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ESTIMATION OF THE ENERGY VALUE OF EWE MILK

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Summary

Energy, fat, protein, and lactose were determined in 68 samples of milk obtained from Merino ewes 3 to 77 days post-partum. Energy, fat, total solids and solids-not-fat were determined in 24 samples from Border Leicester ewes 30 to 60 days post-partum. Several relationships between these variables were calculated.

For Merino milks, the intercepts of relationships between energy (Y, kJ/100 g) and fat (F, per cent w/w) differed significantly between two stages of lactation (D, days), probably owing to the increase in protein and decrease in lactose with time, but did not differ when D was included as a second independent variable. The resulting equation for all Merino milks was similar to one of the same form for Border Leicesters, and the equation for both breeds was:

$$Y = 32.80F + 0.25D + 220.33 \qquad (RSD \pm 14.02)$$

Energy of milk analysed in an independent study was predicted satisfactorily by this equation, and by equations relating energy to total solids, or to fat and solids-not-fat (RSD $\pm$ 10.17 and 9.87 kJ/100 g respectively) but derived from the results for Border Leicester milk only. Other equations, including two published previously, gave biased predictions.

I. INTRODUCTION

The nutritional value to the lamb of the milk it consumes is determined primarily by the energy content, which is also an index of the amount of feed used by the ewe for lactation. Analysis of milk by bomb calorimetry is very time-consuming, and this paper reports equations for predicting energy content.

II. MATERIALS AND METHODS

Three groups (15, 16 and 16) of fine-wool Merino ewes grazing *Phalaris tuberosa/Trifolium repens* pastures at densities of 30, 20 and 10 per ha respectively were milked as described by Corbett (1968) on one day, when they were, on average, 27 days post-partum (range 3 to 42 days). Five weeks later, 7 ewes from each of the three groups were milked again when 52 to 77, mean 65, days post-partum.

A 50 ml sample of milk from each ewe preserved with 12 mg mercuric

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oxide plus 53 mg potassium dichromate* was stored in a refrigerator until analysed for fat by the Gerber method, total nitrogen, and lactose, as detailed by Corbett (1968). Approximately 4 g milk was freeze dried for combustion in an adiabatic bomb calorimeter; the usual corrections were made for the acids formed during the combustion.

Similar methods were used to obtain 24 measurements of daily yields, and fat and energy contents, of milk from Border Leicester ewes. Ten ewes grazing at a low stocking density were each milked on two or three occasions during days 30 to 60 of lactation, and samples were preserved by freezing (–20°C). Protein and lactose were not determined, but total solids was measured by drying 1 g quantities at 90°C to constant weight; solids-not-fat was calculated as total solids minus fat.

III. RESULTS

(a) Merino milk

Mean values for yield and composition for the 68 milks are given in Table 1. The variation between groups in herbage availability on their pastures, which caused differences of 10 to 15 kg in mean liveweights, was reflected in the milk yields, but differences in milk composition were small. The relationship between fat per cent and stage of lactation (D, days) was non-significant ($r + 0.06$), but protein and lactose changed significantly ($P < 0.01$) as described by the expressions ($4.28 + 0.016D$), and ($5.355 - 0.005D$) respectively. The simple correlation between protein and lactose was -0.52; correlations between fat and protein, fat and lactose, energy and protein, and energy and lactose were all low ($\leqslant 0.28$).

In an equation with energy (Y, kJ/ 100 g) as the dependent variable, and fat (F), protein (P) and lactose (L) as independent variables, the intercept was Don-significant. The equation through the origin was:

$$Y = \underset{\pm 1.13}{31.00F} + \underset{\pm 2.51}{21.97P} + \underset{\pm 2.43}{26.23L} \quad (RSD \pm 11.42,\ R^2 = 0.92) \quad \ldots\ldots \quad (1)$$

Residual variability was not reduced by including daily yields and stage of lactation as additional independent variables.

The correlation between fat and energy was $+0.93$ but the intercept of the relationship differed ($P < 0.01$) between the two times of milking. Inclusion of stage of lactation removed heterogeneity, and the equation calculated from all data was:

$$Y = \underset{\pm 1.38}{30.46F} + \underset{\pm 0.08}{0.25D} + 236.90 \quad (RSD \pm 13.51,\ R^2 = 0.88) \quad \ldots\ldots \quad (2)$$

Inclusion of $(F)^2$ and daily yield did not reduce the RSD.

