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Maintenance energy requirements and energy utilization by the dromedary at rest

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SUMMARY - Five female dromedary camels were used in the present study. They were fasted for four days to estimate the fasting heat production and then fed three different levels of feeding during three successive periods. The dromedaries received 1 kg of barley grains and 0.5 kg of wheat straw in the first period (P1) and twice and four times the amount consumed in P1 during the second (P2) and the third period (P3) respectively. Digestive trials were conducted and heat production of animals was estimated by indirect calorimetry during each period. All the feed offered was consumed, except about 25% of the straw in P3. Energy digestibility of the ration averaged 61% for the three periods and was slightly higher in the third period due to straw refusals. Fasting heat production averaged 52 kcal per kg $W^{0.75}$ and all the dromedaries showed an increase in heat production respect to the level of feeding. Retained energy was regressed against metabolizable energy (ME) intake and the energy requirements for maintenance (MEm, zero energy gain) were estimated to average 73 kcal per kg $W^{0.75}$. However, different estimations of the efficiency of ME utilization, above (kf) and below (km) maintenance, were obtained, indicating that the dromedaries utilized ME below maintenance with an efficiency of 73%, comparable to sheep, and above MEm with an efficiency of 61%, better than sheep. When the data of FHP were considered in the regression, different values of km were obtained suggesting that the linearity of response below MEm is not obvious and at least two different slopes could be obtained.

Key words: Dromedary, digestibility, heat production, maintenance, efficiency.

RESUME - "Exigences énergétiques pour l'entretien et utilisation de l'énergie par le dromadaire au repos". Cinq chamelles ont été utilisées dans le présent travail visant la détermination des besoins énergétiques d'entretien. L'essai a été divisé en deux périodes successives pendant lesquelles les chamelles ont été alimentées par la même ration alimentaire. Cependant, en première période, 2 kg de grains d'orge et 1 kg de paille de blé ont été distribués aux chamelles, alors qu'en deuxième *période, 4 kg de grains d'orge et 2 kg de paille de blé ont été distribués. Les chamelles recevaient 50 g d'un complément minéral et vitaminé et ont eu un accès libre à l'eau d'abreuvement durant les 2 périodes. Durant chaque période et pour chaque chamelle, la digestibilité apparente de la ration et les gaz respiratoires de l'animal ont été mesurés dans le but d'estimer l'énergie métabolisable de la ration (MEI) et la production de chaleur de l'animal (HP). Les résultats suivants ont été obtenus : Alors qu'en première période toute la ration distribuée a été consommée, en seconde période les chamelles ont refusé environ 25% de la quantité de paille distribuée. Ceci a augmenté le pourcentage de l'orge dans la ration et a influencé l'amélioration de la digestibilité apparente de la ration en seconde période. Avec le niveau alimentaire élevé, en période 2, la production de chaleur moyenne des 5 chamelles a augmenté d'environ 32% en comparaison avec la production de chaleur mesurée en première période. Lorsque l'on a calculé la régression de l'énergie retenue (RE est la différence entre l'énergie métabolisable et la production de chaleur) par rapport à l'énergie métabolisable de la ration (MEI) l'équation suivante de régression linéaire a été obtenue : RE = 0,68 x MEI - 3689. Avec R^2 = 0,93. Avec RE = 0, MEI = 3689/0,68 = 5425 kcal. Ceci correspond aux besoins énergétiques d'entretien (MEm) quotidien pour une chamelle d'un poids moyen d'environ 300 kg. Exprimés en poids métabolique, les besoins énergétiques pour l'entretien (MEm) sont : 75 kcal par $kg^{0,75}$ par jour. La même équation indique aussi que les chamelles ont utilisé l'énergie métabolisable de la ration pour l'engraissement avec un rendement de 68%. Les résultats du présent travail suggèrent que le MEm du dromadaire est plus faible que celui des ruminants et que le dromadaire est plus efficace dans l'utilisation de l'EMI pour l'engraissement.*

