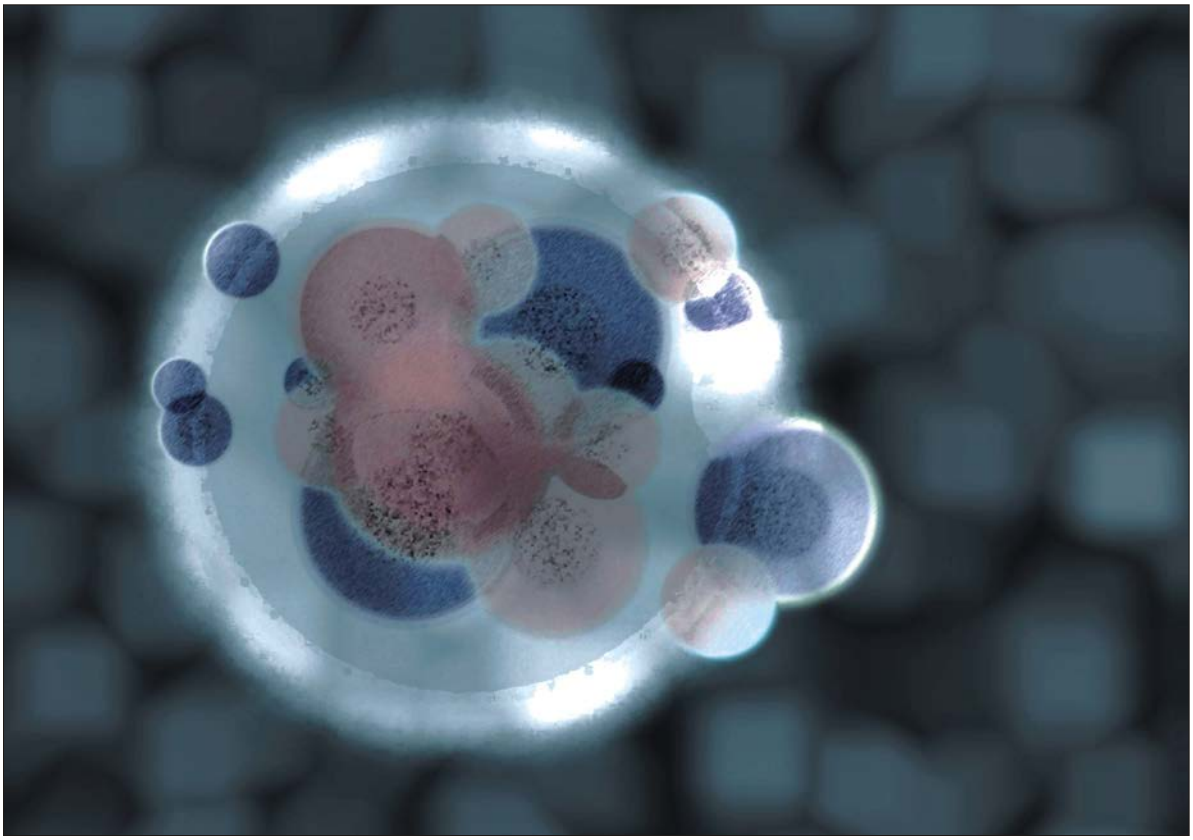

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An Assessment of the ARC Metabolizable Energy System to Predict Live Weight Gain of Brown Swiss Cattle Grown under Feedlot Conditions in Turkey

