AD LIBITUM intake of a forage by ruminants has recently been recognized as an important factor reflecting its feeding value. Because many factors which affect intake are incompletely understood, or are currently subjects of research, the procedures for conducting reliable ad libitum intake assays are still being developed. The inherent variability associated with intake is comparatively high and is one of the major factors affecting the precision of intake measurements. The data from a variety of experiments conducted at this Institute over a 6-year period with sheep were used to evaluate the magnitude and consistency of the animal variability encountered: the effects of forage type, processing and environment on the variability; and to estimate the number of animals, per forage, necessary to detect real ad libitum intake differences.

Procedure

Data from 441 determinations of ad libitum forage intake involving 2,427 individual animal/period measurements were available from a variety of experiments. Each of the 441 determinations was: (1) conducted with sheep individually fed the forage being studied plus trace mineralized salt free choice, (2) an average obtained from at least three but in most cases five or six animals, which were of similar age and liveweight, (3) the result of a 1 week assay period following an adaptation period of at least 10 days during which the feed to be assayed was fed ad libitum (fed 5–10% above consumption), and (4) calculated as average gm. dry matter (DM) consumed daily per kilogram of metabolic size ($W^{0.75}$).

In most of the experiments the determination of ad libitum intakes of various forages was the main objective, and the forages were assayed only once, or twice. In a few trials, however, intake determinations were incidental to the main objectives; in these trials from 4 to 12 successive assays were available for some forages, with each forage fed to a given group of sheep throughout.

Grasses, legumes and grass-legume mixtures, each at several stages of maturity, and wheat straw were represented. Types of processing, or physical form, included field cured, artificially dried, ground and pelleted, frozen, or ensiled. Environmental effects were several types of housing: metabolism stalls, individual pens with slatted floors, individual pens bedded with shavings, and sheep housed in groups but tied in stalls for feeding. The recorded intakes ranged from 12 to 149 intake units (gm./$W^{0.75}$ daily).

The animal variability in ad libitum intakes was estimated by computing standard deviations (SD) and coefficients of variation (CV) for each of the 441 determinations. These SD and CV were the raw data studied and means and standard deviations were calculated for the SD and CV of the various groups noted in the previous paragraph.

The distribution of the data (table 1) makes it impossible to determine interaction effects and the assumption of normal distribution should not be made because the data consist of variances. Therefore, it was considered that further statistical analyses of the data were not appropriate. Because of this the data can only indicate possible trends due to forage type, housing or processing.

Using the average SD for the 441 determinations as an estimate of animal variability, the method of Harris et al. (1948) was used to calculate the number of animals required to give an 80% chance to detect expected real intake differences at the 5% level of significance.

Results

The SD of the 441 ad libitum intake determinations averaged 9.7, with a range of values from 0.9 to 40.6. The CV averaged 16.4% with a range of 2.5 to 81.0%.
TABLE 1. THE NUMBER OF INTAKE ESTIMATES ARRANGED BY TYPE OF FORAGE, PROCESSING METHOD, AND ANIMAL ENVIRONMENT

<table>
<thead>
<tr>
<th>Forage type</th>
<th>Environment</th>
<th>Field cured</th>
<th>Artificially dried</th>
<th>Frozen</th>
<th>Pelleted</th>
<th>Silage</th>
<th>Straw</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>Metabolism stalls</td>
<td>..</td>
<td>32</td>
<td>9</td>
<td>6</td>
<td>..</td>
<td>..</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>Pens—slatted floors</td>
<td>18</td>
<td>..</td>
<td>..</td>
<td>22</td>
<td>35</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pens—shavings</td>
<td>16</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stalls and yard</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>Legume</td>
<td>Metabolism stalls</td>
<td>..</td>
<td>17</td>
<td>14</td>
<td>3</td>
<td>..</td>
<td>..</td>
<td>144</td>
</tr>
<tr>
<td></td>
<td>Pens—slatted floors</td>
<td>30</td>
<td>3</td>
<td>3</td>
<td>..</td>
<td>18</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pens—shavings</td>
<td>24</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stalls and yard</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>6</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>Grass-legume mixture</td>
<td>Metabolism stalls</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>77</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>Pens—slatted floors</td>
<td>30</td>
<td>..</td>
<td>..</td>
<td>6</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pens—shavings</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stalls and yard</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Metabolism stalls</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pens—slatted floors</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>3</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pens—shavings</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>19</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stalls and yard</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>118</td>
<td>52</td>
<td>32</td>
<td>86</td>
<td>138</td>
<td>15</td>
<td>441</td>
</tr>
</tbody>
</table>

Forage Type. Intake variability was only slightly affected by forage type. The SD for intakes of grasses and legumes were similar while the SD for grass-legume mixtures was substantially higher. When the SD was expressed as a percent of the mean (CV), however, only relatively minor trends were evident with CV for legume intakes somewhat lower than for grasses and grass-legume mixtures intermediate (table 2).

