Growth performance, behaviour, forestomach development and meat quality of veal calves provided with barley grain or ground wheat straw for welfare purpose

Giulio Cozzi¹, Flaviana Gottardo¹, Franco Mutinelli², Barbara Contiero¹, Gianluca Fregolent¹, Severino Segato¹, Igino Andrighetto¹

¹ Dipartimento di Scienze Zootecniche, Università di Padova, Italy
² Istituto Zooprofilattico e Sperimentale delle Venezie, Legnaro (PD), Italy

ABSTRACT

Two different feeding plans for veal calves were compared in the study: a traditional liquid diet supplemented with 250 g/calf/d of barley grain or with 250 g/calf/d of ground wheat straw. The two solid feeds had different chemical composition but a similar particle size obtained by grinding the straw in a mill with an 8-mm mesh screen. Twenty-four Polish Friesian male calves were used in the study and they were housed in individual wooden stalls (0.83 x 1.80 m). The health status of all the calves was satisfactory for the entire fattening period and no specific medical treatment was required during the trial. Calves fed wheat straw showed a greater intake of solid feed (196 vs. 139 g/d; P<0.01) and a higher average daily gain (1288 vs. 1203 g/d; P<0.05) than those receiving barley grain. The consumption of milk replacer was not affected by the type of solid feed and no milk refusal episodes were detected. The haemoglobin concentration was similar in calves receiving the two feeding treatments despite the higher iron intake provided by the wheat straw throughout the fattening period (2.12 vs. 1.15 g; P<0.001). It is likely that the iron in wheat straw was less available for the calves’ metabolism. Feeding behaviour was affected by the provision of solid feeds. Eating and chewing were prolonged in calves receiving ground wheat straw and the same solid feed reduced the frequency of oral stereotypies at the end of the fattening period. At the slaughterhouse, no differences were observed between the feeding treatments as regards carcass weight and dressing percentage. The calves fed ground wheat straw had a heavier weight of the empty omasum (518 vs. 341 g; P<0.01) whereas the empty weight of the reticulorumen and abomasum were similar to those of calves fed barley grain. The incidence of abomasal erosions, ulcers and scars was similar in both treatments; however the index of abomasal damage, which considers the number and the seriousness of different type of lesions, was higher in calves receiving barley grain. Therefore, the grinding of straw particles, as opposed to barley grain, can reduce the abrasiveness of roughage at the abomasum level. Visual evaluation of the carcass colour and instrumental measurement of meat colour did not show significant differences between diets. The study confirmed that in the veal calf, carcass and meat colour are not strictly correlated with the iron intake from solid feeds.

