Comparative Digestion in Sheep and Cattle Fed Different Forage to Concentrate Ratios at High and Low Intakes

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ABSTRACT

Effect of maintenance and ad libitum intakes on digestibility of different feed fractions was studied with six ruminally fistulated cows and six ruminally fistulated wethers to validate the use of sheep as a model for cattle. Complete diets were made up of ratios of alfalfa:cracked corn and soybean meal of 80:20, 55:45, and 30:70. The regression coefficient of the line relating organic matter digestibility with proportion of concentrate in the diet was smaller for the cows at ad libitum intake than for the other groups. Increasing the intake caused a decrease in digestibility of different fractions. The depression in digestibility was greater for the 30:70 forage:concentrate diet than for the others. At high intake, digestion values in the cows were less than those in the sheep for all diets. An increase in intake depressed the digestion of cell wall fractions and cell solubles including starch in cows, whereas in sheep, an increase in intake reduced cell wall digestion and to a lesser extent cell solubles, without affecting starch digestion. The digestive physiology of these species is sufficiently different to preclude the use of sheep data in formulating nutrient requirements for cows.

INTRODUCTION

Digestion trials are useful because indigestibility accounts for the largest single loss in nutrient utilization by ruminants. Much of the digestion data has been obtained from trials with sheep and assumes that cattle and sheep are equal in their digestive capacity, and that in both species, variations in intake and type of diet produce similar changes in digestibility of energy and other feed fractions. These assumptions are questionable, because differences in digestive capacity between sheep and cattle have been observed since the late 19th century (18). Although a number of trials have been conducted to compare digestive efficiency of cattle and sheep over the past 100 yr, some trials did not involve the same diet for the two species, some did not use similar feed intakes for both cattle and sheep, some reported on two few animals, and in others, comparison was made when the animals were maintained in different environments. Furthermore, the different ways of expressing intake have complicated interpretation of published data.

The results of a detailed statistical analysis of 1912 trials involving 27 feeds (9) indicated that cattle tended to digest dry roughages and silages better than sheep but that sheep tended to digest concentrates better than cattle. Greater digestibility values have been reported for cattle than for sheep fed low and medium quality roughages (7, 24). This difference in digestive efficiency (with high fiber diets) appears to become larger as roughage quality decreases (35). Results with roughages fed at or near maintenance have shown no differences between cattle and sheep in digestion capacity (28). Aerts et al. (1) reported results from 82 digestion trials involving different feedstuffs fed to cattle and sheep at maintenance. Their results showed very small species differences. Wainman (45), using a graphical approach in which sheep digestion data were plotted against cattle data, showed that the greatest differences occurred with mixed diets, where sheep digestion values were higher than those of cattle.

Received August 19, 1988.
Accepted January 11, 1989.
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TABLE 1. Composition (% DM basis) of diets low in concentrate (LC), intermediate in concentrate (IC), and high in concentrate (HC) fed to cows.

<table>
<thead>
<tr>
<th>Ingredients;</th>
<th>LC</th>
<th>IC</th>
<th>HC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopped alfalfa hay</td>
<td>80.00</td>
<td>55.00</td>
<td>30.00</td>
</tr>
<tr>
<td>Cracked corn</td>
<td>16.55</td>
<td>36.45</td>
<td>56.25</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>2.15</td>
<td>6.65</td>
<td>11.24</td>
</tr>
<tr>
<td>Trace mineralized salt</td>
<td>.25</td>
<td>.25</td>
<td>.25</td>
</tr>
<tr>
<td>Monosodium phosphate</td>
<td>1.00</td>
<td>.80</td>
<td>.66</td>
</tr>
<tr>
<td>Limestone</td>
<td>.80</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>Vitamin premix</td>
<td>2.00</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Chemical composition

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>LC</th>
<th>IC</th>
<th>HC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter</td>
<td>92.18</td>
<td>92.94</td>
<td>93.83</td>
</tr>
<tr>
<td>Crude protein (N x 6.25)</td>
<td>17.47</td>
<td>17.18</td>
<td>17.06</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>46.65</td>
<td>35.49</td>
<td>26.04</td>
</tr>
<tr>
<td>Acid detergent fiber</td>
<td>35.16</td>
<td>25.02</td>
<td>15.00</td>
</tr>
<tr>
<td>Lignin</td>
<td>6.56</td>
<td>4.58</td>
<td>2.78</td>
</tr>
<tr>
<td>Starch</td>
<td>9.99</td>
<td>22.15</td>
<td>32.38</td>
</tr>
</tbody>
</table>

1Containing (g/kg): 965 NaCl, 4 Zn, 1.6 Fe, 1.2 Mn, .33 Cu, .07 I, and .04 Co.
2Containing (IU/g): 4400 vitamin A, 1100 vitamin D, and 7700 vitamin E.