Housing. The SD for determinations in metabolism stalls and in individual pens with slatted floors were somewhat smaller than those for individual pens with bedding and for exercise yards with tie stalls. The CV determinations made in metabolism stalls were lowest, those for determinations in exercise yards—tie stalls highest, and those for determinations in individual pens intermediate (table 3).

Physical Form. The SD for pelleted forages was higher than those for other physical forms, whereas the remaining SD were similar (table 4). CV for intakes of frozen forages were smallest, but differed only slightly from those of field cured or artificially dried forages. CV for intakes of straw and silages were highest with those of pelleted forages intermediate.

All of the trends associated with forage type and housing were of a minor nature and not likely to seriously affect the precision of measurements of intake. The higher variabilities associated with straws, silages and pelleted feeds may be of concern, but further work is required to determine if the trends noted herein are real.

Successive Assays of the Same Forage. Except for silages, for which intakes were low in the first assay period, the mean intakes showed no evidence of either an increasing or decreasing trend associated with repeated as-

TABLE 2. VARIABILITY IN DAILY AD LIBITUM INTAKE (gm./W0.75) ASSOCIATED WITH FORAGE TYPE

<table>
<thead>
<tr>
<th>Forage type</th>
<th>No. of determinations</th>
<th>Standard deviation</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>S.D.</td>
</tr>
<tr>
<td>Grass</td>
<td>138</td>
<td>7.7</td>
<td>1.5–26.7</td>
</tr>
<tr>
<td>Legume</td>
<td>144</td>
<td>5.8</td>
<td>2.1–27.9</td>
</tr>
<tr>
<td>Grass-legume mixture</td>
<td>125</td>
<td>13.9</td>
<td>3.1–40.6</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>34</td>
<td>6.7</td>
<td>0.9–14.1</td>
</tr>
<tr>
<td>Aggregate</td>
<td>441</td>
<td>9.7</td>
<td>0.9–40.6</td>
</tr>
</tbody>
</table>
**AD LIBITUM FORAGE FOR SHEEP**

**TABLE 3. VARIABILITY IN DAILY AD LIBITUM INTAKE (gm./W0.75) ASSOCIATED WITH ENVIRONMENT**

<table>
<thead>
<tr>
<th>Environment</th>
<th>No. of determinations</th>
<th>Standard deviation</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean Range S.D.</td>
<td>Mean Range S.D.</td>
</tr>
<tr>
<td>Metabolism stall</td>
<td>81</td>
<td>8.2 3.2-26.7 4.34</td>
<td>11.5 3.4-31.2 5.70</td>
</tr>
<tr>
<td>Individual pens—slatted</td>
<td>97</td>
<td>7.4 1.5-27.4 4.11</td>
<td>19.4 3.9-81.0 13.95</td>
</tr>
<tr>
<td>floors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual pens—shavings</td>
<td>245</td>
<td>11.1 0.9-40.6 7.52</td>
<td>16.2 2.5-45.0 8.39</td>
</tr>
<tr>
<td>Exercise yards and stalls</td>
<td>18</td>
<td>10.8 5.1-27.9 6.60</td>
<td>25.9 5.8-40.5 9.82</td>
</tr>
<tr>
<td>Aggregate</td>
<td>441</td>
<td>9.7 0.9-40.6 5.57</td>
<td>16.4 2.5-81.0 9.89</td>
</tr>
</tbody>
</table>

says of the same forage with the same animals (table 5). The SD and CV indicate that repeated assays are of no value in reducing animal variability. Moreover, the changes in variability from period to period showed no consistent pattern and appeared to fluctuate at random.