Key words: Veal calves, Solid feeds, Behaviour, Abomasal lesions, Meat quality.
Lo studio ha messo a confronto due diversi alimenti solidi: la granella d’orzo e la paglia di frumento forniti in quantità di 250 g/capo/d in aggiunta alla dieta lattea. Gli alimenti avevano simili dimensioni particellari ottenute macinando la paglia con un mulino con griglia di 8 mm; in questo modo si intendeva verificare se una diminuzione delle dimensioni dell’alimento fibroso poteva ridurre l’effetto abrasivo a livello abomasale. La prova di alimentazione ha avuto una durata di 21 settimane e ha utilizzato 24 vitelli Frisoni di ceppo polacco (peso vivo iniziale 60,8 ± 8,7 kg), stabulati in recinti individuali di legno (83 x 180 cm). Gli animali sono stati ripartiti tra le due diete sperimentali (granella di orzo vs. paglia di frumento macinata) sulla base del peso vivo iniziale e il loro programma alimentare ha previsto la distribuzione della dieta lattea in due pasti (07:00 e 19:00) mentre gli alimenti solidi venivano somministrati al mattino a partire dalla 2a settimana di allevamento. Lo stato di salute dei vitelli di entrambe le tesi è risultato eccellente non richiedendo l’esecuzione di trattamenti sanitari di alcun tipo durante l’intero ciclo di allevamento. Il consumo di latte è stato similare tra le due tesi e non si sono mai verificati episodi e rifiuto anche parziale della dose offerta. Il consumo di alimento solido è stato più elevato nei vitelli che ricevevano la paglia macinata (196 vs. 139 g/d; P<0.01) e gli stessi animali hanno presentato un più favorevole incremento ponderale giornaliero rispetto ai soggetti alimentati con la granella d’orzo (1288 vs. 1203 g/d; P<0.05). A questo risultato non è tuttavia corrisposta una più elevata resa alla macellazione ed è quindi ipotizzabile che la somministrazione della paglia abbia portato ad un aumento del contenuto gastro-intestinale. Il comportamento degli animali è stato valutato attraverso una serie di osservazioni individuali eseguite alla 2a, 11a e 21a settimana di allevamento registrando ogni 2 min l’attività svolta dall’animale nell’intervallo di tempo compreso tra le 06:00 e le 20:00 della giornata. La somministrazione della paglia macinata ha prolungato il tempo dedicato dai vitelli all’assunzione dell’alimento solido e alla masticazione. Inoltre, rispetto alla granella, la paglia macinata ha ridotto la manifestazione delle stereotipie orali alline il ciclo di ingrasso. Al macello, il colore della carcassa non è stato diverso tra le due tesi, nonostante la paglia abbia fornito nel corso dell’intero ciclo di allevamento un quantitativo di ferro superiore rispetto alla granella d’orzo (2.12 vs. 1.15 g; P<0.001). Questo risultato, confermato anche dall’andamento dell’emoglobina durante il ciclo di allevamento, conferma la limitata biodisponibilità del ferro in un alimento fibroso come la paglia dove il microelemento risulterebbe legato ai costituenti delle pareti cellulari. La somministrazione della paglia macinata ha stimolato lo sviluppo dell’omaso (518 vs. 341 g; P<0.01), mentre entrambi i solidi hanno eliminato la presenza di pilobezoari a livello ruminale. Il numero di vitelli che presentavano delle lesioni abomasali è stato similare tra le due tesi; tuttavia, il calcolo di un indice di danno abomasale sulla base del numero e della gravità delle diverse lesioni ha visto valori più favorevoli per i soggetti che ricevevano la paglia. Una macinazione della paglia è quindi in grado di ridurre significativamente, rispetto all’orzo, l’effetto meccanico abrasivo a livello della mucosa abomasale senza compromettere la positiva ricaduta fornita dall’alimento fibroso sul benessere del vitello a carne bianca. Considerando l’elevato consumo osservato per questo alimento, ulteriori studi dovranno verificare se la dose di 250 g/d utilizzata in questa ricerca sia sufficiente per soddisfare i bisogni comportamentali del vitello durante l’intero ciclo di allevamento.

**Parole chiave:** Vitello a carne bianca, Alimenti solidi, Comportamento, Lesioni abomasali, Qualità della carne.

**Introduction**

Since the beginning of 1997, a Directive has been in force in EU countries (97/2/EC) which sets a minimum amount of fibrous feed to be provided to veal calves from 8 to 20 wks of age in order to improve their welfare. The “ideal” feed for veal calves should fulfil behavioural and physiological requirements and prevent the occurrence of abomasal lesions producing pale-coloured meat. Several studies have been carried out with the aim of identifying specific solid feeds with these traits (Morisse et al. 1999, Morisse 2000, Cozzi et al., 2001; Cozzi et al., 2002, Mattiello et al. 2002); however, none of the tested concentrates and roughage sources possessed all the required properties.

Among the tested feeds, straw was capable of decreasing abnormal oral behaviours (Mattiello et al., 2002) without detrimental effects on meat colour (Cozzi et al., 2002). However, when compared to a concentrate feed, the same roughage source caused a higher occurrence of abomasal lesions, most likely through the mechanically abrasive effect of its particles on the mucosa of the abomasum (Van Putten, 1982). The abrasiveness of straw could arise from its high fibre content as...
well as from its particle size, when the roughage is coarsely chopped. Therefore, it may be possible to reduce the damage to the abomasal mucosa by grinding straw particles more finely. In the present study, this hypothesis was tested by feeding ground wheat straw to veal calves for the purpose of enhancing their welfare and comparing the effects with those produced by whole barley grain having the same particle size. Calf welfare related to the provision of the two solid feeds was evaluated by measuring growth performance, feeding behaviour, forestomach development and abomasal lesions.