***Mots-clés** : Dromadaire, digestibilité, production de chaleur, entretien, efficience.*

Introduction

The dromedary camel has a remarkable ability to exploit the scanty feed and water in its natural habitat. Long distances are covered in search of feed and water. In extreme cases of limited natural vegetation, the camel not only decreases its feed intake, but also reduces its metabolic rate (Dahlborn *et al.*, 1992). In these circumstances, production is adjusted to energy intake which, in part, explains the supposed poor production of the camel. The worst effects are encountered when the high demanding physiological stages coincide with the dry season. To improve the overall camel productivity, it is necessary first to define the minimum nutritional requirements to keep the animal's body in stable energetic state. This basic data will help in the establishment of the energy requirements for growing, pregnant, lactating and working camel. There have been few investigations on feeding standards for camel and assessment of its nutritional requirements remains very empirical and often extrapolated from cattle data. The present study was designed to estimate the nutrient requirements of the dromedary at maintenance when using the regression method. Coefficients for efficiency of ME utilization for maintenance (km) and fattening (kf) were also computed.

Materials and methods

Five healthy, 8 to 10 year old female camels were used over four successive periods with different levels of feeding in each one (Table 1). The diet consisted of 66% barley grains and 34% wheat straw and was fed at 0 (FHP), 0.5 (P1), 1 (P2) and 2 (P3) times maintenance energy requirements (MEm) recommended to sheep by INRA (1978), which is 95 kcal of ME intake per kg $W^{0.75}$.

Table 1. Diet ingredients and levels of feeding (FM basis)[a]

	Periods of study			
	FHP	P1	P2	P3
Diet ingredients				
Barley grains (kg)	0	1	2	4
Wheat straw (kg)	0	0.5	1	4
Vitamins and minerals supplement (g)[b]	0	50	50	50

[a]On fresh matter basis, with 90% dry matter in the ration
[b]Vitamins and minerals supplement was composed of 18% Calcium, 15% Sodium Chloride, 12% Phosphorus, 2% Magnesium, 1% Sulfur, 1.5% Trace Elements, 0.5% Vitamins and 50% excipient

Before the beginning of the study, the animals were adapted to faecal collection bags and to the indirect calorimetry chamber for a period of one month. During each period of the study, a pre-sacked diet was offered to the animals 3 days prior and 7 days during the digestive trials at 9:00 (am) daily. The uneaten feed was removed and weighed after 24 h in order to determine the amount of feed consumed. The exact intake measurement started one day prior to faecal collection and concluded one day before the final daily faecal collection. Faeces were removed from the faecal collection bag daily during 7 consecutive days, weighed and 10% of it was dried and added to composite dry aliquot for each animal. Faecal and diet dry matter were determined by drying the samples at 105°C during 24 h. The gross energy contents of the feeds and faeces were determined on 1 g pelleted samples in an adiabatic bomb calorimeter (Parr, 1241). The digestible energy (DE) intake was determined by substracting the faecal energy from the intake energy while the ME intake was estimated from the DE intake by using the following ME/DE ratios: 0.82, 0.83 and 0.88 in P1, P2 and P3, respectively. These values were obtained in sheep fed similar diets at comparable feeding levels (Blaxter and Wainman, 1964; Vermorel *et al.*, 1987).

An indirect calorimetry system of an open circuit type was used to measure the oxygen consumption during 24 h per animal per period. Heat production (HP) was estimated by using the equation of McLean (1972):

$$\text{HP (kcal/d)} = (O_2 \text{ In-Out}) \times \text{Flow (STPD)} \times 4.89$$

The (O_2 In-Out) was the difference in percentage of O_2 between outside air and the exhausted air while the flow (STPD) corresponded to the amount of exhausted air flowing through the flowmeter converted to standard conditions of temperature, pressure and humidity. Fasting heat production (FHP) was also estimated by measuring gaseous exchanges of each dromedary on day 4 of a fast. It should be noted that for similar diets and feeding levels, heat production was underestimated by 0.5% in P1, P2 and P3 by the McLean's (1972) equation compared to the Brouwer's (1965) equation. However, during the fourth day of fast, methane production was very low and the underestimation of HP is about 2.3%. Therefore, the determined FHP was increased correspondingly.

Retained energy (RE) was determined by substracting HP from ME intake. Linear regression equations were computed between RE and ME intake in order to determine the MEm of the animals. The regression equations gave several estimations of MEm and efficiencies of ME utilization above and below zero energy retention. Results are presented as means and standard deviations. The effect of feeding level on diet digestibility and heat production of animals was tested by the paired t-test.

