (Veissier et al., 1998). A detailed ethogram of calves was defined recording the following behaviors: chewing (all repetitive movements of lower jaw in the lateral plane); self-grooming; sniffing other calves; licking other calves; cross-sucking (including urine drinking); tongue playing: repetitive, circular

movements of the tongue outside the mouth; tongue rolling: repetitive, circular movements of the tongue inside the mouth; biting (taking substrate into the mouth without manipulating it with the tongue); sucking (taking substrate into the mouth and making sucking movements and sounds); and nibbling (taking substrate into the mouth and manipulating it with the tongue).

In addition to direct observations, at wk 2, 7, 17, and 23 we also carried out video-recorded observations for 20 h from 0830 to 1830 and from 2030 to 0630 (scan sampling every 4 min; Martin and Bateson, 1993). Video recording of calves' individual behavior on videotapes was carried out with a system of 11 wide-angle black-and-white cameras, time-lapse video recorders, and digital field switchers. There were two cameras for every two individual crates, one frontal camera and one aerial, and three cameras for every two group pens, two frontal and one rear.

From videotapes, we could distinguish the following general behavioral categories: contact bucket, contact structures, contact feed trough, self-grooming, social contacts, and cross-sucking. We also calculated the percentages of time spent standing or lying. For obvious reasons, cross-sucking could be analyzed only for group-housed calves. The time to consume the solid feeds was measured at wk 2 and 23.

Hematological Values. We collected blood samples at wk 3, 13, 18, and 23. Blood samples were taken from all the calves by jugular venipuncture before the morning meal using K₃EDTA vacutainer tubes (Becton Dickinson Inson, Meylan Cedex, France). Hematocrit and blood formula (including platelets, white blood cells (WBC), neutrophils, lymphocytes, eosinophils, and monocytes) were determined using an automatic cell counter (Cell-Dyn 3500R, Abbott, Abbott Park, IL) and the N:L ratio was calculated. In the second batch of calves, Na concentration was measured by a colorimetric assay using an automatic analyzer (Roche BM Hitachi 911, Hitachi Medical Systems, Tarrytown, NY).

ACTH Challenge. We carried out an ACTH challenge at wk 20 of the fattening period to evaluate the level of chronic stress. The procedure was established following previous knowledge from Veissier and Le Neindre (1988). We injected the calves intravenously with Synacthene (Novartis Pharma S.A., Rueil-Malmaison, France) at a dose of 0.5 IU/kg metabolic weight and we took blood samples by jugular venipuncture at 0, 30, and 180 min after injection. Each test was accompanied by a control test with saline injection and blood samplings at the same time points after injection. The actual ACTH challenge and the control test were separated by 4 d. Half of the animals received ACTH and 4 d later saline, whereas the other half received the ACTH and the saline treatment in the opposite order. The order of the treatments (ACTH or saline) was equally distributed within each experimental treatment. We performed all tests after the morning meal. In order to reduce stress due to handling, for 5 d prior

to the tests, calves had been trained to be restrained by blocking them every day at the feeding gate for 1 h after the morning milk meal.

Plasma free cortisol levels were determined by radioimmunoassay (antibody produced by Cognié and Poulin, INRA Tours, France), without extraction of the corticoids. The detection limit was 0.02 ng/mL. Within- and between-assay coefficients of variation were 15 and 24% for low (4 ng/mL) and 6.6 and 13.7% for high (32 ng/mL) controls.

Abomasal Ulcers. After slaughter, three histological samples were excised from the abomasum of each calf (one from the pyloric region, one from the fundic region, and one from the monticulus). Moreover, histological samples from lesions or suspected lesions found in the abomasum were collected. Samples were immediately fixed in 10% neutral buffered formalin and submitted to histological examination after hematoxylin eosin staining. Lesions were classed as ulcers (presence of focal excavation of the mucosa due to necrosis and sloughing of the necrotic tissue; the excavation involved the whole thickness of the mucosa and reached the submucosa or the deeper layers of the abomasal wall), erosions (lesions similar to an ulcer, but characterized by a superficial involvement of the mucosa), or inflammations (presence of lymphocytes and plasma cells in the lamina propria of the mucosa).

