
VOLUME 62 2002

Use of breeding values for live weight to calculate individual live weight targets for dairy heifers

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ABSTRACT

Replacement heifers need to reach specific target live weights (LW) to ensure they calve as two year olds, and subsequently achieve high milk yields and good fertility. Currently, different LW targets are recommended for heifers based on their expected mature LW according to appearance or breed. However, the mature LW is difficult to estimate without knowledge of the animals' genetic potential for LW. The objective of this paper is to develop and validate a growth model which uses estimated breeding values for LW (EBV LW) of individual heifers of any breed to calculate target LW from birth to maturity. Predicted live weights are presented for a range of four EBV LW, from –40 to 100 kg. These values were very similar to other published target values. Data from the Dexcel Holstein Friesian Strain Trial was used to validate the model with respect to LW and age at puberty. For LW at puberty the predicted values were significantly correlated ($P<0.05$), but were marginally higher (3-5%) than the actual values. A report can be formulated to enable farmers to identify individual heifers which are below (or above) their target LW at any date

Keywords: dairy cattle; live weight targets; breeding values; heifer replacements.

INTRODUCTION

In New Zealand's pastoral dairying system, approximately 20% of the herd is replaced annually with two year-old heifers. Rearing these dairy replacements is a significant cost in the dairy operation. The level of feeding and consequent growth of these animals influences their ability to reach puberty before 12 months of age. Reaching puberty before 12 months of age, maximises submission and conception rates when the heifers are due to be mated at 14 to 15 months of age (Macmillan, 1994). In addition, the level of feeding also determines the heifers' ability to achieve to their genetic potential for milksolids (MS) production, survive in the herd, and calve at 12 month intervals (Bryant and McRobbie, 1991).

Correct nutritional management throughout the heifer's development encourages mammary gland development, and ensures high live weights (LW) at calving (Heinrichs, 1993). There is a positive relationship between LW at first parturition and MS production in the first lactation (Keown and Everett, 1986; Penno, 1997). In New Zealand this relationship ranges from 0.12 to 0.43 kg of extra MS for every additional kg of LW at two years of age (Bryant and McRobbie, 1991; Penno *et al.*, 1997; van der Waaij *et al.*, 1997). A significant amount of this increased production arises from greater mobilisation during lactation of body reserves which were deposited as a consequence of the extra feeding from 15-22 months of age to achieve higher LW targets (Penno *et al.*, 1997).

Live weight is also a key determinant of the time of onset of puberty, because a heifer reaches puberty when she attains about 42 - 48 % of her mature LW (Garcia-Muniz *et al.*, 1998; McNaughton *et al.*, 2002). The effects of feeding level and growth rate on the reproductive performance of Jersey and Holstein Friesian (HF) heifers were shown in the trial reported by Penno (1997). Only 80 % of heifers fed to grow slowly reached puberty by 15 months of age (average LW = 252 kg) compared with over 90 % in feeding level groups that averaged more than 300 kg. Similar results were reported in the Jersey heifers.

A number of investigators have described target LW for heifers for a New Zealand system (Penno *et al.*, 1997; Bryant and McRobbie, 1991). Target LW at mating (15 months) and calving (24 months) of 60% and 90% of the estimated mature LW, respectively, were suggested by Troccon (1993) in Australia, and supported by Penno *et al.* (1997) for New Zealand. However, it is difficult to estimate the mature LW of an individual heifer without information relating to her genetic background. Studies by Garcia-Muniz *et al.* (1998) and McNaughton *et al*. (2002) indicate there is a large amount of (genetic) variation between animals in LW, even within the same breed of cattle. Therefore, different LW targets are needed throughout development appropriate to the individuals genetic makeup (Hoffman, 1997). This is especially important in New Zealand due to the greater variation in breed type used compared with other countries.

The objective of this paper is to present a model, which uses the estimated breeding value for mature LW

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(EBV LW) of individual heifers, to calculate target LW at important stages of growth. The model is validated by comparison between its predicted LW for ages and the actual data from three experiments, which studied different strains of HF, or HF and Jerseys managed with different levels of feeding.