Results and discussion

Body weight mean, gross energy intake and digestibility variations with the feeding level are presented in Table 2. The average body weight of the dromedaries increased linearly with feeding level from FHP (fast) to P3 (twice maintenance) by 7.13 kg per kg of dry feed. A four day fast reduced the body weight of the dromedaries by 3.16% compared to the weight measured in P1 when the animals were fed half the requirements and by 5.85% compared to the weight measured in P2 when the animals were fed to maintenance requirements. In P3, when the ration was doubled, body weight increased by 5.52% compared to the average weight measured in P2.

Table 2. Body weight, feed energy intake and digestibility variation with the level of feeding received by animals

	Periods of study			
	FHP	P1	P2	P3
Body weight (kg)				
Mean[a]	299.00	308.40	308.40	334.20
SD[b]	30.70	27.75	27.75	30.70
Gross energy intake (kcal per day)				
	0	5648	11427	21102
SD	0	225	189	1523
Energy digestibility (%)				
Mean	-	61.01	60.88	62.82
SD	-	4.12	3.45	3.09

[a] Mean for the data of five dromedaries used in the study
[b] Standard deviation

In the first and the second periods, the amount of food offered to the dromedaries was totally consumed. However, in the third period all the barley grains offered were consumed, but about 25% of the wheat straw was refused. Consequently, barley grains constituted about 66% of the diet in P1 and P2 and 72% in P3. This may explain the higher energy digestibility value observed in P3 (63%) compared to values determined in P1 and P2 (61%) (Fig. 1). Straw digestibility was calculated in P1 and P2 assuming that barley energy digestibility was 83% (INRA, 1988). In P3, the energy digestibility of the ration was corrected to take account of the difference in diet composition among the periods. It was reduced from 62.8% to 59.0% when the percentage of barley decreased from 72% to 66%.

