The energy and protein requirements of pregnant and lactating dairy goats
The Agriculture and Food Research Council report

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Abstract

The basis for the recently published estimates of the requirements of lactating goats for metabolisable energy (ME) and metabolisable protein (MP) in the Agriculture and Food Research Council Report [Agriculture and Food Research Council Report (AFRC), 1998. The Nutrition of Goats. CAB International, Wallingford, UK] are presented and the values are compared with the earlier estimates of allowances from the Institut National de la Recherche Agronomique [Institut National de la Recherche Agronomique (INRA), 1988. Alimentation des Bovins, Ovins, et Caprins. INRA, Paris; Institut National de la Recherche Agronomique (INRA), 1989. Ruminant Nutrition: Recommended Allowances and Feed Tables. Jarrige, R. (Ed.), John Libbey, London] in terms of Unite Fourragère Lait (UFL) and Protéines Digestibles dans l’Intestin (PDI). It is concluded that good agreement exists between the recommendations for the energy and protein requirements of lactating goats for maintenance, milk production and LW change but there are serious differences regarding pregnancy. Principal areas of uncertainty or disagreement were identified as: composition of live weight change (LWC), particularly protein; ME and MP requirements for pregnancy; and activity factors.

Résumé


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1. Introduction

The energy and protein requirements of ruminants in the UK are described in terms of metabolisable energy (ME, Agricultural Research Council (ARC, 1980) and metabolisable protein (MP, Agriculture and Food Research Council (AFRC, 1992) respectively. These were summarised and set in a more practical format in AFRC (1993). These publications concentrate primarily on cattle and sheep though with some references to goats, particularly in AFRC (1993) which included a preview of some of the main points published later in AFRC (1998). The AFRC recognised that there were no comprehensive recommendations for goats in the UK and set up a Technical Committee on Responses to Nutrients (TCORN) Working Party to remedy this omission. The Working Party reported the results of their review in 1998 in TCORN Report No.11, The Nutrition of Goats (CABI, Wallingford, UK).

To achieve its objective the Working Party reviewed the literature, particularly research reports, relating to goat nutrition in temperate zones. One question was whether the basic framework for determining energy and protein requirements, which had been developed largely for cattle and sheep, could be applied also to goats. The results of the literature survey were then compared with the earlier recommendations for cattle and sheep. In the present paper the final outcome of these deliberations is set out and is compared with the recommendations of Institut National de la Recherche Agronomique INRA (1988, 1989) which are in the form of allowances rather than requirements as in AFRC (1998). This comparison presents few problems in terms of protein since MP and Protéines Digestibles dans l’Intestin (PDI) are essentially similar units. However it is more difficult in terms of energy since the UK systems are based on metabolisable energy while the INRA system is based on net energy expressed in terms of Unité Fourragère Lait (UFL) which is defined as 1700 kcal (or 7.11 MJ) net energy for lactation (NE_L). Values for NE_L were converted to ME assuming an efficiency of 0.63.

The topics covered in the Report are: Composition of Products, Digestive Physiology, Feed Intake, Energy, Protein, Vitamins and Minerals, and Production of kids, milk and fibre. The present paper covers the energy and protein requirements of pregnant and lactating dairy goats.

2. Lactation cycle

The lactation cycle of goats is very similar to that of cows and is summarised in INRA (1988). Milk yield reaches a maximum 1–2 months after parturition and then declines. Live weight falls rapidly to a minimum about 6 weeks after parturition and then slowly recovers until a rapid increase in the last 3 months of pregnancy. Feed intake increases more slowly than milk production to a maximum at about 8 weeks after parturition and then declines slowly until the third month of pregnancy when it stabilizes. One result is that, as with dairy cows, dairy goats experience a period of negative energy and nitrogen balance during the early weeks of the lactation cycle. The efficient rationing of the dairy goat at this stage of lactation therefore requires accurate knowledge of the extent and composition of tissue mobilisation.

