Dry Matter Intake in Dairy Heifers.
2. Equations to Predict Intake of Heifers Under Intensive Management[1]

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ABSTRACT

An equation was developed to predict daily dry matter intake of heifers weighing 100 to 400 kg. One hundred eighteen Holstein heifers were grouped according to body weight (100, 200, 300 kg) and fed total mixed rations of corn silage, ground orchardgrass hay, high moisture corn, soybean meal, and minerals once daily for 28 d in two trials. Sixty-four heifers were reused in the second trial, a total of 5096 observations of daily dry matter intake. Rations were balanced for mean body weight according to National Research Council recommendations for protein, vitamins, and minerals and 85, 95, 105, and 115% of recommendation for total digestible nutrients. Independent variables used in multiple regression and crossvalidation were body weight, body weight gain, ration total digestible nutrient concentration, ambient temperature, squared and interaction terms, and metabolic body weight. Predictive model accounted for 59% of total variation in daily dry matter intake in individual animals. Predicted intake was similar to National Research Council predictions at .6 to .7 kg daily gain and ration total digestible nutrient concentration recommended by National Research Council but varied at rates of daily gain above and below .6 to .7 kg/d.

INTRODUCTION

Accurate prediction of dry matter (DM) intake requires that factors significantly influencing intake be included in predictive models. Research conducted with lactating cows has improved accuracy of DM intake prediction equations by elucidating factors influencing intake and incorporating these into predictive equations (5). Research at this station (11) has identified several factors important to predicting intake in dairy heifers in confinement housing fed for ad libitum consumption of total mixed rations (TMR). Although body weight, daily gain (8, 11), ration energy concentration (2, 7, 11), bulk density (1, 3, 4, 6, 11), and environmental temperature (9, 11) have influenced nutrient intake of ruminants, published tables predicting DM intake (8) are based on body weight and gain only. Further, published prediction equations are based on data from heifers fed at less than ad libitum feeding.

Management of replacement heifers has become more intensive with increasing numbers of heifers raised in confinement systems where growth and feed intake may be monitored more accurately. With increased emphasis on rapid growth and increased feed intake, accurate predictions based on ad libitum feeding trials are required. Further, prediction equations incorporated into computerized ration formulation programs require inputs readily available or estimable by program users. The object of this study was to develop an equation to predict DM intake of growing dairy heifers weighing 100 to 400 kg in confinement housing and fed for ad libitum consumption.

MATERIALS AND METHODS

One hundred eighteen Holstein heifers were used in two 28-d feeding trials. Sixty-four heifers were reused in trial 2, resulting in 182 28-d measurements. Care and feeding of animals and data collection have been described (11). Independent variables used in model develop-

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ment were body weight (kg, BW), BW squared (BWSQ), rate of daily gain (kg, GAIN), GAIN squared (GAINSQ), ration total digestible nutrient concentration (% of DM, TDN), TDN squared (TDNSQ), ambient temperature (degrees, AMBT), and AMBT squared (AMBTSQ). Also included in initial screening were metabolic BW ($kg^{.75}$, METBW) and interaction terms gain × AMBT (GANAMBT) and BW × AMBT (BWAMBT).

Data set was completed by including all variables from both trials on a daily basis. Ration TDN was predicted from acid detergent fiber in ration DM analyzed weekly. Ration TDN was selected for initial screening over ration acid detergent fiber, neutral detergent fiber, or bulk density (11) because National Research Council recommends TDN in published tables of nutrient requirements (8). Daily BW and GAIN were estimated by second-order polynomial regression of day of experiment on weekly BW.

Stepwise multiple regression analysis was conducted as outlined in (10, 12). Independent variables used in stepwise regressions were added to the model if significance of calculated F statistic was $P<.05$. Similarly, variables in the model were removed after addition of a new variable if significance of calculated F statistic became $P>.05$. Model building ended when no variable outside the model had a significant ($P<.05$) F statistic and every variable in the model had a significant ($P<.05$) F statistic.