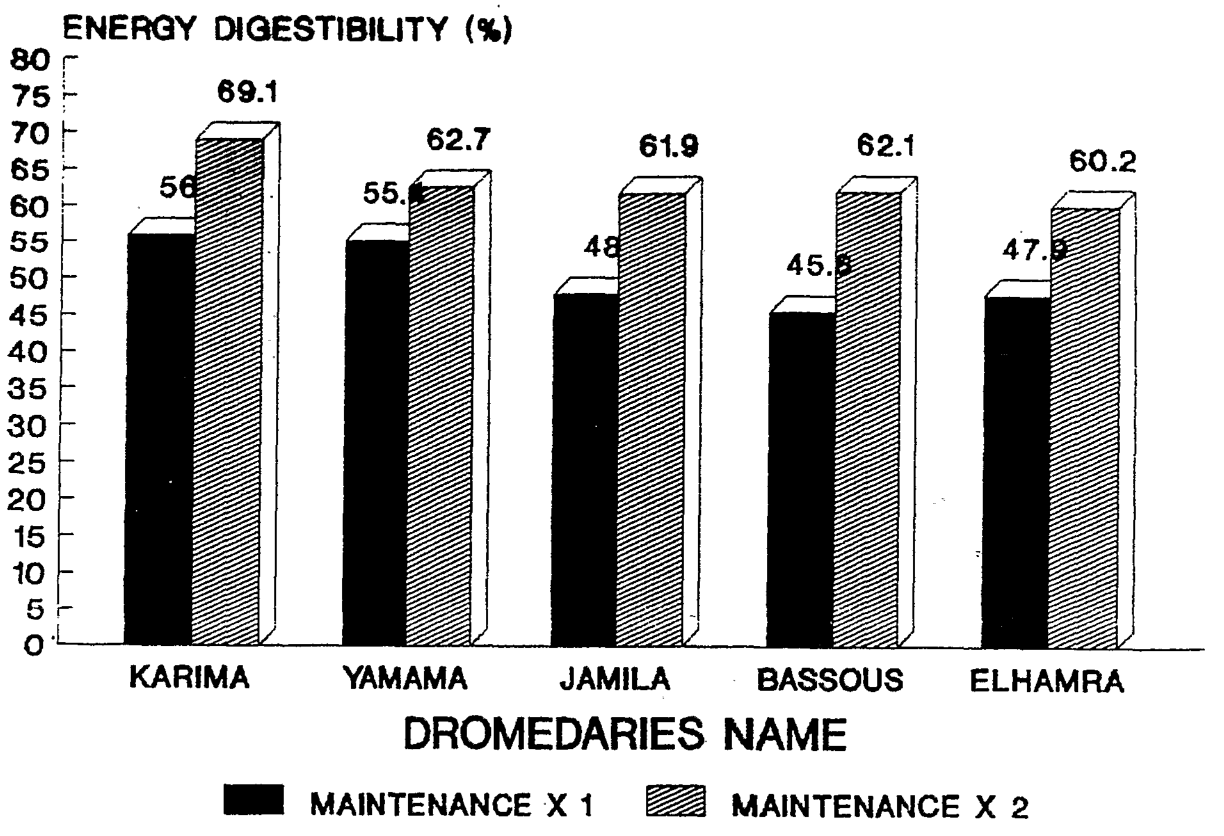

Fig. 1. Feed energy digestibility as percentage of energy intake. Five dromedaries in 2 successive periods.

Metabolizable energy intake, total heat production and retained energy variations with the level of feeding are presented in Table 3. Fasting heat production was estimated from the oxygen consumption of the animals in the forth day of the fast and averaged 51 $\pm$ 3.55 kcal per kg $W^{0.75}$ per day. In Dman sheep fasted for four days, HP averaged 58.5 kcal per kg $W^{0.75}$ (Guerouali, 1990). The FHP of dromedaries determined in the present study compares more closely to the FHP of adult sheep (57.4 kcal per kg $W^{0.75}$) (ARC, 1980) than of adult cattle (76.3 kcal per kg $W^{0.75}$) (Van Es, 1972).

All the dromedaries showed an increase in HP in response to the increase in feed intake, with 38% more heat produced from FHP to P2 and 28% more from P2 to P3

(Fig. 2). When HP was regressed against ME intake the following equation was obtained: HP = (0.29 ± 0.03) * ME + (52.71 ± 6.75); R^2 = 0.85.

This equation indicates that the FHP is 53 kcal per kg $W^{0.75}$ and an average of 29% of ME was dissipated as heat for the different levels of feeding. The increases in heat production in response to the level of feeding were due to the cost of eating (Young, 1966), the work of the gastro-intestinal tract in the processing of the feed (Webster, 1972; Osuji, 1974), the high metabolic rate induced by an increase of the metabolically active organ mass (liver, intestine, heart and kidney) when animals were fed above maintenance requirements as suggested by Koong *et al.* (1985) and the utilization of digestion end-products (volatile fatty acids) instead of body lipids for maintenance and/or above maintenance. With the same diet and under the same experimental conditions, Guerouali (1990) showed that ewes fed at maintenance produced 62% more heat than when fasted for 4 days, whereas ewes fed at maintenance x 2 produced 50% more heat than ewes fed at maintenance (Fig. 2). Compared to sheep, dromedaries produced less heat in response to increasing feeding level and because of this, are more efficient in feed conversion.

Table 3. Metabolizable energy intake and total heat production variation with the level of feeding

Periods of study	FHP	P1	P2	P3
Metabolizable energy intake (kcal per kg $W^{0.75}$)				
Mean[a]	0	38.68	76.63	139.54
SD[b]	0	4.62	8.47	11.52
Total heat production (kcal per kg $W^{0.75}$)				
Mean	51.01	64.92	71.59	92.22
SD	3.55	6.21	8.11	10.56
Retained energy (kcal per kg $W^{0.75}$)				
Mean	-51.01	-26.24	5.04	47.32
SD	3.55	4.97	4.74	9.83

[a] Mean for the data of five dromedaries used in the study
[b] Standard deviation

Retained energy (RE), as the difference between ME intake and HP, averaged a negative value in P1 (half maintenance) and a positive value in P2, indicating that the dromedaries were fed above maintenance. In P3, a positive retained energy was obtained, representing about 34% of the total ME intake, while HP was about 66% (Fig. 3).