3. Feed intake

It was concluded that the INRA Unités d’Encombrement Laitières (UEL) system should form the basis of predicting the feed intake of adult goats. This reflected in part the lack of reliable information on the subject relating specifically to goats, a problem recognised by the French authors also.

4. Calculations of requirements

Information required to allow the calculation of requirements for energy and protein in terms of the UK system is:
requirements in terms of net energy (NE) and net protein (NP)
efficiency factors to convert NE and NP into ME and MP
the above information is required for maintenance, milk production, live-weight change (LWC) and pregnancy

In calculations and examples below, the assumptions are those adopted in AFRC (1998):

- 65 kg Saanen-type multiparous goat
- milk contains 37 g fat and 29 g total protein (26 g true protein)/kg
- pregnant with twins later in the lactation cycle
- the diet has a metabolisability, q value (ME/GE) of 0.6 equivalent to 11.3 MJ ME/kg DM

5. Efficiency factors

From a review of the limited information available for goats, it was decided that the efficiency factors calculated for sheep and cattle for converting ME and MP to NE and NP respectively in ARC (1980) and AFRC (1992) could also be applied to goats. For energy and protein respectively the factors are: for maintenance 0.71 and 1.00; for milk production 0.63 and 0.68; for LW gain 0.60 and 0.59; and for pregnancy 0.13 and 0.85. The values for energy efficiency are based on a standard lactation diet with a q value (ME/GE) of 0.6. Variations in these energy efficiency factors with changes in q are described in ARC (1980). The INRA UFL system uses almost identical efficiency factors, (predicted from dietary q values) as does ARC (1980), to convert dietary ME values to NE lactation values (NE_L) and then to UFL as kg of barley.

6. Maintenance

Estimates of maintenance requirements for energy can be derived from measurements of basal metabolism of fasted animals by calorimetry or from feeding trials in which animals are fed at several different levels of intake. Nine estimates of fasting metabolism of adult goats were found. The mean value of 315 (sd 21.4) kJ/kg W^{0.75}/d compared well with the value in ARC (1980) of 319 kJ/kg W^{0.75}/d for cattle but was markedly higher than the values of 215–230 kJ/kg W^{0.75}/d for sheep. From 17 feeding trials, a mean value of 438 kJ ME/kg W^{0.75}/d (sd 10.9) was calculated. This agrees well with the value of 441 kJ ME/kg W^{0.75}/d that can be calculated from the value for fasting metabolism at a diet q value of 0.6. INRA (1988) base their recommendation of 0.0384 UFL/kg W^{0.75}/d on a value of 273 kJ NE_L/kg W^{0.75}/d. This is equivalent to 434 kJ ME/kg W^{0.75}/d which is very close to value adopted in AFRC (1998).

Based on the considerations above, the maintenance energy requirements (for the ‘standard goat’ described above) can be calculated to be 9.9 MJ ME/d from INRA (1988) and 10.2 MJ ME/d from AFRC (1998).

Maintenance requirements must be enhanced by a factor for activity. Goats are very active animals and estimates of that energy cost vary widely. Recommendations by National Research Council (NRC, 1981) and Morand-Fehr et al. (1987), which were summarised in AFRC (1998), are shown in Table 1. Agreement amongst the estimates is reasonable but their reliability remains uncertain due mainly to the difficulty of quantifying activity itself. Estimates of maintenance requirements in AFRC (1998) and INRA (1988) include a factor for activity estimated for housed goats.

Both INRA and AFRC give similar estimates of

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<tr>
<th>Table 1</th>
<th>Estimates of the cost of activity as % above maintenance</th>
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<td>Pasture</td>
<td>25</td>
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<tr>
<td>Good range</td>
<td>30–50</td>
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<tr>
<td>Poor range</td>
<td>50</td>
</tr>
<tr>
<td>Mountainous</td>
<td>75</td>
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the maintenance requirements for protein as 53 g PDI or MP/d, although derived by different methods. The AFRC estimate is based on the same basic principles and values as those for cattle and sheep described in AFRC (1993) with a value for Basal Endogenous N of 0.35 g/kg W^{0.75} /d plus dermal losses. The INRA estimate is based on N balance results at 2.5 g PDI/kg W^{0.75} /d.