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Abstract: A set of data from Brown Swiss cattle grown under feedlot conditions was used to evaluate the energy feeding system adopted by the Agricultural Research Council (ARC) in the United Kingdom in order for prediction accuracy of beef performance. The discrepancies between observed and predicted values of Live weight Gains (LWG) were small (0.012±0.057) and there was a substantial agreement between observed and predicted values by the model in the test data. There was no significant difference between the discrepancies. LWG predictions by the model were 0.98 times (or 11.6%) less for the test data. The high regression and correlation coefficients (0.93 and 0.97, respectively) and the very low mean prediction error MPE (0.00122) indicate model prediction ability. The Mean-square Prediction Error (MSPE) was used for the evaluation of the equations used for the model. Live weight gains were underpredicted especially for the observed values less than 0.9 kg/day. The MSPE of the predictions by the model was 0.0013 kg/day for this data set. In terms of contribution of components to MSPE; the values of bias, line and random error were 11, 0.1 and 88.9%, respectively. The model had a greater proportion of error derived from random than other components. A small proportion of line as a component of MSPE showed that the error derived from line was substantially low and there was a minimal variation between predicted and observed LWGs. The accuracy of measurement and error of experimentation and predictions were within the acceptable range for the observed values for the data examined in this study. Although the model based on the energy system may have limitations due to the empirically derived equations, the data presented in this study indicated that the model provides very close agreement with reality for prediction of live-weight gain.

Key words: Beef production, energy system, performance, prediction

INTRODUCTION

It is generally agreed that the energy evaluation of foods for ruminants should be based on a net energy rather than a digestible energy method. Moe and Tyrell[1] have reviewed recent net energy systems proposed by Lofgreen and Garrett[2], Blaxter[3], Schiemann *et al.*[4] and Moe *et al.*[5]. That of Blaxter[3] as outlined in Agricultural Research Council (ARC)[6] is probably the most sophisticated, taking into account variations in feeding level and the efficiency of utilization of metabolizable energy for different functions and food.

Although the basic concept of this system has been widely accepted, it has not been generally used as a practical method of rationing ruminants. This results partly from its complexity but also from the fact that it allows only prediction of performance from given energy input. As a result, formulation of diets is cumbersome and time consuming since it involves an iterative procedure[7].

A simplified Net Energy system for ruminants is described. It is based on the Metabolizable Energy system outlined by the ARC[6] and enables a non-iterative approach to be used in the formulation of rations. The method is suitable for use in linear programming work and is illustrated, with appropriate tables, for growing cattle. However, there is clearly a need for more reliable and precise estimates of performance of cattle fed in different situation and in any practical application of the system[8].

Predictive models, ranging from simplified representations such as the energy and protein systems for ruminants adopted in the United Kingdom and in the United States[6-9] to more complex dynamic models such as those of Graham *et al.*[10], Newton and Edelsten[11], Forbes[12,13], Geisler and Neal[14], have tended to be empirical representations and as such have limited applicability to situations outside those in which the data sets were collected[15].

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There are some debates that the system as recommended by the ARC[6] to specify the energy requirements of ruminants can be easily used to predict the performance of growing animals but, because the Metabolizable Energy (ME) requirements of growing cattle depend on the ME concentration of the ration, it is not well suited to the formulation of rations to produce specified daily live-weight gains[16].

Therefore, this experiment was designed to evaluate the prediction ability of ARC equations to estimate the Brown-Swiss cattle performance grown under feedlot conditions in Turkey and to examine applicability of the system model to situations outside those in which the data sets were collected.

MATERIALS AND METHODS

This experiment was conducted at the Suleyman Demirel University, Atabey Vocational School farm. The present study included 40 Brown Swiss calves at six months of age and average 140 kg live weight. The animals were kept in feedlot with the four paddocks and each paddock consisted of ten animals. The experiment was begun on the 10th of February, 2002 and lasted for 11 months until the 10th of January, 2003. The dimension of feedlot area and each pen were 24 m length and 48 m width and 24 m length and 12 m width, respectively.

Animals were initially weighed at the beginning of the experiment and were divided into groups on the basis of close live weights and each group consisted of ten animals and they were weighed fortnightly and performances and growths of animals were monitored.

Diets consisting of sugar beet bulb and dried hay as roughages and ground barley and cotton seed meal as concentrates, were provided to obtain a target Live weight gain of 1 kg/day and designed according to live weight change of animals. Diets were changed as the weight of groups increased.

Prediction of live weight gain based on the energy system (Energy Model, EM): Excel Spreadsheets was used for prediction of live weight gain.

