# The effects of processing of barley-based supplements on rumen pH, rate of digestion and voluntary intake of dried grass in sheep

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1. In one experiment the effect on rumen pH of feeding with restricted amounts of whole or pelleted barley was studied. With whole barley there was little variation in rumen pH associated with feeding time, but with pelleted barley the pH decreased from about 7·0 before feeding to about 5·3, 2–3 h after feeding.

2. The rate of disappearance of dried grass during incubation in the rumens of sheep receiving either whole or pelleted barley was studied in a second experiment. After 24 h incubation only 423 mg/g incubated had disappeared in the rumen of sheep receiving pelleted barley while 625 mg/g incubated had disappeared when it was incubated in the rumen of sheep receiving whole barley.

3. The voluntary intake of dried grass by lambs was studied in a third experiment when they received supplements of either 25 or 50 g whole or pelleted barley/kg live weight$^{0.75}$. At the high level, pelleted barley reduced intake of dried grass by 534 g/kg but whole barley reduced it by only 352 g/kg. The digestibility of acid-detergent fibre was reduced more by pelleted barley than by whole barley but there was a tendency for a small increase in digestibility of the barley due to processing.

4. The implications of these findings on supplementation of roughages with cereals are discussed.

The results of several recent experiments have indicated considerable advantages in giving whole rather than ground or pelleted cereals to sheep (Fraser & Ørskov, 1974; Ørskov, Fraser & McHattie, 1974). Whole barley improved animal health as rumenitis was eliminated (Ørskov, 1973) and the problem of soft fat generally experienced in lambs fed on cereals was considerably reduced (Ørskov, Fraser & Gordon, 1974), while digestibility and animal performance was essentially unaltered.

One of the main differences found between sheep given processed cereals and those given whole cereals is that the pH of rumen liquor is consistently about 1 unit higher with whole grain (Ørskov, Fraser & Gordon, 1974). This finding led us to study the use of whole grain as a supplement to roughages, because one of the problems associated with supplementing roughages with concentrate is the reduction in rumen pH. Low rumen pH is generally associated with a reduction both in cellulose digestion and in voluntary intake of roughages (Lonsdale, Poutiainen & Tayler, 1971). In Expt 1 diurnal changes in pH for sheep given restricted amounts of whole or pelleted barley were studied and in Expt 2 the rate of disappearance of dry matter (DM) from dried grass incubated in the rumen of sheep fed on either pelleted or whole barley was studied. In Expt 3 the voluntary intake and digestibility of dried grass by lambs was measured when the dry grass was supplemented with either whole or pelleted barley.

## MATERIALS AND METHODS

### *Expt* 1

Six Suffolk × (Finnish Landrace × Dorset Horn) lambs, 6 weeks old at the start of the experiment, were allocated to two 3 × 3 Latin squares. The lambs in one 'Latin square' were given a diet based on whole barley and those in the other 'Latin square' were given a diet based on pelleted barley (7·4 mm die). Within each 'Latin square' the lambs received three treatments: no urea or 20 g urea/kg diet either absorbed or adhered to the grain. The results of the effects of the urea treatments on rumen ammonia concentration, and other details, have been reported by Ørskov, Smart & Mehrez (1974). The lambs were given two equal amounts of food daily at 08.00 and 20.00 hours. The rate of feeding was 0·85 of the estimated maximal intake. Samples of rumen contents were obtained from rumen cannulas at intervals after feeding and the pH was determined.

### *Expt* 2

Four mature sheep (70 kg live weight) fitted with large (32 mm) rumen cannulas (McKenzie & Kay, 1968) were used. Two were given a diet based on whole barley and two were given a similar diet pelleted through a 7·4 mm die. The rumen pH values were similar to those found in a previous trial with whole or pelleted barley (Ørskov, Smart & Mehrez, 1974). They were given 1 kg air-dry food/d in two equal feeds. Dried grass containing 198 g crude protein (nitrogen × 6·25)/kg DM was incubated in Dacron bags in the rumen of the sheep. The technique was similar to that described by Schoeman, De Wet & Burger (1972). To assist accessibility by rumen bacteria the dried grass was put through a laboratory hammer mill with no screen attached. For 2 consecutive days four Dacron bags each containing approximately 5 g dried grass were incubated in the rumen of each of the four sheep. They were withdrawn after 6, 12, 18 or 24 h incubation. After rinsing, the residual DM in each of the Dacron bags was determined after their contents had been dried for 48 h at 100°.