7. Milk production

From a survey of milk composition of UK dairy goat breeds, it was concluded that two basic types of milk needed to be considered (Table 2). The protein values are in terms of total protein (IR analysis calibrated against N × 6.38), not true protein (IR analysis calibrated against ‘noir amido’) as in France (H. Rulquin, pers. comm.). True protein was estimated to represent 0.9 × total protein in goats milk in AFRC (1998).

From the published information, the ME requirements for the production of milk from Saanens and Anglo-Nubians respectively would be 4.5 and 5.2 MJ/kg according to AFRC (1998) and 4.6 and 5.4 MJ ME/kg according to INRA (1988). These are in good agreement. It should be noted, however, that the UK ME system includes a ‘level of intake’ correction factor which assumes that ME requirements are increased by 1.8% for every increase of one multiple of maintenance above maintenance (ARC, 1980; AFRC, 1998). This correction becomes appreciable for high-yielding goats which may be consuming diets at 3–4 times maintenance. INRA (1988) did not include a feed intake correction factor in the calculation of the energy requirements of goats.

The MP requirements would be 38 and 47 g/kg for the two breeds yielding milk with 29 and 36 g total protein/kg respectively according to AFRC (1998). INRA (1988) recommend a value of 45 g PDI/kg for a goat giving 29 g true protein/kg for which AFRC (1998) would recommend 42 g MP/day, slightly lower than INRA. INRA does not recommend adjusting the MP ration for different milk protein values within the normal range for Saanen-type goats (D. Sauvant, pers. comm.). However, on a pro rata basis the value for Anglo-Nubians would be 50 g PDI/kg.

8. Live-weight change

AFRC (1998) adopted the INRA (1988) values for live weight (LW) loss or gain in lactating goats with minor modifications. Thus it was assumed that goats lose 1.0 kg/week for the first 4 weeks of lactation but none in weeks 5–8 compared with losses of 0.5 kg/week adopted by INRA (1988). It was further assumed that they gain 1.2 kg/month from the fourth month (2.2 kg/month for primiparous goats). These assumptions modify the animal’s energy and protein requirements during lactation, depending on whether nutrients are being mobilised from or stored in the body.

The important question then is the composition of the LW change. ARC (1980) adopted a NE value of 23.9 MJ/kg for LW gain and loss in cattle and sheep and, after a review of the literature, AFRC (1998) accepted the same value for goats. This is slightly lower than the values recommended for goats by INRA (1988) which are 3.7 UFL/kg (26.3 MJ NE₇kg/kg) for loss and 3.9 UFL/kg (27.7 MJ NE₇kg/kg) for gain.

Values for Net Protein changes are less easy to quantify on the basis of LW change and the composition of that change. AFRC (1998) suggested that the value of 138 g NP/kg LW change adopted for

<table>
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<td>Composition of the milk of the two main groups of UK dairy goats</td>
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<tr>
<th></th>
<th>Fat g/kg</th>
<th>Total protein g/kg</th>
<th>Lactose g/kg</th>
<th>Net energy a MJ/kg</th>
<th>Net protein b g/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saanen/Toggenburg</td>
<td>37</td>
<td>29</td>
<td>44</td>
<td>2.8</td>
<td>26</td>
</tr>
<tr>
<td>Anglo-Nubian</td>
<td>47</td>
<td>36</td>
<td>43</td>
<td>3.4</td>
<td>32</td>
</tr>
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a Calculated from the equation of Tyrrell and Reid (1965) for dairy cows.
b Total protein × 0.9.
cattle and sheep in AFRC (1992) be adopted for goats also. However neither AFRC (1998) nor INRA (1988) used this approach for calculating their recommendations for MP or PDI requirements. The INRA (1988) recommendations are based on measured N balances from basic work in France on protein mobilisation and retention, rather than the extent and N content of LW change. They suggested the acceptance of maximum deficits of 85 PDI g/d in week 1 and 25 g/d in week 2 with balance being the target in week 3. They further recommended that an allowance of 4 g PDI/d be added from the fourth month for multiparous goats (13 g/d for primiparous goats). AFRC (1998) proposed the adoption of deficits of 30 g MP/d for the first 4 weeks (giving a very similar total to the INRA recommendations) and an additional 4 g MP/d allowance for LW gain from month 4 as in INRA (1988).