The system used to specify the energy requirements of growing cattle was outlined by ARC[6] and fully described by the Ministry of Agriculture, Fisheries and Food, MAFF[17]. To formulate a requirement in terms of metabolizable energy the Net Energy (NE) requirement must be known together with the efficiency with which dietary Metabolizable Energy (ME) is used to satisfy that requirement[17]. Net energy was calculated using the following equations.

For Maintenance (E_m): Metabolizable energy requirement of the animals for maintenance was calculated from the net energy required for fasting metabolism. Metabolizable energy required for maintenance (E_m) and can be expressed as:

$$E_m = 5.67 + 0.061\ W \qquad (1)$$

Where, E_m= Maintenance allowance (MJ/day), W= Live weight in kg.

The efficiency with which ME is used for maintenance (k_m) was calculated from the energy concentration (M/D) of the ration, using the equation:

$$k_m = 0.55 + 0.061\ M/D \qquad (2)$$

Where, k_m = The efficiency of utilization of ME for maintenance.

M/D = Energy concentration of the ration (MJ/kg DM).

However, since over a range of ME concentrations (M/D) varies from 8 to 14 MJ/kg DM, k_m varies from 0.68 to 0.77 and therefore an average value of 0.72 for the efficiency of utilization of ME was assumed. Therefore, Eq. 1 can be rearranged as:

$$E_m = \frac{(5.67 + 0.061W)}{k_m} \qquad (3)$$

Substitution of k_m into Eq. 3 results in the following equation:

$$E_m = \frac{(5.67 + 0.061W)}{0.72} \qquad (4)$$

Then Eq. 4 can be expressed as follows:

$$E_m = 7.88 + 0.085\ W \qquad (5)$$

For Production (MEP): The metabolizable energy available for production was obtained by deducting the ME allowance for maintenance (E_m) from the total Metabolizable Energy Intake (MEI).

$$MEP = MEI - Em \qquad (6)$$

Substituting E_m in Eq. 5 into Eq. 6 yields the following equation:

$$MEP = MEI - (7.88 + 0.85\ W) \qquad (7)$$

Calculation of predicted live weight gain: The energy available for growth (E_g) is obtained from the ME available for production (MEP). The efficiency with which ME is utilized for production (k_g) is a function of the ME concentration of the dietary dry matter (M/D), which is expressed as:

$$k_g = 0.0435 \text{ M/D} \quad (8)$$

Accordingly E_g is described by the following equation:

$$E_g = \text{MEP} \times k_g \quad (9)$$

Substituting MEP and k_g into Eq. 9 results in the following equation:

$$E_g = \text{MEI-}(7.88+0.085\text{ W})\times 0.0435 \text{ M/D} \quad (10)$$

LWG which can be achieved from the stored energy (E_g) is dependent upon the energy value of the gain (EV_g). The net energy stored for gain (E_g) is the energy content of that gain and is the product of the weight of the gain (LWG) and its energy value (EV_g).

$$\text{LWG} = \frac{E_g}{EV_g} \quad (11)$$

For cattle, the energy value of gain (EV_g) is related to the Live weight in kg (W) and the energy stored in MJ (E_g) and was calculated using the following equation:

$$Ev_g = 6.28 + 0.3E_g + 0.0188 \text{ W} \quad (12)$$

By substituting EV_g from Eq. 12 into Eq. 11 the following equation was obtained.

$$\text{LWG} = \frac{E_g}{6.28 + 0.3\, E_g + 0.0188 \text{ W}} \quad (13)$$

Finally, substituting E_g from Eq. 10 into Eq. 13 provides an equation to calculate Live weight gains (kg/day) for growing and fattening cattle from a given intake of ME (MEI), the animals' body weight (W) and ME concentration of the ration (M/D).

$$\text{LWG} = \frac{\text{MEI-}(7.88+0.085\text{W})\times 0.0435 \text{ M/D}}{\left[6.28+0.3\left[\begin{array}{l}\text{MEI-}(7.88+0.085\text{ W})\\ \times 0.0435 \text{ M/D}+0.0188\text{ W}\end{array}\right]\right]} \quad (14)$$

Statistical analysis: The difference between actual and predicted LWGs was examined by Students' t-test using statistical package program Minitab v.13 for windows[18]. The observed and predicted live weight gains were also compared using the MSPE:

$$\text{MSPE} = \frac{1}{n}\sum_{i=1}^{n}(\text{Oi} - \text{Pi})^2$$

Where, n is the number of pairs of observed and predicted values being compared. I = (1, 2, 3,……, n).
Oi is the observed LWGs with ith variable. Pi is the predicted LWGs with ith variable.