Statistical Analysis

We transformed absolute frequencies of scans into percentages by dividing the number of times a calf was observed to perform a given behavior by the total number of scans on the same calf (120 scans for direct observations and 300 scans for video-recorded observations) for each week of observation. We submitted data collected during each week of observation to arcsin-root transformation (Martin and Bateson, 1993). All of the behaviors were separately analyzed, but most of them showed a low frequency. Therefore, we grouped some of them into more general behavioral categories as follows: social contacts (sniffing/licking other calves); abnormal oral behavior (tongue playing/rolling plus biting/sucking/nibbling bucket/structures).

For the ACTH challenge, we used the differences between the three samples after ACTH injection and the saline controls at time 0 min (Delta 0), 30 min (Delta 30), and 180 min (Delta 180) as variables for statistical analysis.

Data were analyzed using a General Linear Model for repeated measures with four fixed factors: batch (two levels), source of roughage (three levels), housing system (two levels), provision of water (two levels), and all possible interactions among the last three factors (SAS Inst. Inc., Cary, NC). For the analysis of Na concentration, batch was not included in the model because data were available only for the second batch of calves.

For behavioral and hematological data, we used the week of observation as the repetition, whereas for

ACTH data we used the time of blood sampling (0, 30, or 180 min) as the repetition and we took Delta 0 as the starting point for the analysis of the interaction between time and all the other factors.

For individually housed calves, the experimental unit was the individual calf, and for group-housed calves the unit was the group-mean. Because the variance of a mean of n observations is σ^2/n , we used the number of observations per mean (five for group-housed calves and one for individually housed calves) as a weighting in the analysis, thus correcting the imbalance of the design.

Normality and homogeneity of the residues were checked at the end of the analysis.

Least squares means were used for presentation of the results. The experimental error was estimated by the pooled standard error of the mean (SEM). Nonorthogonal contrasts were performed using the PDIF statement (SAS Inst., Inc.).

The number of calves with or without lesions in the abomasum were compared by χ^2 test (SAS Inst., Inc.) according to the different feeding treatments.

Results

We found no relevant interaction among the three main factors (diet, type of housing, and water provision); therefore, the results obtained feeding the calves with different solid feeds will be discussed independently from the other treatments. The results regarding the effects of the other two main factors will be presented in following separate articles.

Behavioral Observations

Direct Observations. The analysis showed that the overall mean frequencies of abnormal oral behavior in the three treatments were different ($F = 5.85$; $P < 0.01$) and that there was also an effect of the interaction between week and feeding treatment ($F = 2.60$; $P < 0.01$). This behavior started with low frequencies in all treatments, and then it increased in Control calves and calves fed beet pulp (Figure 1). Differences among treatments were significant at wk 7 ($F = 5.19$; $P < 0.01$) and at wk 13 ($F = 7.30$; $P < 0.01$). Abnormal oral behavior was significantly lower in calves fed wheat straw at wk 7 ($P < 0.01$) and at wk 13 (wheat straw vs Control: $P < 0.001$; wheat straw vs beet pulp: $P < 0.01$), and at wk 23 significant differences were present only between Control calves and those fed wheat straw ($P < 0.01$).

A treatment effect was observed on the overall mean frequency of chewing ($F = 22.12$; $P < 0.001$) and on its interaction with week ($F = 12.71$; $P < 0.001$; Figure 2). At wk 2, Control calves spent significantly less time chewing than calves provided with solid feed ($F = 20.96$; $P < 0.001$). Significant differences were detected at wk 7 ($F = 44.92$; $P < 0.001$): Calves fed beet pulp showed a marked decrease in chewing, which slightly differed from that of Control calves ($P < 0.05$), whereas calves

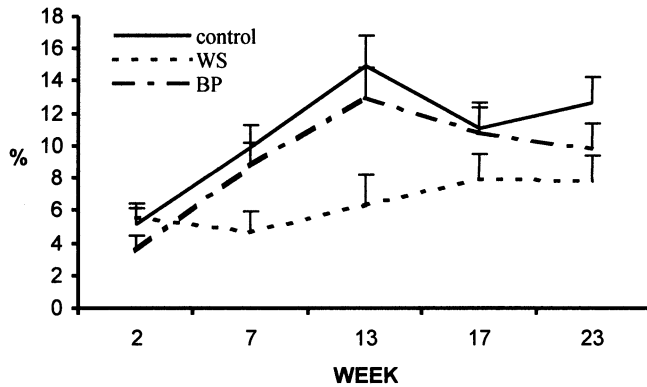


Figure 1. Development of the frequency of abnormal oral behavior (least squares means + SEM) from direct observations around mealtimes in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (---, BP), or milk replacer + 250 g/d of wheat straw (· · ·, WS) at the 2nd, 7th, 13th, 17th, and 23rd wk of the fattening period.