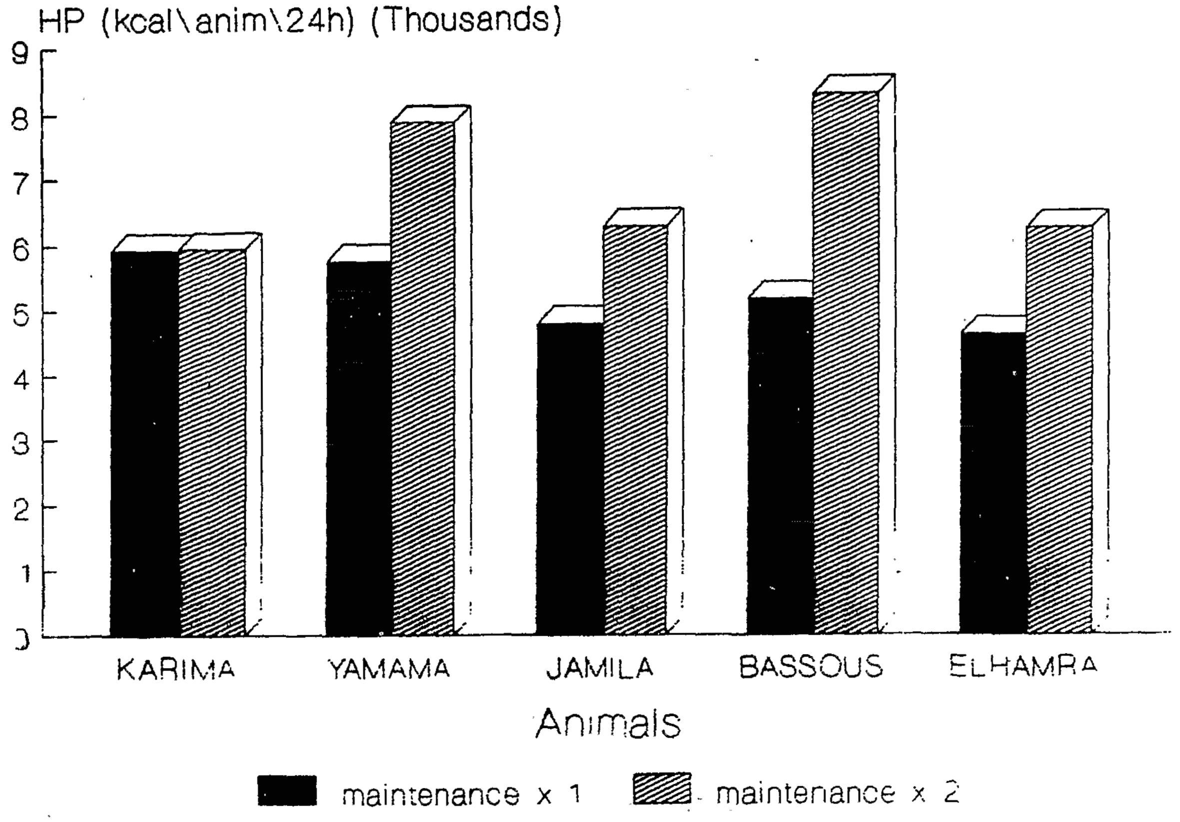

Fig. 2. Heat production variation with the level of feeding. Five dromedaries studied in 2 periods.

Retained energy was regressed against ME intake for different sets of data (Fig. 4) and the linear regression equations obtained are presented in Table 4. These equations indicate, when assuming RE = 0, that MEm averaged 72.6 ± 3.8 kcal per kg $W^{0.75}$. This value is higher than the only value found in the literature for dromedaries (52 kcal per kg $W^{0.75}$) reported by Schmidt-Nielsen *et al.* (1967). However, it should be noted that in the Schmidt-Nielsen study, heat production was determined by measuring respiratory gases with mask, when the animals were under heat stress conditions. Engelhardt and Schneider (1977), using carbon-nitrogen balance technique, estimated the MEm of the llama to be 61.2 kcal per kg $W^{0.75}$, while Carmean *et al.* (1991), using respiration calorimetry technique, estimated the MEm of the llama to be 84.5 kcal per kg $W^{0.75}$. Most of the MEm values in the literature for camelids are different from the value reported in this study. More likely, the difference is due to technique of determination, diet and plane of nutrition effects. Estimates of MEm requirements range from 72 to 107 kcal per kg $W^{0.75}$ for sheep depending on level of activity and ME content of the diet (Van Es, 1972). A broad range of MEm requirements, dependent on diet ME content and level of activity, would be expected for dromedaries as well.

