# An estimate of the nutrients utilized for live-weight gain by Merino sheep

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1. One hundred and seven fine-wool Merino wethers and non-pregnant ewes varying in age from newly born to 110 months and in live weight from 1·7 to 55·1 kg were slaughtered and minced.

2. The nitrogen, fat, ash, calcium, phosphorus, sodium and potassium contents of the mince were determined. Energy content was estimated from the contents of fat and fat-free organic matter.

3. Weighted regression relationships were calculated between the energy, N, Ca, P, Na and K contents of the sheep, and age, live weight and (age × live weight). The relationships were differentiated with respect to age and live weight, and the rates of nutrient deposition at different rates of live-weight gain, and for sheep differing in age and live weight were calculated.

4. The rates of nutrient deposition were compared with those estimated by the Agricultural Research Council (1965) and by Mitchell (1962), and were in general lower in energy content and higher in ash constituents per unit live-weight gain.

The Agricultural Research Council's (1965) estimates of the nutrients required for live-weight gain by sheep were calculated from information on the chemical composition of a number of sheep and on the availability of the nutrients of their diet. Complete analysis of sheep are relatively few in number; some of the determinations were made more than 50 years ago (e.g. Lawes & Gilbert, 1859, 1883) and some of the sheep were from fat lamb and mutton breeds (e.g. Mitchell, 1962) which might be expected to differ in composition from the late-maturing Merino.

In the present study fifty-three Merino wethers and fifty-four unmated ewes were slaughtered and analysed chemically to provide estimates of the nutrients required for live-weight gain. This study complements an earlier report on the chemical composition of the Merino foetus (Langlands & Sutherland, 1968).

## EXPERIMENTAL

The sheep were selected from a fine-wool Merino flock based on 'Havelah' blood, and had been born and reared at pasture. They ranged in age from newly born to 110 months, and were selected from the 5000 sheep available to cover as wide a range in live weight at each age as possible. The range in live weight was from 1·7 to 55·1 kg. The sheep were shorn, fasted overnight and slaughtered with a captive bolt pistol. Live weights were determined immediately after slaughter, the contents of the gastro-intestinal tracts were then removed and weighed, and the carcasses including the gastro-intestinal tracts, skins, and blood were sealed in polythene bags, and stored at −12°.

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The frozen carcass was processed by the procedures described by Morris & Moir (1964). In brief, the carcass was cut with a band saw into cubes with sides of approximately 10 cm, and was then passed twice through a 'Jeffco Cutter Grinder' (Size 10, Model 262, Jeffress Foundry Pty. Ltd, Brisbane, Queensland) fitted with a 1 cm aperture plate. The carcass was weighed before and after mincing, and again after mixing in a dough mixer. All precautions necessary to minimize loss of material and to ensure that the final sample was representative of the composition of the animal were observed and have been described in detail by Morris & Moir (1964). Samples of mince were sealed in polythene bags and stored at −20° until analysed.

Subsamples of approximately 20 g were freeze-dried for 48 h, and then extracted with di-isopropyl ether to provide estimates of fat content. N was determined in the fat-free samples by the Kjeldahl procedure; other subsamples of approximately 200 g were ignited at 590° for 24 h for the determination of ash content. Ca was estimated by an oxalate–permanganate method (Association of Official Agricultural Chemists, 1955) on ashed samples. The Na, K and P contents of the ash were determined by the techniques described by Langlands & Sutherland (1968).

The energy content of twelve samples of fat and twelve samples of fat-free organic matter from sheep varying in age and weight was determined by bomb calorimetry. The mean value for fat was 9·30 ± 0·12 kcal/g and for fat-free organic matter 5·43 ± 0·08 kcal/g. These factors were used to compute the energy contents of all sheep.

## RESULTS

The live weights and ages of the sheep used in this experiment are shown in Fig. 1 together with the growth curve of the Shropshire ewes studied by Mitchell (1962).