9. Pregnancy

Relying mainly on studies with sheep in the absence of reliable information from goats, AFRC (1998) proposed that the demands of the third, fourth and fifth months of pregnancy respectively amounted to 0.18, 0.43 and 0.82 MJ NE/d or 1.38, 3.31 and 6.31 MJ ME/d for energy and 6.1, 14.6 and 27.4 g NP/d or 7, 17 and 32 g MP/d for protein. INRA (1988) propose no additional allowance for the third month but for the fourth and fifth months respectively they recommend increases equivalent to 0.12 and 0.23 UFL/d (0.85 and 1.63 MJ NE/d) or 1.35 and 2.59 MJ ME/d for energy and 31 and 62 g/d PDI (MP) for protein. Thus AFRC recommendations are much higher than those of INRA for ME and much lower for protein.

10. Summarised requirements

Both INRA (1988) and AFRC (1998) provide tables of recommendations for the energy and protein rationing of goats yielding different amounts of milk and at various stages of the lactation cycle based on the factors described above. A summary is set out in Table 3 and is based on Tables 14.1 and 14.2 in INRA (1988) and Tables 8.5 and 8.6 in AFRC (1998). It should be noted that AFRC (1998) is giving estimates of minimum requirements, with no safety margin added, whereas INRA (1988) define their estimates as allowances, not minimum requirements.

Estimates of the ME recommendations for maintenance are higher in AFRC (1998) than INRA (1988) due mainly to the inclusion of a larger factor for activity. This difference also contributes to the higher AFRC values for the lactating and the pregnant goat. For the lactating goat the ‘level of feeding’ factor noted above also contributes to the higher value in AFRC. Estimates of the recommendations for MP (PDI) for maintenance are in good agreement. For the lactating goat, both sources assume a value of 29 g milk protein/kg but, as already discussed, this is as total protein in the UK and true protein in France and this difference largely accounts for the lower MP recommendations for the lactating goat in AFRC (1998). For the pregnant goat, AFRC recommendations are much higher than those of INRA for ME and considerably lower for

| Table 3 | Summary of the published recommendations for energy and protein rationing of a 65-kg lactating Saanen-type goat at three stages of lactation from INRA (1988) and AFRC (1998) |
|-----------------|-----------------|-----------------|-----------------|
| | Energy* | AFRC | Metabolisable Protein |
| | UFL/d | ME MJ/d | ME MJ/d | UFL/d | ME MJ/d | ME MJ/d |
| Maintenance | 0.84 | 9.5 | 11.5 | 53 | 53 |
| Yielding 4 kg milk/d<sup>a</sup> | 2.38 | 26.9 | 30.6 | 215 | 206 |
| Dry and 5 months pregnant | 1.07 | 12.1 | 20.6 | 115 | 95 |

<sup>a</sup> Assumptions for converting UFL to ME are described in the text above.
<sup>b</sup> Assuming zero body energy change and N balance.
MP, reflecting the large differences in estimates of the requirements for pregnancy noted above.

11. Conclusions

It is concluded that good agreement exists between the recommendations by INRA (1988) and AFRC (1998) for the energy and protein rationing of lactating goats for maintenance, milk production and LW change but there are serious differences regarding pregnancy. Principal areas of uncertainty are:

- composition of LW change, particularly protein
- ME and MP requirements for pregnancy
- activity factors

Acknowledgements

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