Material and methods

Treatments, animals and management

Two different feeding plans for veal calves were compared in the study: a traditional liquid diet was supplemented with 250 g/calf/d of barley grain (BG) or with 250 g/calf/d of ground wheat straw (WS). The two solid feeds had different chemical composition (Table 1), but their particle size was similar after a single batch of WS was ground in a hammer mill with an 8-mm mesh screen. Five samples of the solid feeds were submitted to mechanical sieving using 6 sieves with a 25, 100, 400, 900, 1600 and 2500 mesh/cm² and their mean geometrical diameter was calculated according to the method proposed by Ensor et al., (1970).

Twenty-four Polish Friesian male calves were used in the study. All the calves (10-12 d of age) were weighed for 2 consecutive days and, based on their average initial body weight, they were assigned to the 2 experimental feeding plans. The calves were housed in individual stalls (0.83 x 1.80 m) and they were not tethered. The stalls were wooden and had a slatted floor; the lateral partitions were provided with fences to allow social contacts between neighbouring calves. All the calves were fed the same milk replacer diet in a bucket with nipple and the daily dose of milk was delivered in two equal meals at 07:00 and 19:00. A second bucket was used for providing the solid feeds, which were delivered after the morning meal. During the fattening period, the daily amount of milk powder and its concentration in the liquid diet were progressively increased from 400 to 3000 g/calf/d and from 10 to 17.6 % respectively. A Starter milk replacer containing 50% skim milk (Table 2) was administered in the first 30 d of the trial. In the following part of the fattening period, calves received a Finisher milk replacer containing 50% skim milk with more fat and less iron than the Starter (Table 2). Both milk replacers were provided by Realvit Italia S.p.A. (Gheld, Italy). No drinking water was provided to the calves during the fattening period.

Samples of milk replacers and solid feeds were collected monthly during the experimental period and analysed for DM, CP, ether extract, ash and

| Chemical composition | Barley Grain | Ground Wheat Straw |
|----------------------|-------------|--------------------|
| DM %                 | 87.7 ± 0.9  | 91.2 ± 1.0         |
| CP % DM              | 11.5 ± 0.6  | 4.8 ± 2.0          |
| Ether extract        | 2.8 ± 0.4   | 0.7 ± 0.1          |
| Ash                  | 2.0 ± 0.1   | 8.3 ± 1.4          |
| NDF                  | 14.8 ± 1.6  | 77.6 ± 5.8         |
| ADF                  | 4.5 ± 0.6   | 47.6 ± 4.5         |
| NFC<sup>a</sup>      | 68.9 ± 2.3  | 5.8 ± 1.7          |
| Iron ppm             | 49.6 ± 5.6  | 68.3 ± 10.2        |
| Roughage value % DM  | 11.8 ± 1.6  | 77.6 ± 5.8         |
| Mean geometrical diameter mm | 7.5 ± 0.1  | 7.7 ± 0.5          |

<sup>a</sup>Non-fibrous carbohydrates.
iron content with AOAC methods (1990). Barley grain and wheat straw samples were also analysed for NDF and ADF content (Van Soest et al., 1991); their nonfibrous carbohydrate content and roughage value were calculated according to the method described by Mertens (1992).

Calves’ daily gain, feed intake and health status

The calves’ average daily gain was calculated by weighing the animals on 2 consecutive days at the beginning and at the end of the experimental period, which lasted 147 d. Individual intake of milk replacer and solid feed was recorded daily. Feed efficiency was calculated by dividing daily gain by DM intake.

The health status of the animals was monitored twice a day at mealtimes; feed refusal and any type of medical treatment were recorded according to the protocol described by Cozzi et al. (2002). Blood samples were taken from all the calves by jugular vein puncture before the morning meal using K3EDTA vacutainer tubes (Becton Dickinson Inson, Meylan Cedex, France) to measure plasma haemoglobin according to the procedure developed by Sigma (1984).