fed wheat straw spent significantly more time chewing than all other calves ($P < 0.001$). Significant differences were also found ($F = 6.87$; $P < 0.01$) at wk 13: calves fed beet pulp did not differ from Controls anymore, and calves on both of these treatments spent significantly less time chewing than calves fed wheat straw ($P < 0.01$). At wk 17 a treatment effect was still observed ($F = 5.78$; $P < 0.01$), due to the lesser time spent chewing by calves fed beet pulp compared to Controls ($P < 0.05$) and calves fed wheat straw ($P < 0.001$); no difference was observed between Control calves and those fed wheat straw at this stage of the fattening period. At the end of the trial, no differences among treatments were found in the frequency of chewing.

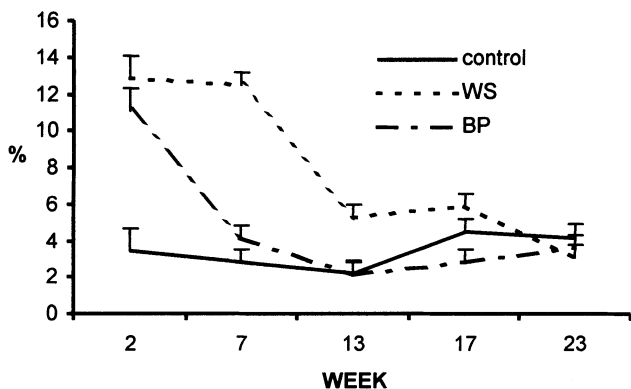


Figure 2. Development of the frequency of chewing (least squares means + SEM) from direct observations around mealtimes in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (---, BP), or milk replacer + 250 g/d of wheat straw (· · ·, WS) at the 2nd, 7th, 13th, 17th, and 23rd wk of the fattening period.

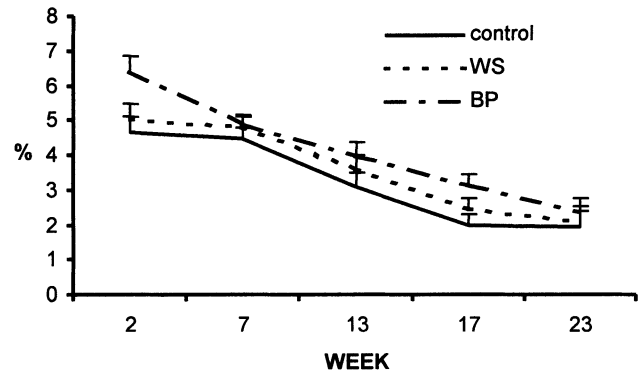


Figure 3. Development of the frequency of self-grooming (least squares means + SEM) from direct observations around mealtimes in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (---, BP), or milk replacer + 250 g/d of wheat straw (· · ·, WS) at the 2nd, 7th, 13th, 17th, and 23rd wk of the fattening period.

A significant treatment effect ($F = 5.60$; $P < 0.01$) was observed on the overall mean frequency of self-grooming, which was higher in calves fed beet pulp than in Controls and calves fed wheat straw (Figure 3). From wk 2 to wk 23, this behavior showed a decreasing trend (week effect: $F = 45.56$; $P < 0.001$).

An overall treatment effect was found for social contacts ($F = 3.41$; $P < 0.05$), which were observed more frequently in Control calves and, to a lesser extent, in calves fed beet pulp. A significant effect of the feeding treatment was also observed in interaction with the week of observation ($F = 2.38$; $P < 0.05$). Calves fed with straw tended to have fewer social contacts than other calves, and this difference was significant at wk 17 (wheat straw vs Control and wheat straw vs beet pulp: $P < 0.05$) and at wk 23 (wheat straw vs beet pulp: $P < 0.01$).

Cross-sucking was analyzed for grouped calves only. This behavior was performed with a low frequency, gradually decreasing from 4.70% at wk 2 to 1.05% at wk 23, and it was not affected by the feeding treatment.

Video-Recorded Observations. The feeding treatment had no significant effect on the percentage of time spent standing and lying. Calves spent most of their time lying (from 80.4% at wk 2 to 75.8% at wk 23) and the remaining time standing.