The high intake treatment of sheep started when the wethers were 5 mo old, whereas the low intake treatment began when the sheep were 9 mo old. The sheep were kept in individual pens bedded with wood shavings when intake was high. During the digestion trials, they were held in metabolism cages. The animals were maintained in metabolism cages for the duration of the low intake. Water was available ad libitum. At the beginning of the experiments animals were treated with thiabendazole to control helminths, injected intramuscularly with the vitamins retinol and cholecalciferol, and closely shorn at intervals of 2 mo.

Diets and Feeding

**Lactating Cows.** Three diets were formulated to contain different forage:concentrate ratios (Table 1). Chopped second cut alfalfa-grass hay, with alfalfa predominating, was used as the roughage source and will be referred to as alfalfa hay. Hay sufficient for the entire experiment was harvested from one field, chopped, and stored in plastic bags. The chemical composition (% DM basis) of the alfalfa hay was as follows: organic matter 93.0, CP 17.8, NDF 54.6, and ADF 41.6. This basal roughage was mixed with cracked corn and soybean meal to produce mixed diets with the following forage:concentrate ratios: 80:20, 55:
TABLE 2. Composition (% DM basis) of diets low in concentrate (LC), intermediate in concentrate (IC), and high in concentrate (HC) fed to sheep.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>LC</th>
<th>IC</th>
<th>HC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopped alfalfa hay</td>
<td>80.20</td>
<td>55.30</td>
<td>30.25</td>
</tr>
<tr>
<td>Cracked corn</td>
<td>17.70</td>
<td>38.10</td>
<td>58.55</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>2.10</td>
<td>6.60</td>
<td>11.60</td>
</tr>
<tr>
<td>Organic matter</td>
<td>95.08</td>
<td>95.85</td>
<td>96.84</td>
</tr>
<tr>
<td>Crude protein (N x 6.25)</td>
<td>17.19</td>
<td>17.48</td>
<td>17.30</td>
</tr>
<tr>
<td>Neutral detergent fiber</td>
<td>46.16</td>
<td>36.41</td>
<td>25.58</td>
</tr>
<tr>
<td>Acid detergent fiber</td>
<td>34.52</td>
<td>25.18</td>
<td>15.43</td>
</tr>
<tr>
<td>Lignin</td>
<td>6.12</td>
<td>4.37</td>
<td>2.60</td>
</tr>
<tr>
<td>Starch</td>
<td>9.52</td>
<td>20.12</td>
<td>32.93</td>
</tr>
</tbody>
</table>

45, and 30:70. The diets were designated as LC, IC, and HC to denote low, intermediate, and high concentrate, respectively. In addition, a mineral-vitamin mix, specific for each diet, was formulated to meet requirements for Ca, P, and NaCl. Diets were formulated and adjusted for CP, energy, and minerals according to the NRC requirements for lactating cows (30). To formulate isonitrogenous diets, the corn:soybean meal ratio was changed from 8.4:1 for the LC diet to 5.8:1 and 5.2:1 for the IC and HC diets, respectively. The three complete diets were mixed by hand at each feeding time. Lactating cows were fed ad libitum quantities, to a 10% refusal rate, during d 8 to 11 of each experimental period. Feed was offered at 0600 and 1400 h in individual feed trays. Any uneaten food was collected and weighed daily before the morning feeding. Voluntary DM intake was recorded on an individual animal basis.

Dry Cows. These were the same as the lactating cows and they were fed the same diets as described earlier but at the NRC (30) values for maintenance. Feed was offered at 0830 and 1600 h.

Sheep. Sheep and cow diets were similar except that no supplemental mineral mix or vitamins were included in sheep diets. Sheep had continuous access to mineral blocks containing (g/kg): 990.0 NaCl, .04 Co, and .07 I. The components of these diets and chemical composition are shown in Table 2. As with lactating cows, the sheep at the high intake received diets ad libitum during d 8 to 11 in each experimental period. At low intake, the three diets were fed to the same animals according to NRC requirements (29) for maintenance.