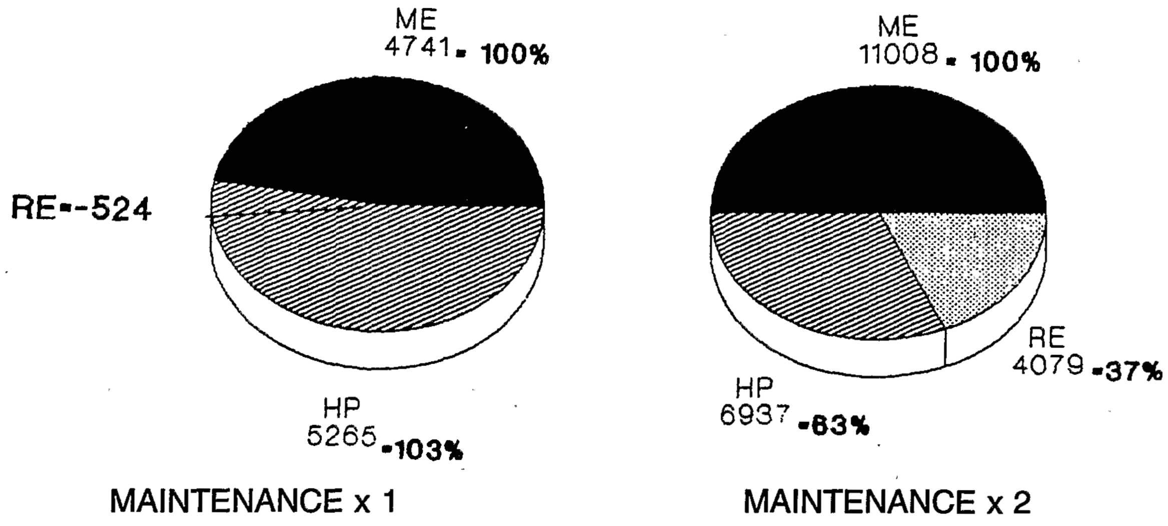

Fig. 3. Energy balance in 5 dromedaries fed two levels of feeding. Values are average of five animals (expressed in kcal per animal per day).

Different values of the efficiency of utilization of ME intake, above and below maintenance requirements were obtained through regression equations, indicating that ME was used below maintenance with an efficiency of 73% (km = 0.73) and above maintenance with an efficiency of 61% (kf = 0.61). This km value is close to those (Blaxter and Wainman, 1964; ARC, 1980) calculated from energy balance studies in sheep and cows fed a mixed diet of the same metabolizability. However, the kf value is higher than most values (kf varied between 41% and 56%) found in the literature (Blaxter, 1974; Garrett *et al.*, 1976). With the high value of kf, it seems likely that the dromedary utilizes nutrients for body tissue gain better than other ruminants.

It should be noted in the present study that ME efficiency below maintenance depended on the nutritional status of the animal. Between FHP (fourth day of fast) and P1 (half maintenance) km was estimated to be 0.65, whereas between P1 and P2 (maintenance) it was estimated to be 0.76. This data may indicate that the dromedaries were using ME with a lower efficiency from FHP to P1 than from P1 to P2. Considering these results, it may be suggested that in P1 the amount of feed offered to the dromedaries (half maintenance) was not large enough to supply all the glucose and amino acids required for maintenance. Consequently, body tissue proteins could be broken down to provide a source of glucose precursors. Ørskov and Ryle (1990) reported that fasting metabolism is associated with an increased level of β-hydroxybutyrate in the blood and an increased level of nitrogen excreted in urine. Kuvera *et al.* (1988) showed that, by infusing glucose into the abomasum, fasting urinary nitrogen excretion could be reduced to basal levels and blood levels of β-hydroxybutyrate also fell to normal levels. Heat production sometimes decreased, while urea and other nitrogenous compounds excreted in the urine declined. In the feeding step from half MEm to MEm, it is likely that the amount of feed offered to dromedaries supplied all the metabolites needed for the metabolism, especially glucose, and less protein mobilization may have occurred, which may explain the higher efficiency observed during this step.