Far from the meals, cross-sucking was performed with very low frequencies (from 0.57% at wk 2 to 0.1% at wk 23), whereas the activity toward the structures was quite frequent (from 10.5% at wk 2 to 14.5% at wk 23), but neither cross-sucking nor structure contact was significantly affected by the feeding treatment.

Consistent with the results from direct observations, self-grooming showed a decreasing trend from wk 2 to wk 23 (week effect: $F = 53.82$; $P < 0.001$). Control calves spent significantly less time grooming themselves than calves provided with solid feed ($F = 3.19$; $P < 0.05$).

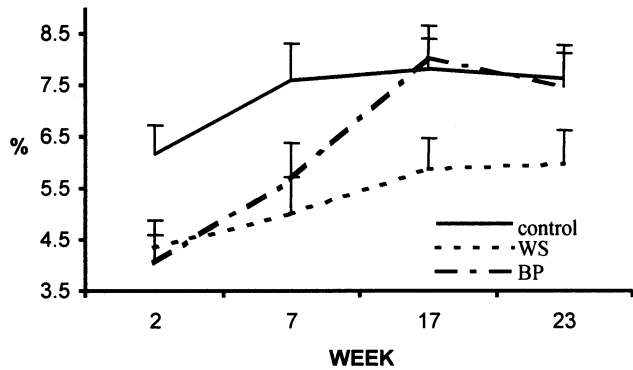


Figure 4. Development of the frequency of contacting the bucket (least squares means + SEM) from video-recorded observations in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (— · —, BP), or milk replacer + 250 g/d of wheat straw (---, WS) at the 2nd, 7th, 17th, and 23rd wk of the fattening period.

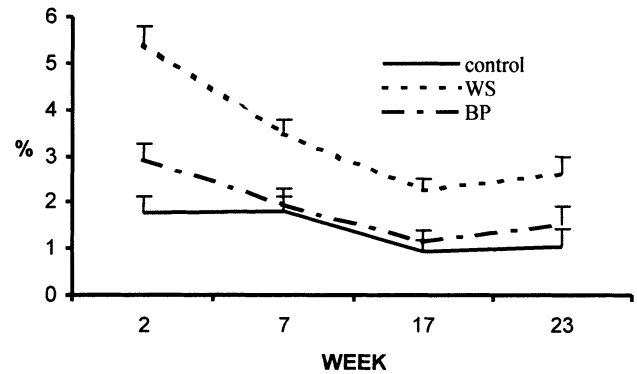


Figure 5. Development of the frequency of contacting the feed trough (least squares means + SEM) from video-recorded observations in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (— · —, BP), or milk replacer + 250 g/d of wheat straw (---, WS) at the 2nd, 7th, 17th, and 23rd wk of the fattening period.

A significant effect of the interaction between week and feeding treatment was found for social contacts ($F = 2.54$; $P < 0.05$). In fact, social contacts were significantly more frequent in calves fed wheat straw than in those fed beet pulp (11.0% vs 8.8%, respectively; $P < 0.05$) and in Control calves (8.2%, $P < 0.01$) only at the end of the fattening period (wk 23, $F = 4.15$; $P < 0.05$).

The feeding treatment significantly affected the frequency of time in contact with the bucket ($F = 7.31$; $P < 0.01$), which showed an increasing trend with week ($F = 10.94$; $P < 0.001$). This behavior was lower in calves fed wheat straw and higher in Control calves and was intermediate in calves fed beet pulp (Figure 4).

The percentage of time in contact with the feed trough decreased with age (week effect: $F = 19.92$; $P < 0.001$) and was significantly higher in calves fed wheat straw than in Control's or calves fed beet pulp ($F = 23.25$; $P < 0.001$; Figure 5). At wk 2, calves needed 14 ± 2 min to consume the beet pulp, but at the end of the trial this time had decreased to 7 ± 1 min. Also, wheat straw was consumed faster at the end of the trial (26 ± 11 min) than at the beginning, when it lasted for the whole day with some residues.