Calves’ behaviour

Direct observations of the calves’ behaviour were carried out at wk 2, 11, and 21 of the fattening period using a scan sampling technique (one scan every 2 min; Martin and Bateson, 1993). Calves were monitored by 3 trained observers for 14 h starting from one hour before the morning meal until one hour after the evening one. The recorded behaviours were: eating, chewing, oral stereotypes (tongue playing and rolling) and non-nutritive oral activities (biting, sucking and nibbling housing structures or buckets).

Slaughter measurements, forestomach development and abomasal damages

At the slaughterhouse, carcasses were weighed and this value was divided by the final weight measured at the farm at the end of the fattening period to calculate individual dressing percentages. Carcasses were graded for conformation and fatness according to the European grading scheme.

| Item                                      | Starter | Finisher |
|-------------------------------------------|---------|----------|
| Feed composition (as-fed basis):          |         |          |
| Spray skim milk powder                    | %       | 50       |
| Whey powder                              | "       | 28       |
| Fat                                       | "       | 15       |
| Soy lecithin                              | "       | 1        |
| Maize starch                              | "       | 3        |
| Dextrose                                  | "       | 1        |
| Vitamin and mineral supplement            | "       | 2        |
| Chemical composition:                     |         |          |
| DM                                        | %       | 94.6 ± 0.2 |
| CP                                        | % DM    | 21.5 ± 0.2 |
| Ether extract                             | "       | 19.9 ± 0.7 |
| Ash                                       | "       | 7.0 ± 0.1  |
| Iron                                      | ppm     | 53.1 ± 3.0 |
|                                            |         | 15.0 ± 0.7 |

Table 2. Feed and chemical composition of the milk replacers used in the study.
A 15-point scale was created by dividing each of the five main classes of EUROP in three subclasses: from 1 = Poor- to 15 = Excellent+ and fatness from 1 = Minimum to 15 = Maximum. An evaluation of carcass colour was made by visual observation of the visible external muscular tissue using the following four point scale: 1 = white; 2 = pale pink; 3 = pink; 4 = dark pink.

Empty forestomachs and abomasas were weighed to assess their development and the number of calves showing hairballs in their rumen was counted. The rumen of the calves was inspected and the consistency of the ruminal content was evaluated using the following categories: 1 = liquid; 2 = pasty and frothy; 3 = thick and firm. The colour of the ruminal mucosa was visually evaluated and the following scores were assigned: 1 for white-yellow; 2 for light brown; 3 for dark brown-grey. The abomasas of the calves were opened and examined for the presence of erosions, ulcers and scars. Histological examination was also carried out on samples collected from gross lesion areas and fixed in 10% neutral buffered formalin. A synthetic index of abomasal damage for each veal calf was calculated on the basis of the evaluation scale proposed by Wiepkema et al. (1987). The individual score was obtained by summing the values attributed to the different number and type of lesions as follows: intact wall = 0; from 1 to 3 erosions = 1; from 4 to 6 erosions = 2; > 6 erosions = 3; per ulcer = 2; per scar = 3.

Meat quality evaluation

Twenty-four hours after slaughter, a joint sample of the m. l. thoracis was collected from the right half carcass of each calf for meat quality evaluation. The sample was excised from 5th rib to the 9th rib, vacuum packaged and stored at 2-4°C in a chilling room for 6 d. Meat pH was measured with a specific electrode (Boccard et al., 1981). Meat moisture content was measured