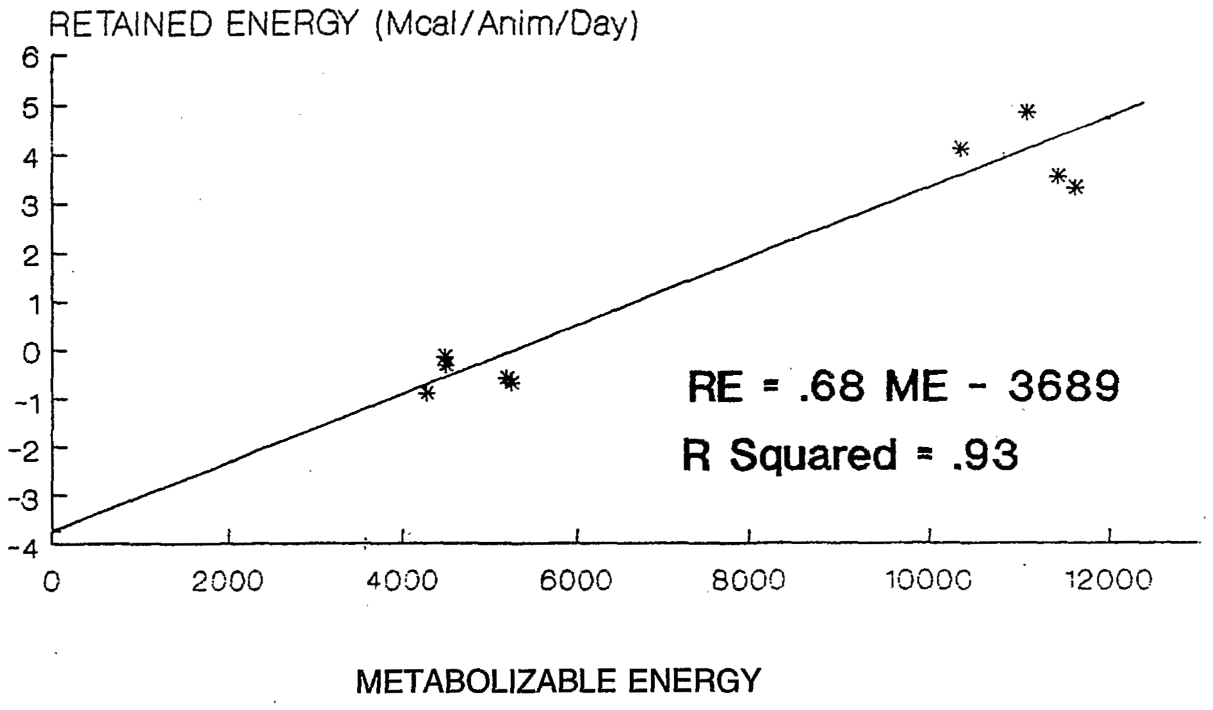

Fig. 4. Retained energy *vs* metabolizable energy. Regression and correlation coefficients. *Retained energy. When RE = 0; Mem = 3689/0.68 = 5425 kcal per animal per day. Kf = 0.68, coefficient of efficiency for ME used for gain.

Table 4. Linear regression of retained energy against metabolizable energy at different levels of feeding

Data considered	Regression equation	Determination coefficient (R2)	MEm (kcal per MBS)[a]
FHP, P1, P2, P3	RE = 0.70ME-51.37	0.97	73.38
FHP, P1, P2	RE = 0.73ME-52.37	0.95	71.74
FHP, P1	RE = 0.65ME-51.69	0.89	79.52
P1, P2, P3	RE = 0.69ME-50.39	0.94	73.03
P1, P2	RE = 0.76ME-54.22	0.86	71.34
P2, P3	RE = 0.61ME-40.73	0.89	66.77
Mean	-	-	72.63
SD	-	-	3.76

[a] Maintenance energy requirements expressed in kcal per metabolic body size ($kg^{0.75}$)

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