Hematological Values

Mean values for the considered variables in the three feeding treatments are reported in Table 1. White blood cells were significantly higher in calves fed beet pulp. In those calves, the percentage of neutrophils was higher and the percentage of lymphocytes was lower, and therefore the N:L ratio was higher. The N:L ratio showed a decreasing trend from the beginning (N:L = 67.86) to the end of the trial (N:L = 59.43), although week effect was not statistically significant ($F = 1.66$). There was a significant interaction of week \times feeding treatment effect ($F = 2.24$; $P < 0.05$) for the percentage

of eosinophils, which was higher in Control calves only at the end of the fattening period (Control = 0.94, beet pulp = 0.51; wheat straw = 0.29; SEM = 0.16; $F = 4.38$; $P < 0.05$). No significant differences among feeding treatments were found for monocytes. Platelets were lower in calves fed beet pulp (Table 1), and there was a significant interaction of week \times feeding treatment ($F = 6.37$; $P < 0.001$). Differences between calves fed wheat straw and Control calves became significant at wk 13 ($F = 5.05$; $P < 0.01$) and were even more evident at wk 18 ($F = 10.66$; $P < 0.001$) and at wk 23 ($F = 13.53$; $P < 0.001$; Figure 6). Hematocrit was also affected by the provision of roughage (Table 1), and there was a significant interaction of week \times feeding treatment ($F = 24.79$; $P < 0.001$). From wk 13 until the end of the fattening period, calves fed beet pulp always showed significantly higher hematocrit values than Controls and calves fed wheat straw (wk 13: $F = 26.2$; $P < 0.001$; wk 18: $F = 44.5$; $P < 0.001$; wk 23: $F = 39.2$; $P < 0.001$). A significant week effect was also observed for this variable ($F = 144.27$; $P < 0.001$), which gradually decreased in all feeding treatments (Figure 7).

A significant effect of the interaction of week \times treatment ($F = 4.22$; $P < 0.001$) was observed for Na concentration. Although calves fed beet pulp showed initially lower Na concentration in blood serum (wk 3: Control = 138.5; beet pulp = 137.1; wheat straw = 138.6; SEM = 2.2; $F = 3.4$; $P < 0.05$), from wk 13 until the end of the fattening period they had the highest Na levels. This difference was particularly remarkable and significant at wk 18 (Control = 139.1; beet pulp = 140.9; wheat straw = 139.9; SEM = 1.5; $F = 7.7$; $P < 0.001$).

ACTH Challenge

No significant differences were found in cortisol curves due to the feeding treatment.

Table 1. Hematological values for repeated measures analysis in veal calves receiving different diets

Item	Diet			SEM	<i>F</i>
	Control	BP	WS		
White blood cells, no./mm ³ × 10 ³	7.3 ^y	8.6 ^x	7.5 ^y	0.26	6.68**
Neutrophils, %	26 ^y	33 ^x	28 ^y	1.22	8.29***
Lymphocytes, %	59 ^x	53 ^y	58 ^x	1.40	4.87*
Neutrophil:lymphocytes ratio	0.49 ^y	0.73 ^x	0.56 ^y	0.04	7.03***
Eosinophils, %	0.53	0.35	0.34	0.08	1.82
Monocytes, %	13.72	14.02	13.70	0.39	0.22
Platelets, no./mm ³ × 10 ³	931 ^x	771 ^y	939 ^x	34.27	7.65***
Hematocrit, %	25.9 ^y	30.0 ^x	25.6 ^y	3.0	27.8***
Na, mmol/L ^b	139.1 ^y	140.9 ^x	139.9 ^y	1.5	7.7***

^aControl = milk replacer; BP = milk replacer + 250 g/d of dried beet pulp; WS = milk replacer + 250 g/d of wheat straw.

^bNumber of animals: 84 (second batch).

^{x,y,z}Least squares means in a row with different superscript letters are significantly different ($P < 0.05$).

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

Abomasal Lesions

Both ulcers and erosions were significantly more frequent in calves receiving solid feed, especially in those fed wheat straw, but the frequency of calves with inflammations was not affected by the feeding treatment (Table 2).

Discussion

Abnormal oral behavior at the mealtime and contact with the bucket during the rest of the day were reduced until the end of the fattening period only by the administration of wheat straw. These results are in agreement with the existing literature (Koojiman et al., 1991; Veisier et al., 1998), indicating that the administration of straw can reduce the incidence of abnormal oral behav-

iors. Beet pulp had a limited effect that only controlled the level of contact with the bucket until wk 7 of the fattening period, but then this effect disappeared. The addition of beet pulp to the liquid diet was effective in reducing the incidence of oral behaviors in pregnant gilts (Brouns et al., 1991), but in that study the amount of feed consumed by the gilts ranged from a minimum of 2.0 kg/d to ad libitum intake. In our calves, the amount of beet pulp given as solid feed seemed too limited to reduce oral behavior until the end of the fattening period. In fact, considering the time to consume this solid feed, 250 g/d was probably a sufficient environmental enrichment for young veal calves at the beginning of the trial, but the same dose seemed insufficient at the end of it. Also, for wheat straw there was a marked decrease in the time of consumption from wk 2 to wk 23, but the time measured at the end of the