METHODS

In the model, the mature live weight (LW_m) of an animal is calculated relative to a group of base animals. The base animals chosen were 6-8 year old HF cows, which had an average LW of 529 kg in 2000/2001 (LIC, 2003). The average EBV LW of these animals was estimated to be 50.6 kg (Bill Montgomerie, personal communication):

$LW_m = 529.3 + (\text{EBV LW} - 50.6)$

An estimated value of 1.7 % has been added onto the mature LW of the HF Jersey cross heifer to account for the effect of heterosis (Lopez-Villalobos, 1998).

Studies by Garcia-Muniz *et al.* (1998) found the re-parameterised von Bertanlanffy equation as given by Bakker and Koops (1978) provided the best fit for LW for the light LW selection line animals and ranked similarly to the Brody and Gompertz functions for the heavy LW selection line. Consequently, in this study the re-parameterised von Bertanlanffy function was adopted where the live weight (LW_t) at age t (in months), excluding foetal components, was calculated using:

$LW_t = LW_m\{1-[1-(LW_0/LW_m)1/3]e^{-kt}\}^3$

where LW_m is mature live weight (derived from breeding values), LW_0 is birth live weight calculated as: $(LW_m^{0.73} - 28.89)/2.064$ (Roy, 1980), k is a constant related to rate of maturing (Bakker and Koops, 1978) and e is the base of the natural logarithm.

The weight of the foetal components (W_f) are calculated daily from conception, which is assumed to occur 282 days prior to the animal reaching 2 years of age, using the formula:

$W_f = \log^{2.932-(\exp(-0.00406t)*3.347)}$

where t is days since conception.

The value (W_f) is then multiplied by a factor: LW_o/ 40 kg calf (AFRC, 1993), to determine the weight of the foetal components scaled to the LW of the animal. This value is then added onto LW_t to estimate the actual weight of the animal including foetal components.

Validation

The live weights calculated by the model for 15 and 24 months of age for animals with different EBV LW, were compared with target values recommended by Penno *et al.* (1997), based on their study and an Australian study by Troccon (1993).

Actual data for the date of birth, EBV LW and LW at puberty (monitored by progesterone concentration in the blood), or at the end of the measurement period were obtained for each heifer in three strains of HF cows, overseas 1990 genetics (OS90), New Zealand 1970 genetics (NZ70) and New Zealand 1990 genetics (NZ90) which were used in the Dexcel HF strain trial. These strains were average genetic merit animals of the breed, decade and area they represented. For further details relating to the study see McNaughton *et al*. (2002).

RESULTS AND DISCUSSION

Model outputs and validation

Presented in Table 1 are the model-derived LW targets for average Overseas HF, New Zealand HF, HF Jersey cross and Jersey heifers ranging in EBV LW from +100 to –40 kg, from 9 months of age to maturity. These are very similar to the corresponding target LWs calculated from Penno *et al.* (1997).

TABLE 1: Live weight (LW) targets calculated by the model for heifers with different estimated breeding values for LW (EBV LW) at important management stages.

Probable Breed[1]	OS HF	NZ HF	HF x J	J
EBV LW (kg)	**100**	**60**	**10**	**-40**
Predicted mature LW (kg)	578	538	496	438
9 months	230	214	197	174
15 months (Mating)	353 (350)[2]	329 (320)	299 (295)	264 (260)
21 months	461	429	395	349
24 months (pre-partum)	537 (520)	500 (480)	460 (445)	406 (395)

[1] OS HF = Overseas Holstein Friesian, NZ HF = New Zealand Holstein Friesian, HF x J = Holstein-Friesian Jersey cross, and J = Jersey

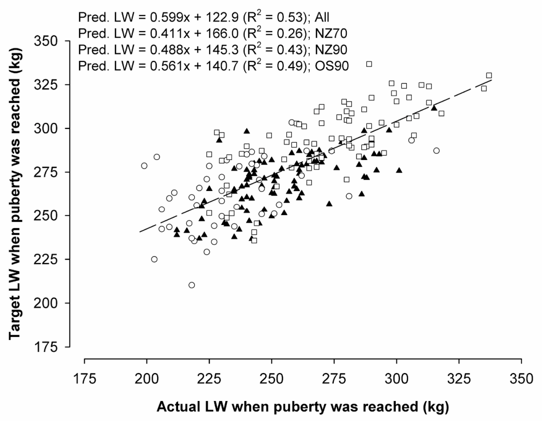
[2] The values in brackets are estimated from Table 3 of Penno et al. (1997) by interpolation between the different values for mature LW.