All possible regression analysis was conducted (12). Each independent variable was evaluated alone and in combination with all subsets of independent variables in the model to provide r^2 and C_p statistics and aid in evaluating inclusion of independent variables. The C_p statistic is an estimate of amount of deviation in predictability from that of the full model; it may be considered an estimate of bias in the model, assuming that the full model contains a low bias component (10).

RESULTS AND DISCUSSION

Stepwise regression of independent variables on intake of DM indicated all variables contributed significantly ($P<.001$) to the model; however, r^2 increased only slightly (.59 to .60) after BW, GAIN, ration TDN, and their squared terms were in the model. Although other variables were statistically significant ($P<.001$), they did not add to predictive power of the model.

All possible regression analyses produced r^2 and C_p statistics for each model. The r^2 statistics ranged from zero with AMBT as the only independent variable to .60 with all variables present. Only slight increases in r^2 were obtained with models containing more than 3 variables. The C_p statistic decreased from 6954.9 with AMBT as the only variable in the model to 10.1 with 10 variables in the model. When more than 5 variables were in the model, C_p decreased only slightly. Minimum C_p statistics were obtained when BW, TDN, GAIN, AMBT, and their squared terms were included, suggesting all were important in reducing bias. Selected models containing 6 or more independent variables were compared to determine amount of improvement by including AMBT (Table 1) Included in the analysis was the PRESS statistic, an estimate of influence of individual observations on prediction (10). The PRESS statistic decreased only about 2%, from 6725 with 6 variables to 6585 with the full model (Table 1), suggesting that 6 variable models should be relatively free of bias caused by individual observations. Evaluation of all statistics suggested that AMBT (models 4, 5, and 6, Table 1) did not improve predictive ability and was excluded from further testing.

Models 1, 2, and 3 (Table 1) were then evaluated by crossvalidation procedures. Full data set was sampled randomly to obtain 100 observations used to fit each model to the data. Subsampling was repeated six times, and r^2, mean square error, and PRESS statistics were determined. No differences were observed in any statistic measured with any of the six subsets. Subsequently, one fitted equation was chosen randomly from the above six models, and a second subset of 100 observations obtained to determine degree of accuracy of the model selected. Comparison of each model was based on a calculated sum of squared residuals $[\Sigma(Y\ predicted - Y\ actual)^2]$ for five subsets of data. No differences were observed in any subset. Any of the three models can adequately predict intake of DM in this data set. Based on slightly better r^2, C_p, and PRESS statistics using the full data set, model 3 (Table 1) was selected.

Interaction terms BW × TDN (BWTDN), BW

× GAIN (BWGAN), and TDN × GAIN (TDNGAN) were added to the model to test possible improvements as recommended by Neter and Wasserman (10). All possible regressions were calculated, and r^2 and C_p statistics were obtained. Results of model containing BWGAN, and TDNGAN, model containing BWTDN, BWGAN, and TDNGAN and 6 variable model were (r^2, C_p): .592, 8.03, .592, 10.0; and .591, 44.7, respectively. Inclusion of BWGAN and TDNGAN reduced PRESS (6725 vs. 6702) and was most descriptive of the data, so it was therefore selected (Table 2).

Comparison of selected model with data from National Research Council [NRC (8)] is in Table 3. Concentrations of TDN in ration DM are recommendations of NRC for listed BW and GAIN. Below .6 kg gain/d, intake of DM estimated by selected model is lower than estimated by NRC. These comparisons indicate importance of ration energy on intake of DM, a factor NRC does not include. At typical GAIN

TABLE 1. Diagnostic statistics of selected models to predict dry matter intake.