Experimental Design and Schedule

The experimental design was selected to measure the effect of species (cows, sheep), intake (low, high), and type of diet (forage: concentrate ratios) on digestibility of different feed fractions. Each diet was offered to each animal within species and intake for 35 d using a 6 animals x 3 periods repeated Latin square design (10), making a total of 72 observations (two 3 x 3 Latin squares for each species at each intake). During each experimental period, the following schedule was employed. 1) Days 1 to 11 were used for the adjustment period. With a design in which three diets were sequentially fed to the same animal, problems were avoided when an animal was changed from LC to HC by introducing diets gradually during the first 4 to 5 d. In addition, the appropriate rumen contents were exchanged between animals on the last day of each period. To establish the ad libitum intake for cows and sheep on high intake, diets were offered in excess of maximum intake (10% refusal allowed) during d 8 to 11. 2) Days 12 to 18 were the preliminary period. From d 12 to 35, feed DM offered was limited to the amount established between d 8 to 11. In the case of cows and sheep at low intake, the maintenance intake applied during d 8 to 11 was continued for the remainder of the period. 3) Days 19 to 25 were used for the digestion trial. The rate of passage
of alfalfa was also determined from d 19 to 25 and will be reported in a subsequent paper, as will be the following. 4) On d 26 to 28, nylon bag experiments (digestion rates) and liquid rate of passage were determined. 5) On d 29 to 33, soybean meal rate of passage was determined. 6) On d 34, rumen samples were taken for pH, osmolality, ammonia nitrogen, and VFA determination. 7) On d 35, direct determination of rumen volume was made.

Fecal Collection

Total fecal collections were made over a 7-d period. The urine from the cows was collected separately from feces using inflatable urethral catheters (Foley Catheter, 75-ml balloon, C. R. Bard, Inc., Murray Hill, NJ). Fecal collections started at 0900 h on d 19 and finished at 0900 h on d 26. Cattle feces were collected in galvanized pans attached to the stalls. Wet feces were weighed to the nearest .1 kg, mixed, and subsampled. Feces were frozen daily and composited over the collection period. Subsamples were dried both at 70°C in a forced-draft oven to estimate DM content and in a freeze-drier for subsequent chemical analysis. Sheep feces were collected daily, weighed to the nearest 1 g in nylon fecal collection bags, and stored at -20°C until the end of the 7-d measurement period. The total fecal output for each animal during the digestion trial was mixed and subsampled for DM determination at 70°C and freeze-dried for subsequent chemical analysis. Feed samples were taken daily during the digestion trials, as were any orts, and composited over the collection period.

Laboratory Methods

All feed, orts, and freeze-dried fecal samples used for chemical analysis were ground in a Wiley mill with a 1-mm screen. Nitrogen was determined in feed, orts, and feces using the standard Kjeldahl procedure with K2SO4 and CuSO4 as catalysts. Organic matter was determined by ashing at 600°C for 24 h and gross energy by adiabatic bomb calorimetry. The NDF (cell wall), ADF, and 72% sulfuric acid lignin were analyzed (nonsequentially) as described by Robertson and Van Soest (38). The enzyme α-amylase (bacterial crude Type XI-A from Bacillus subtilis, Sigma Chemical Co., St. Louis, MO) was used in the NDF procedure to remove the starch. Hemicellulose values were obtained by subtracting ADF from NDF values. Neutral detergent soluble matter (NDS) was estimated by subtracting the NDF values from 100. Starch content was determined by enzymatic hydrolysis of starch to glucose (26). Feces were mixed with double distilled water after which pH was measured within 10 min with a Fisher Accumet pH Meter model 610. The ratios of feces:water were 1:1 and 1:3 for the cows and sheep, respectively.