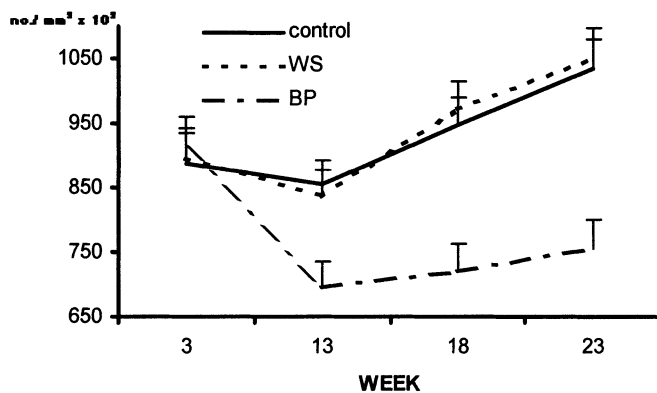


Figure 6. Variations in platelet numbers with age (least squares means + SEM) in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (---, BP), or milk replacer + 250 g/d of wheat straw (---, WS) at the 3rd, 13th, 18th, and 23rd wk of the fattening period.

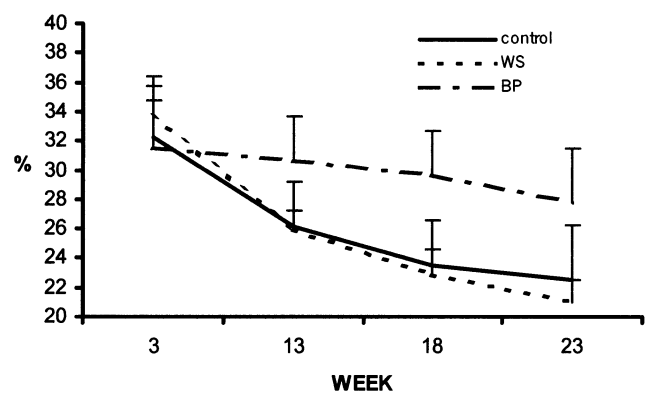


Figure 7. Hematocrit variations with age (least squares means + SEM) in veal calves fed only milk replacer (—, Control), milk replacer + 250 g/d of dried beet pulp (---, BP), or milk replacer + 250 g/d of wheat straw (---, WS) at the 3rd, 13th, 18th, and 23rd wk of the fattening period.

Table 2. Number (and percentage) of calves with abomasal lesions in veal calves receiving different diets

Item	Diet ^a			Total	χ^2
	Control	BP	WS		
Inflammations	27 (58.70)	25 (54.35)	19 (41.30)	71 (51.45)	3.02
Erosions	12 (26.09) ^y	12 (26.09) ^y	24 (52.17) ^x	48 (34.78)	9.20**
Ulcers	9 (19.56) ^y	19 (41.30) ^x	24 (52.17) ^x	52 (37.68)	10.80**

^aControl = milk replacer; BP = milk replacer + 250 g/d of dried beet pulp; WS = milk replacer + 250 g/d of wheat straw.

^{x,y,z}Means in a row with different superscript letters are significantly different ($P < 0.05$).

** $P < 0.01$.

trial was still longer than that required for beet pulp consumption at wk 2. We can attribute this fact to the higher frequency of chewing and of contacting the feed trough observed at the beginning of the trial in calves receiving solid feed, especially wheat straw, due to its structured fibrous composition. At the end of the fattening period, not even straw could stimulate chewing, because its amount was too small to satisfy the needs of the growing calves. This suggests that 250 g/d of straw (the daily recommended dose by the EC Directive 97/2 for calves aged more than 20 wk) is inadequate to reduce oral behavior of calves at the end of the fattening period. In the case of beet pulp, the same dose becomes limiting at an earlier stage of the growing cycle. When calves fed beet pulp decreased the amount of time spent chewing and in contact with the feed trough (i.e., when feed consumption was too quick, from wk 7 onward), oral behavior increased. Therefore, we cannot state that beet pulp is not an adequate source of roughage for veal calves' welfare, only that 250 g/d is certainly not enough. It is possible that a higher amount may have a more positive effect on calves' welfare, as it had in the case of gilts (Brouns et al., 1991).