Model[1]	r^2	MSE[2]	C_p	PRESS
1	.590	1.40	56.55	6725.13
2	.590	1.40	56.43	6725.03
3	.590	1.40	56.32	6724.84
4	.594	1.39	27.36	6606.50
5	.596	1.39	11.72	6584.56
6	.596	1.39	12.00	6584.96

[1]Models are: 1) kilograms body weight (BW), BW squared (BWSQ), rate of daily gain (kg, GAIN), GAIN squared (GAINSQ), total digestible nutrient concentration (% of dry matter, TDN), TDN squared (TDNSQ); 2) BW, metabolic BW ($kg^{.75}$, MET BW), GAIN, GAINSQ, TDN, TDNSQ; 3) BWSQ, METBWT, GAIN, GAINSQ, TDN, TDNSQ; 4) BW, BWSQ, GAIN, GAINSQ, TDN, TDNSQ, AMBIENT TEMPERATURE (degrees, AMBT), AMBT squared (AMBTSQ); 5) BW, BWSQ, GAIN, GAINSQ, TDN, TDNSQ, AMBT, ABMTSQ, BW × AMBT (BWAMBT), gain × ambient temperature (GANAMBT).

[2]MSE = Mean square error.

[3]PRESS = An estimate of influence of individual observations on prediction.

TABLE 2. Parameter estimates[1] and standard error (SE) of estimates for selected model to predict dry matter intake.

Independent[2] variable	Coefficient	SE
Intercept	−29.86365959	1.143
BWSQ	−1.5425468E-05	3.51E-06
METBW	.15748749	.010
GAIN	2.08951563	.350
GAINSQ	−.11770722	.024
TDN	.72957095	.033
TDNSQ	−.00481779	2.55E-04
BWGAN	−.00136331	5.12E-04
TDNGAN	−.01908410	.005

[1]All estimates significant at $P<.0001$, except BWGAN, $P<.001$; n = 4797, r^2 = .592; $s_{y \cdot x}$ = 1.18, CV = 19.4.

[2]BWSQ = Body weight squared, METBW = metabolic body weight, GAIN = rate of daily gain, GAINSQ = gain squared, TDN = total digestible nutrient concentration, TDNSQ = TDN squared, BWGAN = BW × GAIN, TDNGAN = TDN × GAIN.

TABLE 3. Comparison of selected model versus NRC[1] predictions of dry matter (DM) intake of heifers from 100 to 400 kg.

Body weight	Daily gain	TDN[2] in ration DM	NRC	Selected model
(kg)		(%)	(kg)	
100	.5	67.5	2.80	2.56
	.6	71.4	2.80	2.80
	.7	75.0	2.80	2.89
	.8	77.9	2.80	2.86
150	.5	63.0	4.00	3.69
	.6	66.0	4.00	4.04
	.7	69.0	4.00	4.28
	.8	72.0	4.00	4.43
200	.5	61.3	5.20	4.81
	.6	63.7	5.20	5.14
	.7	66.3	5.20	5.42
	.8	68.5	5.20	5.60
250	.5	59.4	6.30	5.69
	.6	62.1	6.30	6.10
	.7	64.3	6.30	6.37
	.8	66.5	6.30	6.59
300	.5	60.7	7.20	6.87
	.6	63.3	7.20	7.22
	.7	65.1	7.20	7.43
	.8	67.6	7.20	7.64
350	.5	59.0	8.00	7.46
	.6	61.3	8.00	7.83
	.7	63.3	8.00	8.09
	.8	65.0	8.00	8.28
400	.4	57.1	8.50	7.87
	.6	61.3	8.60	8.56
	.7	63.4	8.60	8.82
	.8	65.2	8.60	9.01

[1] 1978 National Research Council (8).

[2] Total digestible nutrients as listed (8).

(.6 to .7 kg/d), ration energy recommended by NRC (8) is similar to that fed in this study, and intake of DM is similar (Table 3).

This model predicts with relative accuracy the daily DM intake of replacement heifers from 100 to 400 kg when fed TMR. Incorporation of ration TDN into the model attempts to account for physical and metabolic controls of intake (11). Incorporation of a prediction equation into a ration program may require validation and modification to meet local conditions and requirements.

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