(b) Border Leicester milk

Mean yield was 2150 (range 1355 to 3680) g/d. The mean (and range) for fat content was 10.5 per cent (6.6 to 14.0), for total solids (TS) 20.64 per

*Lactabs, Thomson and Capper Ltd., Liverpool, U.K.

TABLE 1

Yield and composition of Merino ewe milks studied for estimation of energy value

No. of ewes		Milk yield* (g/day)	Composition (% w/w)*‡			Heat of combustion* (kJ/100g liquid milk)
Per ha. pasture	Milked		Fat	Protein††	Lactose	
10	16†	1441 ± 292	6.80 ± 0.75	4.73 ± 0.25	5.19 ± 0.14	452.7 ± 25.9
20	16†	1161 ± 265	7.23 ± 0.81	4.72 ± 0.27	5.28 ± 0.14	465.7 ± 27.2
30	15†	970 ± 241	7.11 ± 1.13	4.59 ± 0.36	5.20 ± 0.15	455.2 ± 38.9
10	7	904 ± 94	6.94 ± 0.91	5.15 ± 0.34	5.07 ± 0.17	469.9 ± 34.3
20	7	805 ± 187	7.81 ± 1.28	5.35 ± 0.48	5.01 ± 0.23	486.2 ± 36.8
30	7	812 ± 164	7.70 ± 2.50	5.63 ± 0.32	4.87 ± 0.05	488.3 ± 76.1
Range in values:		547 — 2256	5.2 — 12.2	3.96 — 6.05	4.78 — 5.59	394.1 —634.3
General means:		1083 ± 327	7.18 ± 1.20	4.89 ± 0.47	5.15 ± 0.19	465.3 ± 39.3**

*Means and standard deviations. ‡0.172 ± 0.018% Ca; 0.151 ± 0.013% P.
†21 of these 47 ewes milked a second time five weeks later giving results listed in following three rows.
††Total nitrogen x 6.38.
**111.2 ± 9.4 kcal/100 g, range 94 — 152.

cent (17.61 to 22.99), for solids-not-fat (SNF) 10.14 per cent (9.15 to 11.02), and for energy 576.6 kJ/100 g (447.7 to 692.0 = 107.0 to 165.4 kcal/100 g). Correlations between energy and fat, energy and TS, and energy and SNF were + 0.97, + 0.99, and − 0.35 respectively; that between fat and SNF was − 0.52.

The following equations were calculated:

$$Y = \underset{\pm 1.67}{34.43F} + 215.18 \ (RSD \pm 15.19) \quad \ldots \quad (3)$$

$$Y = \underset{\pm 0.96}{36.53F} + \underset{\pm 1.00}{19.04SNF} \ (RSD \pm 9.87, R^2 = 0.98) \quad \ldots \quad (4)$$

$$Y = \underset{\pm 1.30}{39.20TS} - 233.09 \ (RSD \pm 10.17) \quad \ldots \quad (5)$$

(c) Combined results

Equation (2) tended to underestimate the energy of some Border Leicester milks with fat contents greater than in any of the Merino milks, but did not differ significantly from an equation of the same form calculated from the results for the Border Leicesters alone. The. equation from all 92 sets of analyses for both breeds was :

$$Y = \underset{\pm 0.71}{32.80F} + \underset{\pm 0.08}{0.25D} + 220.33 \ (RSD \pm 14.02, R^2 = 0.96) \quad \ldots \quad (6)$$

IV. DISCUSSION

Variation in the energy content of milk is associated principally with the fat content because fat has a higher heat of combustion, and is more variable and usually higher in concentration, than either protein or lactose. In agreement with previous studies on ewe milk (e.g., Perrin 1958*a*; Corbett 1968), protein content of the Merino milk increased with stage of lactation and lactose decreased. These changes tend to be compensatory with respect to energy content, but were not wholly compensatory, which probably accounted for the difference between the two times of milking in equations where fat was the only independent variable. The difference was removed satisfactorily by inclusion of a term for day of lactation; if this is not known exactly, but only to within about a week, the error in values predicted by equations (2) or (6) would be small, about 1.7 kJ/100 g.