According to Veissier et al. (1998), the lack of development of feeding behavior appropriate to ruminants is partially responsible for the arousal of nonnutritive oral activities. The time the calves spend eating solid feed can also probably compensate, in part, for the calves' need for feed searching after the milk meals, which is expressed by licking other calves immediately after the end of the meal. This might explain the higher frequency of social contacts around mealtime in Control's and calves fed beet pulp, whereas calves fed wheat straw had the lowest incidence of this behavior. Cross-sucking is a nonnutritive oral activity and, therefore, we imagine that its frequency may be reduced by the administration of solid feeds after the milk meal. Nevertheless, the percentage of time the calves spent sucking each other did not differ among the three feeding treatments, possibly due to the very low frequency of this behavior in our calves, which is in agreement with the results by Veissier et al. (1998). The low frequency of cross-sucking in our study might be attributed to the presence of nipples in the buckets for milk distribution. In fact, cross-sucking is higher when nipple feeders are

not provided (Scientific Veterinary Committee, 1995). Nevertheless, in accordance with the results of Veissier et al. (1998), this behavior was more frequent around mealtimes, confirming the hypothesis proposed by de Passillé et al. (1992, 1997) and Lidfors (1993) that the ingestion of milk elicits sucking behavior.

The frequency of self-grooming was higher around mealtimes, and it decreased far from the meals. This is in contrast with the results from Veissier et al. (1997), who found that veal calves spent around 5% of their time in this behavior far from the meals. Excessive self-licking may occur in response to deprivation situations, such as lack of roughage sources or housing in individual stalls (de Wilt, 1985; Broom, 1991). The low frequency of self-grooming observed in our calves suggests that its role in our study was haircoat maintenance, rather than conflict, and therefore it cannot be considered an indicator of poor welfare. This is confirmed by the fact that Control calves, which were supposed to be the more deprived, showed the lowest level of self-grooming. This is interesting in relation to the hypothesis that self-grooming can be related to the formation of hairballs (Fraser and Broom, 1990). Our Control calves showed the lowest levels of self-grooming but they had the highest incidence of hairballs (Cozzi et al., 2002). Therefore, our results, rather than support the previous hypothesis, seem to confirm the hypothesis of Morisse et al. (1999, 2000) suggesting that the introduction of solid feed can stimulate ruminal motility, thus facilitating the elimination of ingested hair.

No evidence of chronic stress was shown by the calves' response to ACTH challenge. Veissier et al. (1998) also found no significant neuroendocrine response in calves provided or not with solid feed (concentrate plus chopped straw) in addition to the milk replacer. Veissier et al. (1998) attributed this lack of difference to a compensation of stress due to the increased time spent nibbling at tires or chains that had been offered to these calves as an environmental enrichment. In our study, we actually found an increase in the time spent in oral activities in calves without solid feed, and this may have helped the calves to compensate for chronic stress. Another hypothesis that might explain the lack of significance in the response to the ACTH challenge is related to the fact that this trial was carried out near the

end of the fattening period. We may hypothesize that 1) by that age, calves had already become adapted to rearing conditions (Friend [1980] reported that responses to ACTH decrease after some weeks of exposure to a chronic stress) or 2) 250 g/d of roughage at wk 20 of the fattening period no longer had positive effect on calves' welfare. This last hypothesis is in agreement with our results showing that behavioral differences are greatly reduced or completely absent by the end of the fattening period. We cannot exclude that an ACTH challenge of younger calves might have induced a different cortisol response.

Most hematological values, except for platelets, fall into the normal range for calves (Jain, 1986). In calves, platelets normally range from 192 to 892 (no./mm³ × 10³). Calves fed beet pulp maintained platelet values close to this range throughout the whole fattening period, whereas Control's and calves fed wheat straw showed an increase in platelet numbers that considerably exceeded normal values from wk 18 until the end of the trial. These variations are surprising, because changes in platelet numbers with age are usually minimal (Jain, 1986), and are difficult to explain. We can only hypothesize that they represent a consequence of the variation of other blood components in response to the different feeding treatments, as discussed below.