### *Expt* 3

Ten early-weaned Suffolk × (Finnish Landrace × Dorset Horn) lambs were allocated to five treatments according to two Latin squares. The 'Latin squares' were not adjusted for carry-over effects because with the length of periods used they were not likely to be important. Chopped, dried grass containing 156 g crude protein (N × 6·25) and 282 g acid-detergent fibre (ADF) (Van Soest, 1963)/kg DM was offered *ad lib.* either alone or with 25 or 50 g whole- or pelleted-barley concentrate/kg live weight$^{0.75}$. The concentrate contained barley and a pelleted premix (900 and 100 g/kg respectively). The premix (4·4 mm die) contained (g/kg): white fish meal 800, limestone 150, molasses 40, trace minerals and vitamins 10. The trace minerals were added to supply (mg/kg diet): 200 $MgO$, 150 $ZnSO_4.7H_2O$, 80 $MnSO_4.4H_2O$, 1 $KIO_3$, 5 $CoSO_4.7H_2O$. Vitamins were added to give (mg/kg diet): 1·5 retinyl palmitate, 0·025 cholecalciferol, 20 DL-$\alpha$-tocopheryl acetate. The concentrate was mixed with the loose,

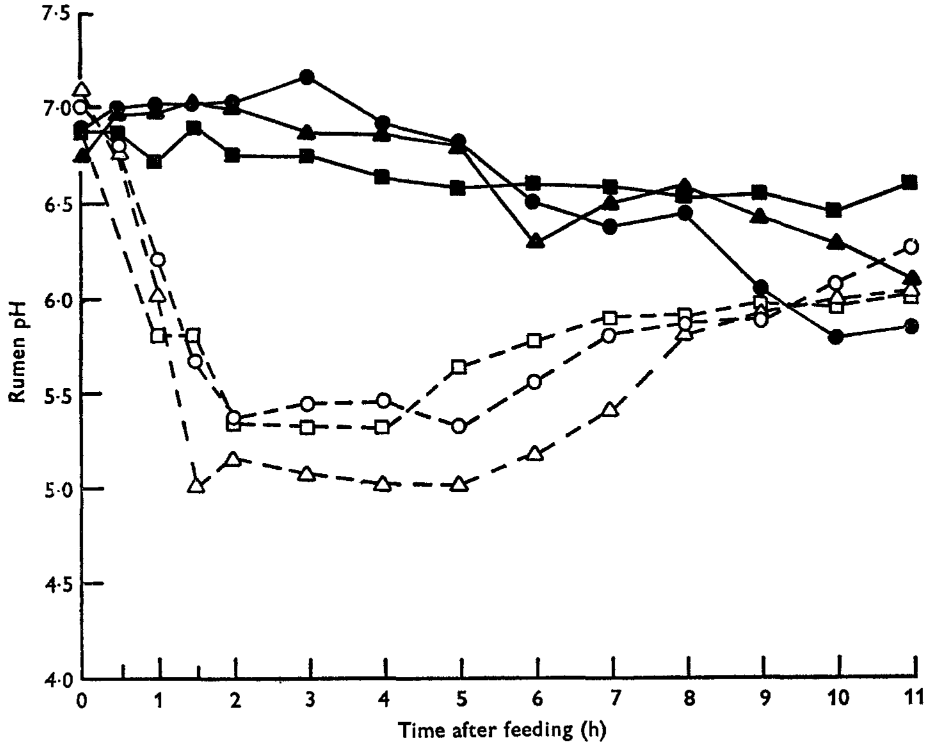


Fig. 1. Expt 1. The effect of feeding whole (———) or pelleted (– – – – –) barley with no added urea (■, □) or with 20 g urea/kg, either absorbed (▲, △) or adhered (●, ○) to the grain, on rumen pH of lambs with time after feeding; for details of experiment, see p. 494. Each point represents the mean value for three determinations.

whole grain or incorporated into the pelleted barley. In the experimental period of 24 d, the faeces were collected for the last 8 d for determination of N, DM, organic matter (OM) and ADF digestibility. The urine was collected into a dilute $H_2SO_4$ solution to ensure a final pH of less than 5. The N content of food, faeces and urine was determined by the micro-Kjeldahl method described by Davidson, Mathieson & Boyne (1970). The ADF content was determined by the method of Van Soest (1963).

## RESULTS

### *Expt* 1

The results of the pH determinations are shown in Fig. 1. The urea treatments had no apparent effect on the changes in rumen pH with time after feeding. Although the results shown in Fig. 1 clearly indicated the differences associated with feeding whole- and pelleted-barley diets, statistical analysis of these results suggested that the variability of the pH values for the pelleted-barley diet was significantly greater ($P < 0·01$) than that for the whole-barley diet.

Table 1. *Expt 2. The proportion of dried-grass dry matter digested (mg/g) after incubation for different periods in the rumens of mature sheep fed on diets containing whole or pelleted barley**

(Mean values for ten determinations)

| Period of incubation (h) | Diet: Whole barley | Diet: Pelleted barley | SE of treatment differences |
|---|---|---|---|
| 6 | 285 | 242 | 36 |
| 12 | 453 | 373 | 11 |
| 18 | 530 | 406 | 20 |
| 24 | 625 | 423 | 23 |

* For details of experimental procedures, see p. 494.