Figure 1. Intake of solid feed throughout the fattening period in veal calves receiving milk replacer + 250 g/d of Barley Grain (■) or milk replacer + 250 g/d of Ground Wheat Straw (○) for the purpose of enhancing their welfare.
by drying 10 g of sample to a constant weight in a 105°C oven (Boccard et al., 1981). Intramuscular fat content was measured as ether extract (AOAC, 1990). Total pigment content was measured as haematin on fresh meat samples as proposed by Hornsey (1956). A CR 100 Chromometer (Minolta Camera Co. Ltd, Osaka, Japan) equipped with C illuminant was used to measure meat colour in samples exposed for 1 h to air at 2°C. The colour scale adopted was the $L^a*b^*$ of the CIE colour space reference (Honikel, 1998). Cooking weight losses were determined in 2.5 cm thick steaks that had been heated in a water bath at 75°C for 50 min and cooled under running tap water for at least 40 min (Boccard et al., 1981). The instrumental measurement of veal meat tenderness was carried out using a Warner-Blatzer shear meter (Instron Ltd., High Wycombe, UK) on 1.25 cm diameter cylindrical core samples of cooked meat (Honikel, 1998).

### Statistical analysis

Within each of the 3 observation sessions, behavioural data were expressed in terms of frequency, calculated by dividing the number of times a calf was observed to perform a given behaviour by the total number of scans on the same calf (420). The normal distribution of all the variables included in the dataset was tested with the PROC UNIVARIATE of SAS (1989) using the Shapiro-Wilk test. All the tested variables showed values of W>0.80 and they were considered normal and submitted to ANOVA within PROC GLM (SAS, 1989). The linear model considered the effect of the solid feed. The repeated measures option within PROC GLM (SAS, 1989) was used for behavioural and haematological values processing with observation wk and sampling wk taken respectively as repetitions. Scores were analyzed by means of the Wilcoxon two-sample test included in PROC.
Results

Health status and growth performance

The health status of all the calves was satisfactory for the entire fattening period and no specific medical treatment was required during the trial. Calves fed WS showed a higher average daily gain compared to those fed BG. The consumption of wheat straw was greater than barley grain throughout the fattening period (Figure 1), whereas milk replacer intake was similar in both feeding groups (Table 3) and no episodes of milk replacer refusal were detected. Iron intake was lower in BG calves because of the lower consumption of solid feed and the fact that BG is poorer in iron content than WS (Tables 1 and 3). However, the haemoglobin concentration measured in blood samples taken at successive times during the fattening period was always similar in both feeding groups (Figure 2).

Slaughter performance and meat quality

Despite the higher final body weight of WS calves (Table 3), carcass weight and dressing percentage were comparable for both feeding treatments (Table 5). The carcass evaluation showed no differences between diets for EURO, fatness and colour scores (Table 5). Feeding WS significantly increased the weight of the empty

Figure 2. Haemoglobin concentration in veal calves receiving milk replacer + 250 g/d of Barley Grain (––) or milk replacer + 250 g/d of Ground Wheat Straw (- - - - - -) at wk 2, 11, and 21 of the fattening period.

NPAR1WAY (SAS, 1989), while proportions were compared by \( \chi^2 \) calculation.

Behavioural observations and haematological values

A solid feed effect was observed on the overall mean frequency of eating (SEM = 1.9; \( P<0.01 \)) and chewing (SEM = 4.1; \( P<0.01 \)), as shown in Figures 3 and 4 respectively. Nonnutritive oral behaviours were not affected by the feeding treatment (Figure 5), whereas oral stereotypies (Figure 6) showed an increase in calves fed BG only at wk 21 (SEM = 4.5; \( P<0.05 \)). With respect to blood parameters, no differences between dietary treatments were observed during the fattening period (Table 4).
omasum, whereas empty reticulorumen and abomasum weights of WS calves were similar to those of BG calves (Table 6). No hairballs were found in the rumen of calves receiving either treatment and the consistency of ruminal content was also similar, on average pasty and frothy, regardless of the solid feed administered. The provision of BG significantly increased the pigmentation of the ruminal mucosa (Table 6). The number of calves with abomasal erosions, ulcers and scars was similar for both treatments; however the index of abomasal damage, which considers the number and the seriousness of different types of lesions, was higher in BG calves (Table 7).