The intestinal contents averaged 9·3 ± 5·4% of the live weight, and this percentage did not change significantly with live weight. Values for newly born lambs were excluded from this calculation.

Table 1. *Mean values for the chemical composition per kg live weight of fine-wool Merino ewes and wethers with corresponding values given by the Agricultural Research Council* (1965) (*ARC*). *Simple correlations with age* (*r*) *are also given*

| | | Ewes | | Wethers | |
|---|---|---|---|---|---|
| | ARC | Mean and standard deviation | *r* | Mean and standard deviation | *r* |
| Age (months) | — | 20·2 ± 33·0 | — | 24·3 ± 36·6 | — |
| Live weight (kg) | — | 17·9 ± 10·6 | +0·83 | 23·9 ± 16·0 | +0·61 |
| Energy (kcal/kg) | — | 1951 ± 589 | — | 2279 ± 1330 | — |
| Nitrogen (g/kg) | 24–25 | 25·3 ± 2·6 | −0·23 | 23·5 ± 3·9 | −0·20 |
| Ash (g/kg) | — | 39·3 ± 3·4 | −0·17 | 39·5 ± 7·0 | +0·16 |
| Calcium (g/kg) | 8·9 | 12·3 ± 1·3 | +0·11 | 12·9 ± 2·7 | +0·26 |
| Phosphorus (g/kg) | 5·0 | 7·05 ± 1·07 | −0·23 | 7·37 ± 1·72 | +0·10 |
| Sodium (g/kg) | 1·4 | 1·18 ± 0·28 | +0·18 | 1·19 ± 0·28 | +0·20 |
| Potassium (g/kg) | 1·6 | 1·97 ± 0·33 | −0·24 | 1·71 ± 0·42 | −0·21 |

*r* is significant at $P < 0·05$ when $r > 0·23$, and at $P < 0·001$ when $r > 0·44$.

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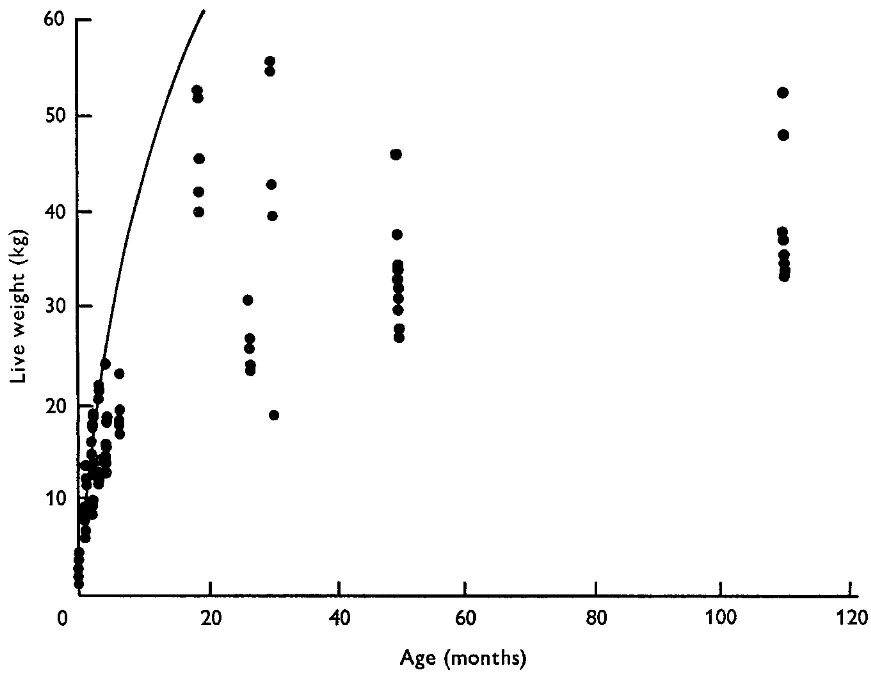


Fig. 1. Live weights and ages of the Merino sheep used and the growth curve of the Shropshire ewes studied by Mitchell (1962).