Table 2. *Expt 3. The effect of offering lambs a dried-grass diet* ad lib., *with or without supplements of whole or pelleted barley, on voluntary intake of dried grass and on total intake of dry matter* (DM) *and of digestible organic matter (DOM)**

(Mean values for ten determinations)

| | | Daily intake of dried grass | | Total daily intake (including supplement) | | |
|---|---|---|---|---|---|---|
| Supplement | Level (g/kg $W^{0.75}$ per d) | g DM | g DM/kg $W^{0.75}$ | g DM | g DM/kg $W^{0.75}$ | g DOM/kg $W^{0.75}$ |
| None | | 991 | 67.7 | 991 | 67.7 | 41.3 |
| Whole barley | 25 | 790 | 53.4 | 1100 | 74.0 | 49.1 |
| | 50 | 642 | 42.8 | 1258 | 82.5 | 56.5 |
| Pelleted barley | 25 | 820 | 55.0 | 1129 | 75.0 | 51.0 |
| | 50 | 472 | 32.1 | 1080 | 73.7 | 53.0 |
| SE of treatment differences | | 45 | 3.1 | 44 | 2.6 | 2.5 |

W, live weight.
* For details of diets and experimental procedures, see pp. 494–5.

## *Expt 2*

The results for dried-grass DM disappearance with increasing period of incubation are given in Table 1. For all periods of incubation the proportion of DM digested was greater when the dried grass was incubated in the rumens of the sheep receiving whole rather than pelleted barley. Except at 6 h these differences were significant ($P < 0.001$).

## *Expt 3*

Voluntary food intakes are given in Table 2. Both forms of barley reduced the intake of dried grass ($P < 0.001$). At the low level of supplementation (25 g/kg live weight$^{0.75}$ per d) there was no significant difference between whole and pelleted barley but at the high level (50 g/kg live weight$^{0.75}$ per d) the lambs receiving pelleted barley ate significantly less grass. At the high level of supplementation the intake of dried grass was reduced by 534 g/kg live weight$^{0.75}$ with pelleted barley but by only 352 g/kg live weight$^{0.75}$ with whole barley ($P < 0.001$). These differences influenced the total intake of DM and digestible OM (DOM).

Table 3. *Expt 3. The effect of offering lambs a dried-grass diet* ad lib., *with or without supplements of whole or pelleted barley, on nitrogen balance (g/d) and digestibility (g/kg)**

(Mean values for ten determinations)

| Supplement | Level (g/kg $W^{0.75}$ per d) | N intake | Urinary N | Faecal N | Retained N | Digestibility of: Dry matter | Organic matter | Acid-detergent fibre† |
|---|---|---|---|---|---|---|---|---|
| None | | 24·8 | 10·9 | 9·2 | 4·9 | 689 | 698 | 805 |
| Whole barley | 25 | 27·4 | 12·0 | 9·6 | 5·8 | 694 | 710 | 761 |
| | 50 | 31·3 | 12·3 | 10·2 | 8·9 | 711 | 731 | 733 |
| Pelleted barley | 25 | 28·0 | 11·9 | 9·8 | 6·3 | 713 | 728 | 777 |
| | 50 | 26·7 | 10·0 | 8·4 | 8·2 | 733 | 754 | 675 |
| SE of treatment differences | | 1·1 | 0·6 | 0·5 | 0·9 | 14 | 14 | 21 |

W, live weight.
* For details of diets and experimental procedures, see pp. 494–5.
† As defined by Van Soest (1963).

The N intake and N retention were consistent with differences in DM intake (Table 3). Barley in both forms increased ($P < 0.01$) apparent digestibility of OM which was slightly though not significantly higher with the pelleted than with the whole barley. This was probably a consequence, in part, of the greater proportion of concentrate eaten relative to dried grass. On the other hand digestibility of ADF was reduced as a result of supplementation at the higher level; the reduction was significantly greater for pelleted barley than for whole barley ($P < 0.05$).

## DISCUSSION

### *Effect of processing of cereal on rumen acidity*

The results of Expt 1 indicated very clearly the increased rumen pH and its greater stability when whole rather than processed barley was fed. As referred to earlier, this would be expected to decrease the problem associated with a reduction in cellulose digestion and voluntary intake generally found when roughages are supplemented with concentrate. The present findings were further supported by results obtained by Mann & Ørskov (1975), who showed that while lambs receiving whole barley had on average $1 \times 10^6$ cellulolytic bacteria/ml rumen fluid, lambs receiving pelleted barley had only $5 \times 10^3$/ml rumen fluid.