No difference was observed between BG and WS calves with respect to the chemical composition of meat samples (Table 8). Consistently with the visual evaluation of carcass colour, the instrumental measurement of meat colour did not show

### Table 4. Blood values for repeated measures analysis in veal calves administered different solid feeds to enhance their welfare.

| Item                  | Solid feed          | SEM   |
|-----------------------|---------------------|-------|
|                       | Barley Grain        | Ground Wheat Straw |
| Calves n.             | 12                  | 12    |
| White blood cells x10^9/l | 7.09                | 7.79  |
| Neutrophils %         | 24.6                | 25.4  |
| Lymphocytes           | 62.1                | 61.3  |
| Neutrophils:Lymphocytes Ratio | 0.46              | 0.51  |
| Eosinophils %         | 0.8                 | 0.4   |
| Monocytes             | 11.8                | 12.2  |
| Haematocrit           | 27.8                | 29.1  |
| Erythrocytes x10^12/l | 8.79                | 8.88  |

No difference was statistically significant.

### Table 5. Slaughter performance and carcass evaluation of veal calves administered different solid feeds to enhance their welfare.

| Item                  | Solid feed          | SEM   |
|-----------------------|---------------------|-------|
|                       | Barley Grain        | Ground Wheat Straw |
| Calves n.             | 12                  | 12    |
| Carcass weight kg     | 140.5               | 146.8 |
| Dressing percentage % BW^a | 59.1               | 58.7  |
| Carcass evaluation:   |                     |       |
| EUROP^c Score         | 8.75 ± 1.36         | 9.25 ± 1.54 |
| Fatness^d             | 6.75 ± 1.54         | 6.75 ± 1.54 |
| Colour^e              | 2.08 ± 1.18         | 2.35 ± 1.14 |

^a measured at the farm at the end of the fattening period.

^b Scores compared using the Wilcoxon two sample test.

^c I = Poor .......... 15 = Excellent+.

^d 1 = Minimum .......... 15 = Maximum.

^e 1 = White ...... 4 = Dark pink.

No difference was statistically significant.
any significant difference between diets. Other meat quality traits such as shear force and cooking weight losses were not affected by the provision of the solid feeds (Table 8).

Discussion

The calves used in the present study did not show any specific health problems during the fattening period. No calves of either feeding treatment required any additional administration of iron. However, it must be pointed out that despite the greater amount of iron provided by wheat straw in comparison to barley grain throughout the fattening period (2.12 vs. 1.15 g, P<0.001) the haemoglobin concentration was similar in both groups and its decrease during the fattening period (Figure 2) followed the normal pattern for veal calves fed milk replacer alone (Reece and Hotchkiss, 1987). Therefore, WS calves did not use all the iron provided by this solid feed, probably because of its limited bioavailability. This result is consistent with the previous findings of Cozzi et al. (2002), who observed the effects of wheat straw in comparison to dried beet pulps. The limited iron bioavailability of straw may be due to the binding of the mineral to cell walls (NDF), which can reduce its absorption as shown by Reinhold et al. (1982) and Leigh et al. (1983) in studies on humans.

One of the main concerns of farmers against the provision of small amounts of solid feeds for welfare purpose, is the possible detrimental effect on milk consumption. In the present study, the different types of solid feeds provided to calves (Table 1) did not affect the intake of milk replacer and no episode of milk replacer refusal or bloating was observed during the fattening period. Calves fed WS showed a higher average daily gain than BG calves, however carcass weight, dressing percentage and fatness scores were similar in both feeding groups (Table 5) and therefore, the better growth performances observed for WS calves were mainly due to the greater content of the gastrointestinal tract.

Considering the calves’ behaviour, the provision of wheat straw appears to have increased the time spent eating and chewing, especially at the

Figure 3. Trend in the frequency of eating in veal calves receiving milk replacer + 250 g/d of Barley Grain (---) or milk replacer + 250 g/d of Ground Wheat Straw (---) at wk 2, 11, and 21 of the fattening period.
Figure 4. Trend in the frequency of chewing in veal calves receiving milk replacer + 250 g/d of Barley Grain (◆) or milk replacer + 250 g/d of Ground Wheat Straw (■) at wk 2, 11, and 21 of the fattening period.