The first step in the validation with respect to puberty was to show EBV LW is related to actual LW at puberty. Initial investigations of such data from the HF strain trial (McNaughton, 2003) showed this relationship does exist (LW at puberty = 204.1 + 0.86 EBV LW; $R^2 = 0.42$). The model was then used to predict from the EBV LW for each heifer, her target LW at the age when she actually reached puberty. The results of this process show that, although the actual LW at puberty were 3 - 5 % lower than the predicted LW at this age the two values were still related ($r^2 = 0.53$) across all three strains (Figure 1).

To test the significance of this relationship within HF strains, the root of mean square prediction error was divided by actual live weight at puberty of each strain. Based on a study by Fuentes-Pila *et al.* (1996), the predictive accuracy of the model is within the acceptable limits (<10%) for the NZ70 (8%), NZ90 (5%) and OS90 (6%) strains.

The results of the validation using the data set of McNaughton *et al.* (2002) support the use of EBV LW to formulate LW targets for HF cattle and in particular for determining target LW at puberty. Further investigations are needed to validate the model and choice of growth curve function for other dairy breeds and at different stages of heifer development. Nonetheless, the LW targets are very similar to those which were recommended by Troccon (1993), and subsequently endorsed by Penno *et al.* (1997) for heifers with similar estimated mature LW (Table 1). The advantage of the system presented here is that mature LW are calculated from EBV LW, whereas the targets described by Troccon (1993), required an estimation of the expected mature LW based on appearance or breed.

FIGURE 1: Relationship between actual live weight (LW) and target LW at puberty in NZ70 (○) NZ90 (▲) OS90 (□) heifers.



The recommended target of 537 kg at 2 years of age for overseas HF heifers (Table 1) are also comparable to the 540 kg target as recommended by Carson *et al.* (2002) for Holstein Friesian heifers in Northern Ireland. Investigations by McNaughton *et al.* (2002) recommended mating LW targets of 340 kg LW and 300 kg LW for OS90 (84 kg EBV LW) and NZ90 animals (48 kg EBV LW), respectively. The values calculated by the model at 15 months of age, for their EBV LW are 339 and 317 kg for the OS90 and NZ90 animals, respectively.

Growth rates of 0.70-0.80 and 0.45-0.55 kg/day for 100 (OSHF) and -40 kg EBV LW (Jersey) heifers, respectively in the pre-pubertal period (90-300 kg) are needed to achieve the target LW. Sejrsen and Purup (1997) have reported these levels of pre-pubertal growth rates have a negative effect on subsequent milk production. However, pre-puberty growth rates of 0.8 and 0.65 kg/day in HF and Jersey heifers, respectively, did not have a significant negative effect on subsequent milk production in New Zealand (Penno, 1997; Penno *et al.*, 1997). Similarly, pre-pubertal growth rates of 0.66 to 0.95 kg/day in HF heifers did not result in a reduction in first lactation milk yield in Northern Ireland (Carson *et al.,* 2000). Therefore, it is unlikely the pre-puberty growth rates needed to reach the LW targets recommended in this study will result in a negative effect on milk production.

Using the model, a management report can be formulated at any weigh date, in which heifers are ranked according to their deviation from individual target LW. The target LW, calculated for age at weighing, is compared with the actual LW, and the difference as a percentage of the target is recorded. Heifers within 5 % of targets are probably at the appropriate LW. The report allows dairy graziers to identify heifers that are significantly below (-10 %) their target value. These animals could then be managed appropriately to ensure they reach target LW at subsequent dates of weighing. Similarly, if animals are significantly above (+10 %) their target value, management should ensure they do not have excessive LW gain before puberty, which could have detrimental effects on milk solids production.

CONCLUSION

The proposed model offers an advanced method for calculating heifer LW targets and so can contribute to the improved nutritional management of individual dairy heifers. When incorporated into an appropriate management report, such improvements will help improve heifer in-calf rates at 15 months, and increase the likelihood of heifers achieving to their genetic capabilities for milk solids production over a long productive lifetime.

ACKNOWLEDGEMENTS

J. Bryant would like to acknowledge the Masterate funding provided by AGMARDT, and the Enterprise Doctoral Scholarship provided jointly by the Livestock Improvement Corporation and the Foundation for Research, Science and Technology (FRST). Thanks to Bill Montgomerie for providing data and suggestions, and the authors also appreciate the efforts of farm staff at the Dexcel dairy grazing unit for care of animals

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