Statistical Methods

Digestibility of different feed fractions and fecal pH data were analyzed by the general linear model procedures of SAS (40) according to the following complete mixed effects model:

\[ Y_{ijklm} = M + S_i + L_j + (SL)_{ij} + P_{ijl} + A_{ik} + b_{ij}D_{ijklm} + e_{ijklm} \]

where:

- \( Y_{ijklm} \) = observation for the \( k \)th animal with the \( i \)th species, at the \( j \)th intake, in the \( l \)th period, and the \( m \)th diet,
- \( M \) = population mean,
- \( S_i \) = fixed effect of the \( i \)th species,
- \( L_j \) = fixed effect of the \( j \)th intake,
- \( (SL)_{ij} \) = interaction of the \( i \)th species with the \( j \)th intake,
- \( P_{ijl} \) = fixed effect of the \( l \)th period within the \( i \)th species and the \( j \)th intake,
- \( A_{ik} \) = random effect of the \( k \)th animal within the \( i \)th species

Due to heterogeneity of experimental error variances between species, the following regression of the measured parameter on diet (proportion of concentrate in the diet) within species and intake,

\[ D_{ijklm} = \text{proportion of concentrate in the } m \text{th diet within the } i \text{th species and the } j \text{th intake}, \]

\[ e_{ijklm} = \text{random error, } N(O, \sigma^2_e) \]

Due to heterogeneity of experimental error variances between species, the following re-
Figure 1. Relationship between organic matter digestibility and proportion of concentrate in the diet. Slopes of the lines are .312, .262, .300, and .153 (SE .017) for sheep at low and at high intakes and for cows at low and at high intakes, respectively.

Reduced mixed model was used to estimate the variance for each species:

\[ Y_{ijkl} = M + L_i + P_{ij} + A_k + b_{ij} + e_{ijkl} \]

where: M, L, P, A, and D are as defined previously.

A weighted least squares analysis of variance was performed under the complete model, weighting the observation by the inverse mean squared error for each species (13). To test the hypothesis H: all b's equal, the following contrasts among regression terms were used: sheep at low vs. high intake; sheep at high intake vs. cows at high intake; cows at low vs. high intake; and sheep at low intake vs. cows at low intake. The adjusted treatment means for each species within intake and diet were analyzed further with linear contrasts.

RESULTS

Effect of Type of Diet

Digestibility values for DM, organic matter (OM), energy, and NDS were positively and linearly related to the proportion of concentrate in the diet \((P<.005)\) in cows and sheep at both intakes (Table 3, Figure 1). The slope of the line relating OM digestibility with proportion of concentrate in the diet was less for cows at high intakes than for the other groups \((P<.005)\).
The linear relationship with CP digestibility was significant only for sheep at low intake ($P<.005$), while CP digestibility and diet were quadratically related in cows at high intake ($P<.05$). The proportion of concentrate in the diet did not affect the digestibility of starch. However, in cows at high intake, starch digestibility tended to decrease from diet LC to HC. Cell wall (CW) digestibility showed a positive linear relationship with proportion of concentrate in the diet at low intakes in both sheep ($P<.05$) and cattle ($P<.005$) but a negative relationship at high intakes in cows ($P<.005$) (Table 3). In sheep at high intakes, digestibility of CW was not affected by diet. The same trend was observed for hemicellulose (HEM) digestibility. No significant effects as a result of diet composition were apparent for digestibility of ADF (ADF) except for cows at low intake where ADF digestibility varied quadratically with a minimum digestibility value on diet IC ($P<.05$). Fecal pH decreased with increasing proportions of concentrate in the diet of sheep at low intakes ($P<.05$) and other groups ($P<.005$) (Table 3).

### Effect of Intake

**Cows.** Increasing the intake in cows decreased fecal pH and digestibility of all feed fractions in the three diets ($P<.05$) except for ADF for the LC diet. The depression in OM digestibility was greater for the HC diet than for the others ($P<.01$, Table 3), even after correcting for intake differences (Table 4, actual depression in digestibility per unit of intake). The HC diet also exhibited a greater depression in digestibility of CW ($P<.05$), ADF ($P<.01$), and HEM ($P<.05$). Table 4 also shows that the decrease in digestibility was always greater for the HC diet components ($P<.05$), with the exception of nitrogen and starch, which were equally depressed in both IC and HC diets. The intake of OM at ad libitum intake was 2.37, 2.78, and 2.98 (SE = .092) times higher than the intake at maintenance for LC, IC, and HC, respectively (Table 4, relative intake). Relative intake for the HC diet was higher ($P<.001$) than for the LC diet but not than for the IC diet ($P>.1$).