Table 6. Empty forestomachs, abomasum weights and rumen measurements of veal calves administered different solid feeds to enhance their welfare.

| Item                                    | Solid feed         | SEM | Significance |
|-----------------------------------------|--------------------|-----|--------------|
|                                        | Barley Grain       |     |              |
| Calves n.                               | 12                 |     |              |
| Empty reticulorumen weight g            | 1898               | 1921| 305          | NS            |
| Empty omasum weight                     | "                  | 341 | 518          | **            |
| Empty abomasum weight                   | "                  | 942 | 911          | NS            |
| Rumen measurements: Calves with hairballs n. | 0                 | 0   | -            | -             |
| Consistency of ruminal content¹ Score  | 1.96 ± 0.66        | 2.33 ± 0.72  | NS           |
| Pigmentation of ruminal mucosa²        | 2.21 ± 0.33        | 1.00 ± 0.00  | ***          |

¹1 = Liquid, 2 = Pasty and frothy, 3 = Thick and firm.
² Scores compared using the Wilcoxon two sample test.
³1 = White-yellow, 2 = Light brown, 3 = Dark brown-grey.
**p < 0.01.
***p < 0.001.
beginning of fattening period (Figures 3 and 4). Both behaviours are naturally present in the ethogram of the bovine and can be observed in young calves from the 3rd wk of age (Swanson and Harris, 1958). However, the frequency of both behaviours was lower in calves fed barley grain, a concentrate feed with a low roughage value, in comparison with those receiving wheat straw, a roughage source rich in structured carbohydrates. To better assess the different time spent by the calves:

| Item | Barley Grain | Ground Wheat Straw | Significance |
|------|--------------|-------------------|--------------|
| Calves: | | | |
| - total | n. | 12 | 12 |
| - with no lesions | " | 3 | 5 | NS |
| - with erosions | " | 9 | 5 | NS |
| - with ulcers | " | 2 | 1 | NS |
| - with scars | " | 6 | 2 | NS |

Index of abomasal damage<sup>c</sup> | Score | 4.58 ± 4.87 | 1.25 ± 1.76 | * |

<sup>a</sup> Proportion compared by χ² calculation.  
<sup>b</sup> The individual score was obtained by summing the values attributed to the different number and type of lesions as follows: intact wall = 0; from 1 to 3 erosions = 1; from 4 to 6 erosions = 2; > 6 erosions = 3; per ulcer = 2; per scar = 3.  
<sup>c</sup> Scores compared using the Wilcoxon two sample test.  
* P < 0.05.
calves of the 2 treatment groups eating and chewing, the overall mean of number of scans was multiplied by 2 (scan interval time). Eating and chewing times of WS calves during the 14 h of observation were on average 26±14 and 90±32 min respectively, while BG calves ate for 8±6 min and chewed for 49±14 min.

The occurrence of oral stereotypies showed an increase in BG calves only during the last observation session (Figure 6). This result is in agreement with a recent study by Mattiello et al. (2002), which showed the limited capability of a concentrate feed (beet pulp) in controlling the incidence of abnormal oral behaviours beyond wk 7 of the fattening period. Therefore, solid feeds that are poor in structured fibre may be not able to fully satisfy the behavioural needs of the growing calf, in particular those related to the fibre allowance. Wheat straw seems to maintain its properties also when it is ground to the same particle size as barley grain.

The provision of ground wheat straw appeared to promote omasum growth to a similar degree as feeding the same roughage coarsely chopped (Cozzi et al., 2002). No calf with rumen hairballs was observed in either feeding group, which confirms the role of solid feeds in continuously removing ingested hair through the stimulation of ruminal motility (Morisse et al., 1999; Cozzi et al., 2002). According to Morisse et al. (1992), the darker pigmentation of the mucosa in the rumen of BG calves may be induced by the increased production of volatile fatty acids resulting from the fermentation of digestible carbohydrates. However, the consequent increase in the energy available to sustain the calves' growth did not result in a more favourable average daily gain, either because of the small amount of cereal consumed by the calves (Figure 1) or because of their lower degree of welfare, as shown by the higher frequency of oral stereotypies.