The MSPE can be considered as the sum of three components described by Rook *et al.*[19].

$$\text{MSPE} = (\bar{O} - \bar{P})^2 + S_p^2(1-b)^2 + (1-r^2)S_o^2$$

Where, $S_O{}^2$ and $S_P{}^2$ are the variance of the observed and predicted live weight gains, respectively. $\bar{O}$ and $\bar{P}$ are the means of the observed and predicted Live weight gains, b is the slope of the regression of observed values on predicted and r is the correlation coefficient between O and P.

RESULTS

There was a substantial agreement between observed and predicted LWGs by the model in this data set. There were no significant differences between observed and predicted values in data set (0.841 and 0.829 kg/day, respectively) (Table 1). The LWG predictions by the model were 0.98 times (or 11.6%) less for the test data. The high regression and correlation coefficients (0.93 and 0.97, respectively) and the very low MPE (0.00122) indicate model prediction ability.

Mean bias (predicted minus observed) for the data was negative (-0.012±0.057) and was not significantly different (Table 2). Live weight gains were underpredicted especially for the observed values less than 0.9 kg/day (Fig. 1). The MSPE of the predictions by the model was 0.0013 kg/day for this data set. In terms of contribution of components to MSPE; the values of bias, line and random error were 11, 0.1 and 88.9%, respectively (Table 2). The model had a greater proportion of error derived from random than other components. A small proportion of line as a component of MSPE showed that the error derived from line was substantially low and there was a minimal variation between predicted and observed LWGs.

Table 1: Prediction accuracy of the model in data set and comparison between observed daily live weight gain and predicted daily live weight gain by the model

LWG	N	Mean (kg/day)	S.D.	S.E.	Var.	b	R^2	r	MPE'
Observed	41	0.841	0.132	0.021	0.017				
Predicted	41	0.829	0.126	0.020	0.016	1.01	0.93	0.97	0.00122

' Mean Prediction Error

Table 2: Mean Square Prediction Error (MSPE) and Proportion of MSPE

				Proportion of MSPE			
	LWG	SE	Mean bias*	MSPE	Bias	Line	Random
N=41							
Observed	0.841	0.021					
Predicted	0.829	0.020	-0.012±0.057	0.0013	0.11	0.001	0.889

* Mean bias was not statistically significant

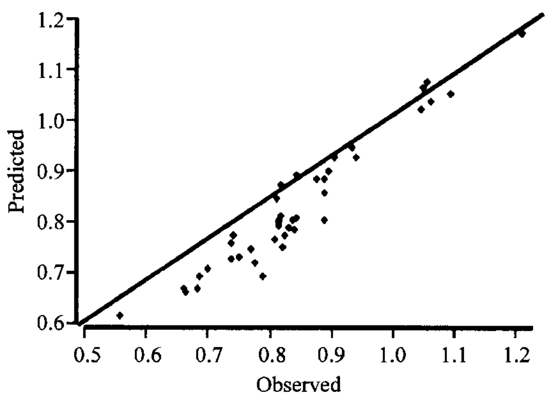

Fig. 1: The predicted LWGs are plotted against observed LWGs for data set. The straight line represents the line of unity and the best prediction

DISCUSSION

The accuracy of the model can be evaluated according to components of MSPE as a proportion of the mean observed LWG in the experiment.

The MSPE can be divided into three components due to mean bias (or mean deviation $(\bar{P}-\bar{O})$ of the prediction). Line bias (or deviation of the slope (b) of the regression of O on P from unity) and the random variation about this regression line. A positive mean bias indicates that the equations are generally overestimating relative to observed values while negative mean bias indicating underestimation.