Table 2. *Weighted partial regression coefficients and coefficients of determination* ($r^2$) *for multiple regression equations relating total energy, nitrogen and mineral contents of the sheep to age* (*months*), *live weight* (*kg*) *and* (*age × live weight*)

| Dependent variable | Intercept | Age | Live weight | (Age × live weight) | $r^2$ |
|---|---|---|---|---|---|
| Energy (kcal) | −5764 | −1445*** | 2737* | 36·56*** | 0·89 |
| Nitrogen (g) | 117·028 | 4·422*** | 22·755*** | −0·121*** | 0·96 |
| Ash (g) | 20·530 | 12·691*** | 35·003*** | −0·296*** | 0·97 |
| Calcium (g) | 5·284 | 4·269*** | 11·139** | −0·0922*** | 0·96 |
| Sodium (g) | 0·9827 | 0·5484*** | 0·9712*** | −0·0117*** | 0·93 |
| Potassium (g) | 0·3932 | 0·4933** | 1·7891*** | −0·0148*** | 0·92 |
| Phosphorus (g) | 3·9505 | 2·1067*** | 6·4335*** | −0·0505*** | 0·94 |

Significance of regression coefficients: *$P < 0·05$, **$P < 0·01$, ***$P < 0·001$.

The mean values for chemical composition per unit live weight are given separately for ewes and wethers in Table 1 together with the values accepted by the Agricultural Research Council (1965). With the exception of Na content per unit live weight, our mean values for mineral composition were greater than those of the Agricultural Research Council (1965). Differences between sexes were small.

Multiple regression analysis was used to relate changes in total energy, N and mineral contents of the sheep to age and live weight. A number of functions of age and live weight were examined as independent variables, but were discarded because they were not consistently significant. In subsequent analyses energy, N and mineral

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Table 3. *Energy and nitrogen, calcium, phosphorus, sodium, and potassium content per kg live-weight gain in Merino sheep varying in age and live weight for rates of live-weight gain of (a) 50, (b) 100 and (c) 200 g/day*