![Table 4: Depression in digestibility of organic matter, CP, starch, NDF, neutral detergent solubles, ADF, and hemicellulose in sheep and cows fed diets low (LC), intermediate (IC), and high (HC) in concentrate (IC), and high in concentrate (HC).](image)

To define which feed fraction contributed the most to the depression in DM digestibility,
TABLE 5. Relative importance of NDF, ADF, hemicellulose, neutral detergent solubles, CP, and starch in accounting for the depression in DM digestibility due to intake in sheep and cattle fed diets low (LC), intermediate (IC), and high in concentrate (HC).

<table>
<thead>
<tr>
<th>Feed fraction (FF)</th>
<th>Sheep</th>
<th>Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LC</td>
<td>IC</td>
</tr>
<tr>
<td>DM</td>
<td>2.4</td>
<td>4.5</td>
</tr>
<tr>
<td>NDF(^1)</td>
<td>67.9</td>
<td>66.8</td>
</tr>
<tr>
<td>ADF</td>
<td>49.2</td>
<td>25.8</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>19.3</td>
<td>42.6</td>
</tr>
<tr>
<td>Neutral detergent solubles</td>
<td>28.0</td>
<td>37.2</td>
</tr>
<tr>
<td>CP</td>
<td>21.5</td>
<td>25.4</td>
</tr>
<tr>
<td>Starch</td>
<td>5.6</td>
<td>6.9</td>
</tr>
</tbody>
</table>

\(^1\)Digestibility of DM at low intake – digestibility DM at high intake.

\(^2\)[(Digestibility of FF at low intake – digestibility of FF at high intake) \times (concentration of FF in the diet)]/[(DMD at low intake – DMD at high intake)].

percentage depression values (uncorrected for intake) were multiplied by the proportion of the feed fraction in the diet and the results expressed as a percentage of decline in DM digestibility (Table 5). In cows, the depression in DM digestibility can be accounted for largely by the corresponding decreases in the digestion of CW (NDF) and cell solubles (NDS). In the LC diet, depression in NDF seems to be more important, but in the IC and HC diets both NDF and NDS are equally affected. Among the fiber fractions, HEM showed the greatest decrease in digestibility. Acid detergent fiber (cellulose and lignin) digestion was affected, but to a smaller degree.

**Sheep.** Increasing the intake did not affect fecal pH or the digestibility of fiber fractions (CW, ADF, and HEM), and NDS (P>.10) of the LC diet. However, for this diet, digestibilities of DM, OM, energy, and starch were less at high intake than at low intake (P<.05, Table 3). In the IC and HC diets, the digestion of all feed fractions was lower at high than at low intakes (P<.01) with the exception of starch for diet HC. As in the case of cows, the extent of digestibility depression of most of the feed fractions seemed to increase with increasing proportions of concentrate in the diet (Table 4). The digestion of CP, NDF, and HEM was more affected by intake in the IC and HC diets than in the LC diet (P<.05, Table 4). Starch digestibility was affected slightly in the LC and IC diets and not at all in the HC diet (Tables 4 and 5).

The results for the three diets indicate that the CW fraction accounted for about 70% of the decline in digestibility of DM when intake was increased (Table 5). Among the fiber fractions, ADF was more affected than HEM in the LC diet. However, HEM digestibility values were more depressed by intake in the IC and HC diets. Cell solubles were also involved in the depression of DMD but to a lesser extent than the CW fractions. Their importance increased from diet LC to diet HC (Table 5). Protein was equally involved in the depression in the three diets.

**Effect of Species**

At high intake, cows digested less OM, energy, CP, starch, and soluble detergent matter than sheep for all diets (P<.001, Table 3). Digestibility of CW was less for cattle than for sheep for diets IC and HC (P<.001). There were no differences in ADF digestibilities between species, but HEM digestibility was less for cattle fed the LC (P<.01), IC, and HC (P<.001) diets. Fecal pH was less for cattle than for sheep for all diets (P<.001).