Rook *et al.*[19] indicated that mean bias generally shows differences between estimation and test data while a large line bias is representative of underlying weakness in the structure of models.

The highest proportional contribution to the MSPE of the model predictions was made by the random error of the data about the regression line in the data set, the line bias component being the least, followed by that of bias. The highest proportional contribution of random error of the data to the MSPE in the model could be attributed to the calculations of ME concentrations. They are themselves dependent on the predictions of ME supply of the silage and concentrates[20].

Bozkurt and Ap Dewi[21] indicated that the general trend in the model based on the ARC prediction equations was for the slope of the regression of observed on predicted values to be more than unity at low observed values in which LWGs were over predicted and to be less than unity at high observed values in which LWGs were underpredicted. However, in the present study the general trend in the model was that the slope of regression was less than unity at low observed values in which LWGs were underpredicted and to be close to or more than unity at high observed values in which LWGs were over predicted.

The poor ability of the model to predict performance in the present study in which LWGs were consistently underpredicted, could be attributed to underestimation of ME values and thus low metabolizable energy concentrations M/D. Laboratory methods of evaluating the feedstuffs used could be one of the major factors contributing to the errors of prediction.

In contrast to study done by Bozkurt and Ap Dewi[21] the model under predicted LWGs at low rates of observed gains. This could be attributed to an under estimate of the energy available for LWG.

Neal *et al.*[20] were incorporated into a computer program designed to be used by livestock advisors for on-farm rationing of beef cattle that equations for the prediction of forage dry-matter intake, Metabolizable Energy (ME), rumen degradable protein and undegradable protein, based on those in the current ARC system. The predictions of silage intake and live weight gain are compared with experimental data.

Burroughs *et al.*[22] pointed out that NRC values may be slightly too low and that the corresponding ARC predicted efficiencies may be too high on the basis of expected and found Live weight gains in the feedlot cattle. On the average the NRC predicted live weight gains were

6% lower than actual values obtained, whereas the ARC predicted values were approximately 26% higher than the actual values obtained.

Bozkurt and Ap Dewi[21], Hirooka and Yamada[23] compared energy model predictions of weight gain with those observed in a range of experiments and found that, on average, the model over predicted LWG by 17% and by about 15%, respectively which was not in close agreement with the findings of the present study in which energy model underpredicted LWG by 11.6%.

Metabolizable Energy System outlined by the ARC[6] enables a non-repetitious approach in the ration formulations. The method is suitable to be used in linear programming for growing cattle. However, there is a clearly a need for more reliable and precise estimates of, or means of predicting the degradability of different protein sources fed in different situation and in any practical application of the system[8].

It was also suggested by Newbold *et al.*[24] that discrepancies between predicted and observed LWG might be due to lack of response to amino acid supply, several of which may be closely co-limiting to growth.

The practical implications of over-and under-predictions by the model should be taken into consideration in their practical application. Over-prediction might suggest that there was a surplus of feed offered, resulting in a delay in reaching the target LW. With under-prediction, the rations would include more concentrates than necessary, resulting in incurred higher total feed costs.

In conclusion ME system proposed by ARC allows the energy system of growing cattle to be represented in all substantial respects (for maintenance and production). The differences between the predicted and observed LWG values are very small in relation to their practical significance, the accuracy of measurement and error of experimentation and predictions were within the acceptable range for the measured outputs for the data examined in this study.

Although the model based on the energy system may have limitations due to the empirically derived equations, the data presented in this study indicated that the model provides very close agreement with reality for prediction of live-weight gain.

Therefore, Live weight gains can be predicted by the ARC[6] ME system with confidence and flexibility because the acceptable agreement and the close relationship between observed and predicted LWG gives general support to energy model to be manipulated with confidence to provide predictions of live-weight gain of pure-bred cattle fed under local conditions. However, there is still a need for further investigations for other European breeds fed under local conditions.

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