**Discussion**

These data show relatively large animal variabilities in *ad libitum* forage intake. There is, however, a striking lack of uniformity in the variability itself, e.g. irrespective of the breakdown of the data, or the category presented, there was a wide range in values for both SD and CV. Even when the same sheep were fed the same forage for several successive weekly periods the animal variabilities, as well as intakes, were inconsistent from week to week. Except for silage, a 10-day pre-assay period appears adequate when sheep adjust to a new forage under *ad libitum* conditions. Blaxter *et al.* (1961) reported a 9–12 day pre-assay period necessary for hays when feed intake was adjusted on a percentage basis.

There are remarkably few reports of animal variabilities associated with forage intakes which are based on metabolic bodyweight. Crampton *et al.* (1960) reported a CV of 13% associated with intake (gm./W0.75) when three early-cut, chopped legume hays were fed to five sheep each. Blaxter *et al.* (1961) also reported a CV of 13% associated with intake (gm./W0.75) when three grass hays of poor, medium and good quality, were each fed to five sheep. In a study of several pure grass swards, each cut at several stages of maturity and frozen, Minson *et al.* (1964) found a CV of 10.5% associated with intake (gm./W0.75). The agreement between the findings of these widely separated laboratories and the general findings reported herein are remarkable, especially since the data in this

**TABLE 4. VARIABILITY IN DAILY AD LIBITUM INTAKE (gm./W0.75) ASSOCIATED WITH PHYSICAL FORM OF FORAGE**

<table>
<thead>
<tr>
<th>Physical form</th>
<th>No. of determinations</th>
<th>Standard deviation</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean Range S.D.</td>
<td>Mean Range S.D.</td>
</tr>
<tr>
<td>Field cured</td>
<td>118</td>
<td>8.5 2.3-27.4 4.52</td>
<td>13.9 4.6-44.5 6.19</td>
</tr>
<tr>
<td>Artificially dried</td>
<td>52</td>
<td>8.0 4.0-22.4 3.37</td>
<td>12.4 5.2-31.2 5.50</td>
</tr>
<tr>
<td>Frozen</td>
<td>32</td>
<td>7.7 3.2-27.9 5.81</td>
<td>10.3 3.4-32.1 7.27</td>
</tr>
<tr>
<td>Pelleted</td>
<td>86</td>
<td>17.6 4.0-40.6 8.70</td>
<td>16.1 3.3-45.0 9.22</td>
</tr>
<tr>
<td>Silage</td>
<td>138</td>
<td>7.1 0.9-20.3 3.40</td>
<td>21.0 2.5-81.0 12.84</td>
</tr>
<tr>
<td>Straw</td>
<td>15</td>
<td>8.2 5.7-14.1 2.20</td>
<td>23.8 15.4-37.1 6.68</td>
</tr>
<tr>
<td>Aggregate</td>
<td>441</td>
<td>9.7 0.9-40.6 5.57</td>
<td>16.4 2.5-81.0 9.89</td>
</tr>
<tr>
<td>Item</td>
<td>Forage</td>
<td>Period</td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------</td>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>Intake (gm./W&lt;sup&gt;0.75&lt;/sup&gt;)</td>
<td>Mixed hay (chopped)</td>
<td>1</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Mixed hay (pelleted)</td>
<td></td>
<td>141</td>
</tr>
<tr>
<td></td>
<td>Timothy hay</td>
<td></td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Oat silage</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Alfalfa silage</td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>S.D.</td>
<td>Mixed hay (chopped)</td>
<td></td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>Mixed hay (pelleted)</td>
<td></td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>Timothy hay</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Oat silage</td>
<td></td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>Alfalfa silage</td>
<td></td>
<td>15.6</td>
</tr>
<tr>
<td>C.V.</td>
<td>Mixed hay (chopped)</td>
<td></td>
<td>11.9</td>
</tr>
<tr>
<td></td>
<td>Mixed hay (pelleted)</td>
<td></td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>Timothy hay</td>
<td></td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Oat silage</td>
<td></td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>Alfalfa hay</td>
<td></td>
<td>35.6</td>
</tr>
</tbody>
</table>
paper demonstrate that animal variability in a
given determination may deviate greatly from
the general averages.

With a tropical forage cut daily and fed
fresh in amounts up to 30% above consump-
tion, Butterworth (1965) found a variability
in intake (gm./W $^{0.75}$) of approximately 7%.
This somewhat lower variability might be due
to the forage species, the form in which it was
fed, or it might only be one of the occasions
which deviates from the general average.
Ingalls et al. (1965) fed four forages cut at
several stages of maturity to four sheep in
4 x 4 latin square experiments. They stated,
"The coefficient of variation for daily DM
intake per kilogram of bodyweight by the 4
sheep ranged from 0.7 to 3.2 gm." Because a
coefficient of variation is by definition a frac-
tional value (SD divided by mean) and is
usually expressed as a percent (Snedecor,
1956), it is apparent that the stated figures
do not represent coefficients of variability and
therefore their (Ingalls et al., 1965) statement
of variability cannot be properly compared
with the results presented herein.