| Live weight (kg) | Age (months) | Energy (kcal/kg) | | | Nitrogen (g/kg) | | | Calcium (g/kg) | | | Phosphorus (g/kg) | | | Sodium (g/kg) | | | Potassium (g/kg) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c | a | b | c |
| 5 | 0·5 | 1921 | 2339 | 2548 | 25·2 | 24·0 | 23·3 | 13·6 | 12·4 | 11·7 | 7·64 | 7·03 | 6·72 | 1·29 | 1·13 | 1·05 | 2·06 | 1·92 | 1·85 |
| | 1·5 | 1960 | 2377 | 2586 | 25·1 | 23·8 | 23·2 | 13·5 | 12·3 | 11·6 | 7·59 | 6·98 | 6·67 | 1·28 | 1·12 | 1·04 | 2·05 | 1·91 | 1·84 |
| 15 | 1·0 | 2198 | 2487 | 2631 | 24·4 | 23·5 | 23·1 | 13·0 | 12·0 | 11·5 | 7·28 | 6·83 | 6·61 | 1·21 | 1·08 | 1·02 | 1·96 | 1·86 | 1·82 |
| | 4·5 | 2333 | 2622 | 2766 | 23·9 | 23·1 | 22·6 | 12·6 | 11·7 | 11·2 | 7·11 | 6·66 | 6·43 | 1·17 | 1·04 | 0·98 | 1·90 | 1·81 | 1·77 |
| 25 | 10·0 | 2802 | 2962 | 3042 | 22·5 | 22·0 | 21·8 | 11·5 | 10·9 | 10·5 | 6·49 | 6·21 | 6·07 | 1·02 | 0·94 | 0·90 | 1·72 | 1·68 | 1·66 |
| | 40·0 | 3959 | 4119 | 4199 | 18·8 | 18·4 | 18·1 | 8·8 | 8·1 | 7·8 | 4·98 | 4·69 | 4·55 | 0·67 | 0·59 | 0·55 | 1·28 | 1·24 | 1·22 |
| 35 | 12·0 | 3136 | 3168 | 3184 | 21·4 | 21·4 | 21·3 | 10·7 | 10·4 | 10·4 | 6·05 | 5·94 | 5·88 | 0·92 | 0·88 | 0·85 | 1·60 | 1·60 | 1·61 |
| | 48·0 | 4524 | 4556 | 4572 | 17·1 | 17·0 | 17·0 | 7·4 | 7·1 | 6·9 | 4·24 | 4·12 | 4·07 | 0·50 | 0·46 | 0·43 | 1·06 | 1·07 | 1·07 |
| 45 | 12·0 | 3393 | 3296 | 3248 | 20·6 | 21·0 | 21·1 | 10·1 | 10·1 | 10·1 | 5·72 | 5·77 | 5·80 | 0·85 | 0·84 | 0·83 | 1·50 | 1·55 | 1·58 |
| | 48·0 | 4781 | 4685 | 4636 | 16·3 | 16·6 | 16·8 | 6·8 | 6·8 | 6·7 | 3·90 | 3·95 | 3·98 | 0·42 | 0·42 | 0·41 | 0·96 | 1·02 | 1·05 |
| 55 | 12·0 | 3650 | 3425 | 3312 | 19·8 | 20·6 | 20·9 | 9·5 | 9·8 | 9·9 | 5·38 | 5·60 | 5·72 | 0·77 | 0·80 | 0·81 | 1·40 | 1·50 | 1·56 |
| | 48·0 | 5038 | 4813 | 4701 | 15·5 | 16·2 | 16·6 | 6·2 | 6·4 | 6·6 | 3·56 | 3·79 | 3·90 | 0·35 | 0·38 | 0·39 | 0·86 | 0·97 | 1·03 |

contents of all sheep were related to age, live weight and (age × live weight). Each observation was weighted (Williams, 1959) inversely to the weight of dry mince because the residual variation of each observation was a function of the quantity of mince. The weighted regression coefficients and coefficients of determination are given in Table 2.

The weighted regression relationships were differentiated with respect to age and live weight and the coefficients given in Table 2 were used to calculate the composition of the live-weight gain of sheep varying in age, live weight and rate of gain. A number of these values is given in Table 3. Values for other rates of live-weight gain may be calculated from equation (1):

$$y = a+[b/c]+d([e/c]+f), \tag{1}$$

where $y$ is the instantaneous rate of change in nutrient content in g/kg or kcal/kg live-weight change, $a$, $b$, and $d$ are the weighted regression coefficients for live weight, age and (live weight × age) respectively (Table 2), $c$ is the rate of live-weight gain in kg/month, and $e$ and $f$ are the live weight (kg) and age (months) of the sheep.

Energy content per unit live-weight gain increased, and N and mineral contents declined, with increasing age and live weight.

## DISCUSSION

Nutrient requirements for live-weight gain can be calculated from Table 3 by multiplying the rate of nutrient storage by the reciprocal of the availability of the nutrient under examination. The availability may vary with the feed. In Australia, sheep are maintained almost exclusively on pasture, and estimates of the availability of metabolizable energy for fattening were reported for a number of temperate pasture species by Armstrong (1964). Net efficiency for fattening could be calculated from digestibility or lignin content and ranged from approximately 40 to 60% when expressed in terms of metabolizable energy. The appropriate factor for calculating energy requirements for live-weight gain in terms of metabolizable energy would therefore range from 2·5 to 1·7 for these grasses. For the two herbages with organic matter digestibilities of 70% cut in spring and autumn by Corbett, Langlands, McDonald & Pullar (1966), the factors were 2·3 and 3·1 respectively. These factors may also vary with the age of the animal and the previous and current nutritional regime, but insufficient information is available. Similar considerations probably apply to other nutrients. The Agricultural Research Council (1965) adopted factors of 1·54 for available N, 2·22 for Ca, 1·25–1·67 for P depending on the age of the animal, and 1·0 for Na and K.