At the low intake, cattle digested less DM (P<.01), CP (P<.05), and NDS (P<.001) than sheep in diet IC and HC (P<.05). Fecal pH was less for cattle than for sheep in all the diets (P<.001). Other digestion measurements did not significantly differ.
Effect of Type of Diet

The linear relationship between DM, OM, and energy digestibilities with percentage of concentrate in the diet concurs with results reported by other workers in sheep and cattle (3, 23). As concentrates are usually more digestible than roughages, total diet digestibility generally increases with increasing proportions of concentrate in the diet. However, a linear positive relationship between OM digestibility or energy and proportions of concentrates in the diet does not always occur. Even if intake does not change among diets, deviation from linearity may be caused by associative effects between feed components. The different slopes of the lines relating OM digestibility with amount of concentrate in the diet indicates that the effect of concentrate proportions in the diet upon OM digestibility varied with species and intake (Figure 1).

The digestibility of starch was similar for all diets within a given intake. Teeter et al. (43) found that addition of 100 g chopped alfalfa hay per kilogram diet had little effect on starch digestibility in cows eating a whole shelled corn diet at maintenance and 1.8 times maintenance intake. When alfalfa hay was used at 400 g/kg diet (43), starch digestibility was reduced at both intakes. Also, Nordin and Campling (31) observed decreased digestibility of starch by increasing the proportion of hay in the diet from 90 to 440 g/kg of diet. However, it seems important to consider the type of forage and source of starch used when evaluating such results. For instance, Russell et al. (39) observed, as was the case in the present experiment (cows at high intake) reduced starch digestibilities in response to increased dietary starch intake in steers fed mixed diets of corn silage and cracked corn-soybean meal mixture. Starch digestibility averaged 99% in a recalculation of published data of barley, corn, and sorghum starch digestibilities from 15 experiments (46).

The protein digestibility values in cows are consistent with previous results (25, 33). Paquay et al. (33) found that the most important factor affecting N digestibility was N content of the diet, whereas forage:concentrate ratio had no effect.
Figure 2. Relationship between dry matter digestibilities in cows (Y) and in sheep (X) at low (Y = 5.64 + .896X; SE of b = .100) and high (Y = 24.19 + .573X; SE of b = .017) intake. The theoretical equivalence (equiv) line (cows = sheep) is also given.

The lowered fecal pH, observed with increasing the proportion of concentrate in the diet, was probably caused by an increase in the amount of starch escaping digestion in the rumen and small intestine and consequently fermented in the colon and cecum. Digestion of starch in the small intestine may be limited by amylase or maltase activity and by the differentials between rate of digestion and passage through the small intestine (32). In sheep, total VFA concentrations, butyrate molar percentages, and lactic acid concentrations increased in the large intestine with increases in the proportions of corn in a corn-alfalfa hay diet; pH and acetate:propionate ratios were lower (12).

Effect of Intake

The different ways of expressing intake complicates interpretation of published results. In most experiments, intake is reported as related to metabolic body size (body weight to the power .75 or .73), whereas others have preferred to express intake as a percent of body weight or per kilogram of body weight (body weight to the power 1.0). When comparing digestive capacity in ruminant species in which there is a 10-fold difference in body weight, adjustment of intake per unit of metabolic body size might be misleading. In digestion studies, the direct expression (BW 1.0) seems to be more logical to use, since the variation in gut capacity is a function of BW to the power 1.0 (34).

Cows. The greater depression in digestibility (DM, OM, and energy) with increasing intake observed on the high concentrate diet is consistent with previous reports (11, 16). The results of Blaxter and Wainman (6) are different only in that they found the same depression in energy digestibility for different mixed diets made up of 400 to 800 g corn/kg diet. However, Andersen et al. (2) showed a greater digestibility depression from increases in intake in diets that were higher rather than lower in fiber. Also, an effect of intake has not been demonstrated in all experiments in which mixed and all concentrate diets were fed (47).

The depression in DM digestibility with increasing intake has been accounted for by decreases in the digestion of both cell solubles and fiber fractions (36, 41). However, other
workers have related this to depressions in either cell solubles or starch fractions (11, 42). Calculations from data presented by Bonsem-biante et al. (8) indicated that cell solubles and starch utilization accounted for most of the total DMD depression in a mixed diet (whole corn grain:corn stovers ratio of 75:25) fed to growing steers at two different intakes. This agrees with results of Galyean et al. (19) where depression of starch digestion accounted for 76% of the depression in DM digestibility in steers fed an 84% cracked corn diet at one and two times maintenance intake. These contrasting results could be a result of the source of roughage and starch used in different experiments, the magnitude of the intake differences between the low and high intakes, analytical technique used to determine fiber fractions, and mathematical manipulation of the data.