Voluntary intake has achieved general rec-
ognition as an important factor reflecting for-
age quality and has been accepted as a meas-
ure which may be used in the determination
of forage feeding value. However, the relative
importance of intake as such a measure may
currently be overestimated. Relative intake
and digestibility of a forage account for ap-
proximately 70% and 30% respectively, of
the numerical value of the proposed nutritive
value index (NVI) because calculations of
NVI reflect the greater magnitude of intake
differences compared to digestibility differ-
ences with no regard to the larger errors en-
countered in intake measurements (Crampton
et al., 1960). Other workers have also pointed
out that intake differences among experi-
mental forages are commonly two and one-
half times as great as the digestibility differ-
ences of the same forages (Ingalls et al.,
1965). However, there is also a large disparity
in the precision with which these two entities
can be determined. Real apparent digestibility
differences of 4 percentage units can be reli-
ably detected with three to four sheep, and
real differences as small as 2 percentage units
can be reliably detected with eight to eleven
sheep, (Raymond et al., 1953). By contrast,
11 sheep per forage will not reliably detect
real differences of 10 intake units (which
agrees with calculations reported by Minson
et al., 1964) and the number of sheep required
to detect differences of five units is prohibitive.
It becomes apparent that while the magnitude of the differences in forage intake may be two and a half times as great as differences in digestibility of the same forage, the intake measurements are less precise. Thus, while intake is unquestionably a valuable indicator of forage quality, further research is required to establish its relative importance compared to other indicators such as digestibility.

Further research is also required to determine, (a) if variability in intake measurements can be significantly reduced by such techniques as pre-trial selection of the experimental animals to eliminate extremes of both intake and liveweight, latin square designs, longer experimental periods etc., and (b) if a reduction in variability in the test animals would provide a better prediction of forage feeding value in view of the fact that high variability in intake appears to be an inherent characteristic of the general sheep population.

In addition to variability, little is known of the effects of such factors as level of selection allowed, wide variations in liveweight or physiological state of the animals, the relationship of the intake of a forage mixture to the intakes of the components of that mixture determined separately, or of the effect of concentrates in the ration on the intake of the forage.

In practice, use of intake as a factor in assessing forage quality may eventually prove worthwhile only for grazing animals, or it may prove to have general value in all instances where forages are included in ruminant rations. It is probable the true situation will fall somewhere between these two extremes. Until more is known of the limitations of intake, and of the interrelationships involved, workers should exercise caution when applying intake as a factor for assessing forage feeding value.

Summary

Standard deviations (SD) and coefficients of variation (CV) were calculated from 441 determinations of ad libitum forage intake involving 2,427 individual animal/period measurements expressed as gm./W^{0.75} daily. The data include various species of grasses, legumes, grass-legume mixtures and straw; various physical forms: frozen, artificially dried, field cured, ensiled and pelleted; several environments: metabolism stalls, individual pens and group housed but tie-stall fed. Animal variability was high with an average SD of 9.7 and an average CV of 16.4%.

Forage Species. No marked between species variation occurred. SD ranged from 6.7 to 13.9 and CV from 14.9 to 19.1%.

Physical Form. SD were similar (7.1–9.7) for all forage types except pelleted (17.6). CV ranged from 10.5–16.4% except for silage (21.0%) and straw (23.8%).

Environment. SD for metabolism stalls (8.21) and slatted-floor individual pens (7.4) were lower than for bedded individual pens (11.1) and group housed but tie-stall fed (10.8). CV for metabolism stalls (11.5%) were lowest, individual bedded (16.2%) and slatted-floor (19.4%) pens intermediate and group housed but tie-stall fed (25.9%) highest.

Repeated assays on the same forage by the same animals did not reduce animal variability. The SD and CV were not consistent from period to period but appeared to fluctuate at random.

Estimates of the number of sheep required to give an 80% chance to detect intake differences at P=.05 show that 10 to 15 sheep are required per forage to detect real differences of approximately 10 intake units.

Literature Cited


