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CALORIMETRIC FACILITIES FOR DAIRY CATTLE AT RUAKURA ANIMAL RESEARCH STATION

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SUMMARY

The open-circuit respiration chambers in operation at Rukaura are briefly described. In eight recovery tests on each of the two chambers, average recovery of CO_2 was 99.93 ± 0.28 and 100.19 ± 0.32%. Six sets of twin cattle in late lactation were used to compare energy utilization of pasture and similar material after partial dejuicing. The twins were split between rations which were fed at two levels, dry matter intake averaging 2.7 and 2.2 kg/100 kg liveweight. In the 24 energy balances involved, the relationship between energy retention derived from the carbon-nitrogen balance (Y) and respiratory exchange (X) was $Y = 0.99X + 2.66$ (RCV., 11.4%). The linear regression of energy balance, corrected to zero tissue loss, on metabolizable energy (ME) intake indicated an efficiency of utilization of ME for milk and body tissue of 52 ± 4.5% and a maintenance requirement of 524 ± 54 kJ/kg $LW^{0.75}$. Ration was without significant effect. In order to achieve the same energy balance, cows at the high level of feeding required 73 ± 32 kJ ME/kg $LW^{0.75}$ more than when at the low level.

INTRODUCTION

The continuing contribution of nutrition research to commercial farming is becoming increasingly dependent on obtaining a clearer definiton of factors influencing the performance of the grazing animal. Of major importance are those factors that affect the conversion of the energy contained in the pasture eaten into animal product. Quantitative study of this energy flow requires techniques that accurately measure changes in energy retention by the animal. Comparative slaughter is such a technique but it is impractical with dairy cattle. As a consequence, alternative indirect calorimetric methods using open circuit respiration chambers have been established at the Raukura Nutrition Section. This paper briefly describes the facilities and, as a basis for assessing their correct functioning and usefulness, presents some results obtained during the first major study.

CALORIMETRIC FACILITIES

Two respiration chambers are presently in use with a further two under construction.

CHAMBER CONSTRUCTION

The animal chamber in which the cow (harnessed for the separate collection of urine and faeces) is restrained by head-stocks is an airtight compartment 1.68 × 2.82 × 2.13 m. Walls and ceiling are made of 50 × 50 mm RHS framing sheathed on the inside with 19 mm chipboard and on the outside with 0.7 mm aluminium sheeting. Insulation material fills the intervening spaces. The rear of the chamber is a door made from 4.8 mm aluminium sheeting backed with 25 mm marine plywood. The feedbox in the front wall is similar to that described by Flatt *et al.* (1958) and beside this is an air lock to provide access while the chamber is in operation. In the front and in one of the side walls are double-glazed windows. The concrete floor is surfaced with epoxy resin as are the interior surfaces of the walls and ceiling. Faeces are collected in a container sealed under the floor of the chamber, whereas urine passes through an S-bend trap to the exterior.

AIR CONDITIONING

Temperature and humidity (RH) control is achieved by a water spray system located above the chamber. Air is drawn (17 m^3/min) from the chamber through filters, a spray chamber and water eliminators. It is then reheated to the set temperature and RH before re-entering the chamber via a false ceiling. Re-heat is controlled by a proportional temperature controller, the sensor of which is a thermistor located in the inlet ducting of the air conditioner. Water (10° C) from a refrigerated holding tank enters the spray chamber through 30 atomizing nozzles, each delivering 1.6 l/min at 170 kN/m^2, returning to the tank by gravity. A continuous record of temperature and RH within the chamber and gas meters is obtained with the aid of thermocouples, a lithium chloride cell and a multichannel recorder. Differences between atmospheric pressure and that within the chamber and gas meters are observed at intervals. Conditions within the chamber are maintained within ± 1° C and ± 5% RH of set levels irrespective of whether the chamber is empty or contains a fully-fed lactating cow.

VENTILATION

Outside air is drawn through the chamber at a rate (15 to 30 m^3/h) sufficient to maintain an average CO_2 concentration of 0.6 to 0.9%. On leaving the chamber, the gas passes through a positive displacement rotary meter (Roots model 1.5M125) before being exhausted through a fan. Valves in the gas lines entering and leaving the chamber result in a negative pressure (1.5 cm water) in the chamber.

GAS SAMPLING AND ANALYSIS

A continuous sample of exhaust gas is drawn into 20 l spirometers by pumping parafin from them into a holding tank. At the end of each collection, usually of 20 to 26 h duration, the spirometer samples and standard gas mixtures are passed through two infrared analysers (Beckman model 315A), to determine CO_2 and CH_4, and a paramagnetic oxygen analyser (Beckman model G2). Analyser outputs are displayed on a digital voltmeter. The analysers are periodically calibrated over their entire range by stepwise dilution of outside air, CO_2 and CH_4 with N_2 for the O_2 (20-21%), CO_2 (0-1%) and CH_4 (0-0.1%) analysers, respectively, using Wosthoff gas metering pumps.