The results of Expt 2 provided support for the expected effect, with quite large differences in the rate of degradation of dried-grass material when it was incubated in the rumens of sheep receiving whole or pelleted barley.

### *Effect of cereal processing on intake of dried grass*

The results of Expt 3 which indicated the effect on voluntary intake of dried grass when the diets were supplemented with pelleted barley, are in agreement with many reports from the literature. Blaxter, Wainman & Wilson (1961) and Lonsdale *et al.* (1971) found that total intake of DM was not greatly increased when grass was supplemented with barley. Although the results of the present study indicated that there was an increased total intake when the diet was supplemented with pelleted barley at the low level, no further increase in total intake was found at a higher level of supplementation. The results of Expts 1 and 2 indicated that some of the adverse effects of feeding cereals to supplement roughage diets might be reduced if the cereals were not processed. The results of Expt 3 provided ample confirmation of this effect with a much greater reduction in intake of grass when it was supplemented at a high level with pelleted rather than whole barley.

### *Effect of processing on digestibility of dried grass*

There was a significant reduction in digestibility of ADF when dried grass was supplemented with barley concentrate at the high level. This was previously found by Head (1953), MacRae & Armstrong (1969) and Lonsdale *et al.* (1971). The reduction in digestibility of the ADF was less with whole than with pelleted barley. If the ADF is assumed to be the only fraction affected by low rumen pH it is then possible to calculate the effect this had on the DOM content of the dried grass when given with supplements of barley. When whole-barley supplements were given the DOM content of dried grass was calculated to be 683 and 675 g/kg OM with the low and high levels of supplementation respectively. The corresponding DOM contents of dried grass given with pelleted-barley supplements were calculated to be 689 and 657 g/kg OM. These values, when compared to DOM content of dried grass eaten alone (698 g/kg OM), would indicate that the reduction in digestibility of the grass was not very serious. On reflexion this may well be expected because the particle size to which the chopped material had to be reduced in order to traverse the reticulo-omasal orifice probably prevented a large reduction in digestibility. It follows from this hypothesis that if the material had been ground, a greater reduction in ADF digestibility might have been expected. This indeed is supported by the results of Lonsdale *et al.* (1971). Much more serious in terms of the effect on voluntary intake is undoubtedly the decrease in rate of fermentation associated with pH conditions unfavourable for cellulolytic bacteria (see Hungate, 1966). This would result in an increase in rumen retention time and, as a consequence, cause physical restrictions to voluntary intake. The results of Expt 2 indicated, for example, that with the 24 h incubation of dried grass 625 mg DM/g incubated had disappeared in the rumens of sheep fed on whole-barley supplements but only 423 mg DM/g incubated had disappeared in the rumens of the sheep given pelleted-barley supplements.

The greater survival of cellulolytic bacteria when whole rather than pelleted barley was offered at a high level of supplementation apparently permitted a normal rate of fermentation of the dried grass and as a consequence maintained higher intakes.

### *Effect of processing on digestibility of barley*

Using the calculated digestibility ratios for dried grass mentioned previously it was possible also to calculate the partial digestibility of the concentrate because the proportions of each diet eaten were known. The DOM contents of whole barley at low and high levels of supplementation calculated thus were 773 and 790 g/kg OM respectively. The respective DOM contents for the pelleted barley were 833 and 830 g/kg OM. If it is assumed that the digestibility of DM from the dried grass was not affected by the cereals, it is possible to calculate that the DM from whole barley was 55 g/kg less digestible than that from pelleted barley. This small reduction in digestibility is not in agreement with previous work (see Ørskov, Fraser & Gordon, 1974) in which no reduction in digestibility was found with the diet consisting entirely of unprocessed barley. The small reduction in digestibility noted here is, no doubt, a real one because more undigested whole grains were found in the faeces than were found in the earlier work with a diet consisting entirely of whole barley (Ørskov, Fraser & Gordon, 1974). The reason for this is likely to be found in earlier findings (Ørskov, Fraser & Kay, 1969; Thomson & Lamming, 1972), that when hay and concentrate, which have two different particle size distributions, were given together, the rate of passage of concentrate was accelerated with the result that more starch escaped the rumen undegraded. A similar finding was reported by Balch (1950) who found that the rate of passage of ground hay was much greater when it was fed as part of a mixed diet with long hay than if ground hay only formed the diet. The small reduction in digestibility can however be tolerated because of the many advantages the feeding of whole grain affords.

In cattle, whole grains have generally been found to be less digestible than rolled or ground grains (Morrison, 1956). It is possible that a minimum amount of processing, possibly only cracking the surface of the grains to ensure access of bacteria and digestive juices, may combine the advantage of stable rumen conditions with no appreciable reduction in digestibility.

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