Feeding WS resulted in a number of calves with abomasal erosions, ulcers and scars comparable to that observed for the BG group, but it decreased the index of abomasal damage.
which takes into account the number and the seriousness of different types of lesions. This finding suggests that the particle size of wheat straw represents a critical factor which can affect the mechanical abrasiveness on the mucosa of the abomasum. Moreover, when straw particles are ground to a size similar to that of a whole cereal grain, their damaging action at the abomasum level becomes lower than that of the grain itself.

Despite the different composition of the two solid feeds compared in the study, meat chemical composition was similar in both treatment groups. Meat colour, which represents the main trait determining the marketability of veal meat, was similar in both groups and therefore it was not affected by the different iron intake of the calves. This result is consistent with that of a previous study (Cozzi et al., 2001), which did not detect any colour difference between veal meat produced by feeding 250 g/d of corn grain or wheat straw to enhance calf welfare. Considering the different iron content of the barley and wheat straw fed to the calves in the present study, it may be confirmed that carcass and meat colour are not strictly correlated with the iron provided by the solid feeds.

**Conclusions**

Calves administered small amounts of barley grain or ground wheat straw to enhance their welfare showed a satisfactory health status and no episode of milk replacer refusal. The two solid feeds had different iron contents but the mineral provided by wheat straw was less available for the calves’ metabolism, resulting in a similar haemoglobin concentration in both treatment groups throughout the fattening period. Despite the similar particle size, eating and chewing were prolonged in calves receiving ground wheat straw and the same feed reduced the frequency of oral stereotypes at the end of the fattening period. The administration of both solid feeds prevented the formation of hairballs in the rumen and the number of calves with abomasal erosions, ulcers and scars was similar in both treatment groups. However, when the number and the seriousness of the same lesions were taken into account accord-
Cozzi et al.

...ing to a specific index of abomasal damage, barley grain appeared to have a more detrimental effect than ground wheat straw. Grinding seems to have reduced the abrasiveness of straw particles at the abomasum level without deleting the positive effects on calves' behaviour. Carcass and meat colour did not show significant differences between diets, thus confirming that in the veal calf they are not strictly correlated with the iron intake from solid feeds. Judging from the results of the present research, ground wheat straw seems an interesting solid feed for enhancing veal calf welfare. However, considering the high intake of this solid feed, further studies should be conducted to verify whether the dose of 250 g/d is sufficient to fully meet the needs of the veal calf.

REFERENCES

AOAC, 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Arlington, VA, USA.

Boccard, R., Buchter, L., Casteels, E., Cozzi, G., Gottardo, F., Mattiello, S., Canal, E., Pesciarelli, A., Cozzi, G., Gottardo, F., Cotté, J.P., Huonnic, D., Verga, M., 2002. The provision of solid feed to veal calves: II. Behaviour, physiology and abomasal damage. J. Anim. Sci. 80:367-375.

Morrissey, J.P., Cotté, J.P., Huonnin, D., 1999. Influence of dry feed supplements on different parameters of welfare in veal calves. Anim. Welf. 8:43-52.

Reeves, W.O., Hotchkiss, D.K., 1987. Blood studies and performance among calves reared by different methods. J. Dairy Sci. 70:1601-1611.

Mortensen, D.R., 1992. Nonstructural and structural carbohydrates. In: H.H. Van Horn and C.J. Wilcox (eds.). Large Dairy Herd Management. American Dairy Science Association, Champaign, IL, USA, pp 219-235.

Mortens, D.R., 1992. Nonstructural and structural carbohydrates. In: H.H. Van Horn and C.J. Wilcox (eds.). Large Dairy Herd Management. American Dairy Science Association, Champaign, IL, USA, pp 219-235.

Swanson, E.W., Harris, J.D., 1958. Development of rumination in the young calf. J. Dairy Sci. 41:1768-1776.

Van Putten, G., 1982. Welfare in veal calf units. Vet. Rec. 111:437-440.

Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wiedema, P.R., Van Hellemmond, K.K., Roosingsh, P., Romberg, H., 1987. Behaviour and abomasal damage in individual veal calves. Appl. Anim. Behav. Sci. 18:257-268.