Fat is the most simply -and rapidly determined chemical component of milk. The additional work of determining protein and lactose to allow use of equation (1) would rarely be justified in the absence of such equipment as the infra-red milk analyser (Goulden 1964) because, as indicated by the RSD, there would be little gain in precision. Equations (4) and (5) had the smallest RSD, but were derived from analyses of a rather small number of milk samples obtained from well-fed sheep of one breed during mid-lactation only.

The regression coefficients in equations (1) and (4) cannot be taken to represent the heats of combustion of F, P, L, and SNF because these variables were correlated, and when this is so, the mathematical derivation of the line of best fit may not yield biologically valid coefficients. Perrin (1958*b*) adopted

*Coefficients in equations (7) and (8) adjusted to kJ from those published in terms of kcal.

theoretical heats of combustion* in proposing the equation:

$$Y = 38.12F + 23.18P + 16.53L \quad \ldots \quad (7)$$

The discrepancy between the determined energy values for the Merino milks and those predicted by equation (7) did not vary significantly with either the protein or lactose contents, but increased ($P < 0.01$) with fat content as described by the expression ($7.61F - 47.45$); there was substantial over-estimation with high fat milks. It is possible that the true energy value of ewe-milk fat is less than 3 8.12 kJ/g because in addition to C_{14} to C_{18} fatty acids for which this or a higher value applies, ruminant milks also contain considerable amounts of shorter chain acids. Yousef and Ashton (1967) found that 22 per cent of the acids in ewe milk fat were of length C_{10} or less; it was calculated that the weighted mean value of this fraction was about 32.22 kJ/g, and for all the acids about 37.67 kJ/g.

Varela-Alvarez ***et al.*** (1970) analysed several samples of milk from each of 25 Columbia x Hampshire-Suffolk ewes, and reported the equation:

$$Y = 36.15TS - 140.37 \text{ (RSD} \pm 22.59) \quad \ldots \quad (8)$$

The RSD from this equation is considerably greater than from the corresponding equation (5), and from the others derived in the present study. When applied to results from the Border Leicesters, equation (8) consistently over-estimated energy, on average ($\pm$ S.D.) by 29.71 $\pm$ 11.30 kJ/100 g. Discrepancies varied with fat ($P < 0.01$ and total solids ($P < 0.05$) as described by the expressions ($65.86 - 3.43F$) and ($96.44 - 3.22TS$). On the assumption that total solids in Merino milk was the sum of the fat, protein and lactose contents plus an arbitrary 0.9 g ash/ 100 g, equation (8) consistently over-estimated energy in these samples, on average by 49.8 $\pm$ 14.2 kJ/100 g. Differences from determined values increased ($P < 0.01$) with both the fat and protein contents.

The equation of Varela-Alvarez ***et al.*** (1970) that included fat as the only independent variable (RSD $\pm$ 7.9) over-estimated the energy of nearly all the Merino and Border Leicester milks. Discrepancies were generally not as large as with equation (8) but were often substantial.

Most reports on the composition of ewe milk give little detailed information, but Peirce (1934, 1936) reported analyses of 27 samples of Merino milk. Equations (7) and (8) consistently under- and over-estimated energy by — 34.7 $\pm$ 8.4 and 33.9 $\pm$ 11.3 kJ/100 g respectively. Equations (1), (3) and (4) gave underestimates in most instances though the average discrepancy with equation (4) was small, — 6.8 $\pm$ 4.6 kJ/100 g or 1.4 per cent.

Means of the values determined by Peirce (1934, 1936) and predicted by equation (5) differed by only -- 1.3 kJ; two-thirds of the predicted values differed by not more than $\pm$ 2 per cent from the actual. About half of the values predicted by equations (2) and (6) differed by not more than $\pm$ 2 per cent from the actual; discrepancies were generally a little less for equation (6) and (2), and were on average — 12.1 and — 13.8 kJ/ 100 g respectively.

The ranges in composition of the Merino and Border Leicester milks encompass many of the values for several breeds of sheep summmarized by Ashton, Owen and Ingleton (1964), but may not represent samples from severely undernourished ewes where fat may increase but solids-not-fat decrease (Barnicoat, Logan and Grant 1949). In this instance all the equations may give biased estimates, but such ewes are likely to produce little milk so that the bias, in terms of milk kJ/day, will probably be small.

It appears that the energy of milk might be predicted most satisfactorily from its total solids content or F and SNF, as in equations (5) and (4). Because these equations are not derived from a wide range of observations, equation (6) is perhaps the most generally useful and reliable of relationships presently available.

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