Sheep. The difference in animal age between both groups (5 mo old, high intake; 9 mo old, low intake) does not preclude meaningful comparisons, given that digestion capacity does not seem to be affected by age in sheep older than 3 mo (15).

The depressing effect of higher intakes on digestibility in the sheep are consistent with earlier findings (4, 14, 24, 37). The greatest depressions in digestibility as a result of intake were observed in the present study and in that of Leaver et al. (24) with the high concentrate diet; however, other workers (37) found this in their diet containing the least amount of concentrate. Both the present and the latter study (37) found that the declines in DE as a result of intake were associated mainly with the CW fraction. The report of Robertson and Van Soest (37) agrees with the sheep data presented by El Khidir and Vestergaard Thomsen (17) in which it was shown that increasing intake caused a decrease in OM digestibility of 3.6, 3.4, and 5.8 percentage units in diets with cell wall contents of 24.6, 32.7, and 41.5%, respectively. From their sheep data (17), the following decreases in digestibility values of NDF and cell solubles as a percentage of depression in OMD were calculated: 54.0, 52.4; 85.6, 1.9; and 94.4, 9.1 in the low CW, intermediate CW, and high CW diets, respectively. These values indicate that the fiber fraction was a primary factor in the decline in digestibility in the high and intermediate CW diets. However, in the low CW diet, the cell solubles were as important as the fiber fraction in accounting for the depression in OM digestibility. Also, both HEM and cellulose accounted for most of the variation in OM digestibility depression with increases in intake of a mixed diet of sodium hydroxide treated straw (55%) and corn-SBM (45%) by sheep (14).

Effect of Species

Our results obtained with sheep and cows fed at low intake confirm previous results in which mixed diets were used (6, 20, 25, 44). However, differences in digestibility between sheep and cattle at the same intake treatment (low or high) could be partially related to the slightly different intake (g/kg BW) observed between species (Table 3). At low intake sheep consumed 1.1 times more OM (g/kg BW) than cows fed any of the three diets. At high intake, cows consumed 1.1, 1.1, and 1.2 times more OM than sheep in diet LC, IC, and HC, respectively. Assuming a linear relationship between digestion of different feed fractions and intake, digestion values for sheep were extrapolated to the intake values observed for cows at the low and high intake (corrected digestibility values). Intake uncorrected (observed) and corrected differences in digestibility (percentage units) are shown in Table 6. The differences in digestibility between species using either method are large at the high intake (up to 9%). They increased in magnitude (for most of the feed fractions) from the LC to the HC diet. Another approach to the study of the effect of diet quality on differential digestion capacity between species is to graph cattle digestibility data against sheep digestibility data at low and high intakes. A different distribution of the plotted points in the low and high intake groups is shown in Figure 2. The linear regression coefficient for the low intake group (.891) was very similar to the value of .881 obtained by Mertens and Ely (27) from published digestibilities for cattle and sheep fed the same diets. This graph (Figure 2) indicates that differences in digestive capacity between species are smaller with less digestible diets.

Few comparisons between cattle and sheep fed mixed diets at high intake (2.5 to 3.0 times maintenance) are available. For instance, Kil-
mer et al. (22) found lower DE values in cows than in sheep fed two complete mixed diets at high intake (DM intake as g/kg BW: cows, 27 to 35; sheep, 25). Data from Blaxter and Wainman (5) show a lower digestive capacity in cattle than in sheep fed a diet made up of 2 parts of hay and 1 part of rolled oats at 2.0 times maintenance. A poorer energy by cattle than sheep fed all grain rations (milo and barley) was also observed by Keating et al. (21).

In summary, the depression in digestibility of different feed fractions with increasing intake was greater for cows than for sheep. For this reason sheep cannot be used in digestion trials as accurate models of cows. Moreover, an increase in intake depressed the digestion of CW fractions and cell solubles including starch in cows, whereas in sheep, an increase in intake reduced CW digestion and to a lesser extent cell solubles, without affecting starch digestion (Table 5). The digestive physiology of these species is sufficiently different to preclude the use of sheep data in formulating nutrient requirements for cows, especially at the high intakes which all cows must maintain to support lactation. A comparison of the digestive physiology of these two species is the subject of a subsequent paper.

REFERENCES

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