ACCURACY OF THE SYSTEM

The operation of the facilities is routinely checked by CO_2 recovery. CO_2 is continuously admitted (150 l/hr) for 15 to 24 h into the chamber. The amount admitted is calculated from the loss in weight of the CO_2 cylinder using two P10 Mettler balances and the amount recovered from measurements on the air entering, leaving and remaining in the chamber. Percentage CO_2 recovery during the most recent series of tests, 8 on each chamber, ranged from 98.8 to 101.5 with a mean ($\pm$ SE) of 99.93 $\pm$ 0.28 and 100.19 $\pm$ 0.32 for Chambers 1 and 2, respectively.

Another method commonly used to assess the reliability of determinations of energy metabolism is to compare energy retention derived from respiratory exchange with that calculated from carbon and nitrogen (CN) retention. Data providing such a comparison were obtained during the first major trial. Six sets of twin cows in the 6-8th month of lactation were used to examine the effect of mechanical dejuicing of pasture on its nutritive value. Two rations were used, pasture herbage and similar material after partial dejuicing with an IBP pulper and belt press. The twins were split between rations and each animal was subjected to two levels of feeding, daily dry matter (DM) intake averaging 2.7

and 2.2 kg/100 kg LW for the high (H) and low (L) levels, respectively. Each level was maintained for 21 days with balance measurements being made during the last 7 days. Respiratory exchange was measured during 20 to 22 h on each of 2 to 4 consecutive days of the 7-day balance period.

For the resulting 24 energy balances, mean energy retention was 27.75 and 25.34 MJ/day for the CN (Y) and respiratory exchange (X) methods, respectively, their relationship being described by the equation

$$Y = \underset{\pm 0.074}{0.99}\, X + \underset{\pm 1.97}{2.66} \quad (\mathrm{RSD} = 3.17,\ r = 0.94)$$

The agreement is considered satisfactory in view of the nature of the feeds, especially since subsequent modifications to the laboratory procedures associated with the carbon and nitrogen analyses appear to have reduced this variation.

COMPARISON OF SOME RESULTS WITH PUBLISHED DATA

Van Es (1975) surveyed the results of 1148 balance trials with lactating cows, comprising most of those which had been performed in the world at that time. He concluded that ME was converted to milk and body tissue with an efficiency of 60% and that the cow's maintenance requirements were 490 kJ/kg $LW^{0.75}$. Similar calculations on the present data resulted in values of 52 ± 4.5% and 524 ± 54, respectively. These estimates, derived from the data shown in Fig. 1, are well within the range of those surveyed by Van Es. As is suggested by Fig. 1, these estimates did not differ significantly for the two rations. In contrast, level of feeding significantly affected partitioning of ME. This was tested by comparing regression equations derived at each of the two feeding levels. Allowance was made for the correlation between observations on the same twin sets and cows at the two feeding levels and on different rations. The relationship derived, based on the mean of the two cows in a set, was

$$\mathrm{EB/kg\ LW^{0.75}} = \underset{\pm 0.072}{0.602}\ \mathrm{ME/kg\ LW^{0.75}} - \begin{cases} 395.8 \text{ (Level H)} \\ 351.6 \text{ (Level L)} \end{cases} \quad (\mathrm{RSD} = 210.0)$$

EB/$kg^{0.75}$ represents total energy balance and includes milk energy together with the gain or loss of body tissue energy, and ME/kg $LW^{0.75}$ is metabolizable energy intake, both being expressed kJ/kg metabolic liveweight. Mean values were 304 and 1126 kJ/kg $LW^{0.75}$, respectively. The coefficient of 0.602 differs from that given earlier, mainly because EB was not corrected to

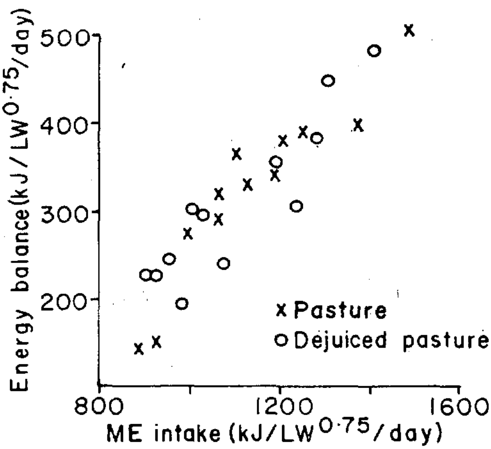

FIG. 1: *Relationship between total energy balance corrected to zero tissue loss and metabolizable energy intake for the two diets.*

zero tissue loss. Loss in tissue energy averaged −4.54 and −4.07 MJ/day for levels H and L, respectively.

The difference in intercepts, 44 ± 19 ($P < 0.10$) indicated that, in order to achieve the same energy balance, cows at a high level of feeding required 73 ± 32 kJ ME/kg $LW^{0.75}$ more each day than when at the low level.

These results are presented to indicate the nature and precision of the results obtainable with the facilities. The objective of the present research programme with these facilities is to examine the energy utilization of the pasture fed cow at various stages of lactation. It is a three-year programme entailing 300 to 400 energy balances and will result in a greatly improved understanding of the cow's ability to convert pasture to milk and of the value of pasture as a foodstuff.

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