The decline in the N:L ratio from the beginning to the end of the fattening period, which was observed in all treatments, is in agreement with the results by Stull and McDonough (1994) and reflects the physiological decrease of neutrophils and increase of lymphocytes normally observed in calves during the 1st yr of life (Jain, 1986). The rapid decrease in hematocrit values, together with a reduction in hemoglobin, observed in our experiment (see also Cozzi et al., 2002), is also common in veal calves due to their peculiar feeding plan (Jain, 1986).

McFarlane et al. (1988) found a significantly higher number of WBC in calves with high iron supplementation and, similar to our results, these differences became evident from wk 13 of the fattening period. Reece and Hotchkiss (1987) also found significantly higher WBC numbers in veal calves supplemented with solid feeds (hay and grain). Those authors attributed this difference to a state of immunodepression in calves fed only with milk replacer; lymphopenia and depressed immune response have been reported in iron-deficient humans. According to this interpretation, the higher WBC number observed in calves fed beet pulp probably reflects the higher level of iron in their diet and the related higher hemoglobin values (Cozzi et al., 2002). A possible state of immunodepression in Control calves seems to be confirmed by the higher number of medical treatments received by these calves compared to those fed beet pulp or wheat straw (Cozzi et al., 2002). These results are not consistent with the higher N:L ratio observed in our experiment in calves fed beet pulp. The N:L ratio has been used as an indicator of a stress response by several authors (McFarlane et al., 1988;

Friend et al., 1987; Stull and McDonough, 1994). However, only Stull and McDonough (1994) found significant differences in this ratio among different housing treatments; Friend et al. (1987) found no differences in N:L ratio in response to different housing treatments, and McFarlane et al. (1988) could point out no differences in calves with different iron supplementation. We can suggest that high N:L values may not always be considered as a reliable indicator of immunodepression due to a stressful situation, especially when feeding regimen can affect the blood formula.

In our study, most of the considered hematological values in calves fed beet pulp differed from those of calves on the other two treatments, probably because of the higher bioavailable iron intake (Cozzi et al., 2002) and/or the higher hemoconcentration observed in those calves, which was indicated by the higher hematocrit and Na concentrations observed in their plasma, as well as by the higher hemoglobin levels reported and discussed previously (Cozzi et al., 2002). This higher hemoconcentration might be attributed to the administration of dried beet pulp, which is considered a hygroscopic feed (Ramanzin et al., 1994).

The presence of small or no differences among feeding treatments for eosinophil and monocyte values is in agreement with other studies (Reece and Hotchkiss, 1987; Friend et al., 1987) and confirms that these traits are less important for indicating changes in response to stressful situations (Rushen, 1994).

Results from histological examination of the abomasas were in accordance with the literature (van der Mei, 1985; Welchman and Baust, 1987), suggesting that pyloric ulceration may be related to the diet, especially to the administration of highly fibrous materials. The higher incidence of ulcers in the calves fed the solid feeds, straw in particular, could be due to the fact that straw may exert a mechanically abrasive effect on the mucosa or cause a partial blockage of the pyloric exit, delaying abomasal emptying and rendering the mucosa more susceptible to different factors such as quantity and concentration of milk substitute diet, as suggested by Welchman and Baust (1987). Feeds with less-structured fiber, such as beet pulp, may have a minor abrasive effect, and this probably explains the lower incidence of abomasal lesions observed in the present study in calves fed beet pulp compared to those fed wheat straw. The different results obtained by Veissier et al. (1998), who found no difference in abomasal damage between milk-fed calves and calves receiving straw in addition to the liquid diet, may be due to the fact that straw was provided mixed with a concentrate starting from the 7th wk of age and its administration was preceded by a period during which calves received only the concentrate.

Implications

The results of the present study, in agreement with previous work, suggest that the administration of some

solid feeds to veal calves can help to improve their welfare from the behavioral point of view. Besides the type of fiber (e.g., ADF and lignin) and physical characteristics of roughage (particle size and roughage value), feed volume must also be taken into account, because it is related to the time spent eating. The dose recommended by the EC Directive 97/2 (250 g/d after wk 20) was almost adequate to control the development of abnormal oral behavior when using very fibrous materials (e.g., straw), whose consumption is slow. The same dose is not sufficient for a fibrous concentrate, such as beet pulp, which is consumed very quickly. However, in the assessment of veal calf welfare, it must be taken into account that the incidence of abomasal lesions was increased by the provision of the solid feeds, particularly by a structured fiber source. A solid feed able to satisfy calves' behavioral needs and improve digestive processes without damaging the digestive apparatus still has to be identified.

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