The most detailed analyses of sheep are those of Mitchell (1962) with the Shropshire breed. He related the energy, protein, Ca and P contents ($y$) of his sheep to age ($x$) by equations of the form, $y = A-Be^{-kx}$ where $A$, $B$ and $k$ are constants. From these equations he calculated the daily gains in live weight and nutrient content. Predicted energy contents per kg live-weight gain at live weights of 9, 26, 43 and 60 kg were calculated to be 3330, 3700, 4230 and 5000 kcal respectively. These values are similar to those adopted by the Agricultural Research Council (1965), which were 2500, 4000



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and 4800 kcal for growing lambs, fattening sheep aged 6–12 months and adult sheep respectively, but are higher than some of the estimates calculated in the present study. Our values for the N content of the Merino are also lower than those of the Agricultural Research Council (1965) and Mitchell (1962). The Agricultural Research Council (1965) adopted values of 25 g N/kg live-weight gain for sheep weighing less than 40 kg and 24 g for heavier sheep, while Mitchell's results range from 24 g N at a live weight of 9 kg to 31 g at a live weight of 60 kg. The estimates in Table 3 decline with increasing age and live weight, the highest value being 25 g. Our estimates refer specifically to fleece-free live-weight gain. Under grazing conditions wool production in this strain of Merino ranges from 4 to 12 g clean wool per day, which is equivalent to approximately 0·6 to 1·9 g N daily.

The Agricultural Research Council (1965) adopted a value of 8·9 g Ca and 5 g P/kg live-weight gain irrespective of age, breed or live weight of the sheep although Mitchell's values indicated that both the Ca and P contents of live-weight gain increased with age. In our study estimated Ca and P contents of the live-weight gain declined with age and live weight, the range in values in Table 3 being from 13·6 to 6·2 g/kg live-weight gain for Ca and from 7·6 to 3·6 g/kg live-weight gain for P. The Ca:P ratio was similar for the Merino and Shropshire, most values falling within the range of 1·7 to 1·8. The values adopted by the Agricultural Research Council (1965) for the Na and K content of live-weight gain in sheep were 1·4 and 1·6 g/kg live-weight gain respectively. Our values for Na content are lower while the ARC values for K fall within the range given in Table 3.

Differences in the rates at which the Shropshire and Merino mature may explain some of the differences between our results and those of Mitchell (1962). The Merino, and particularly the fine-wool strain used in these studies, is late maturing and does not fatten readily, while the Shropshire is heavier, early maturing and at a given age might be expected to synthesize tissue containing more fat and energy and less bone than the Merino. For this reason we believe our estimates to be more appropriate to the Merino than those derived by the Agricultural Research Council (1965), which were based largely on studies with British breeds of sheep. Differences in the proportion of live-weight gain attributable to gut fill may also explain some differences between our results and the Agricultural Research Council (1965) recommendations. In this study gut fill averaged 9% while in the studies summarized by the Agricultural Research Council (1965) values as high as 20% were recorded. Calculations based on Table 3 would overestimate nutrient requirements if gut fill accounted for 20% of live-weight gain. The sheep used were deliberately selected for this study to provide a wide range in age and live weight, and no information was available on the rate of live-weight gain at any age. The estimates given in Table 3 might be refined if rates of growth of the sheep at different ages were available or if relationships were derived with sheep over a restricted range in live weight or age. Such an analysis was not feasible with the results available, and may not be justified until nutrient availability can be estimated with greater precision.

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