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Moving Beyond Weight as the Only Predictor of Breeding Readiness: Using a Breeding Maturity Index

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Summary

A maturity index (MI) was developed using data from Gudmundsen Sandhills Laboratory to predict a heifer's optimal size for breeding. It was developed from observable information such as age, feeding regime, pre-breeding, birth and dam weights. The MI was the most precise predictor of actual percentage of mature weight versus using estimates developed from the herd's estimated average weight or the dam's mature weight. The MI also was a more accurate predictor of first pregnancy than the typically applied measure.

Introduction

Recommendations provided to producers with respect to the size beef cattle replacement females should attain prior to first breeding is generally given as a percentage of their mature body weight. What is not often mentioned is that the heifer's actual measure of percent mature body weight requires knowledge of her mature weight, which is not available until she reaches an age of 4 to 5 years. Animal scientists routinely substitute the herd's estimated average weight as a proxy for an individual animal's mature weight. This measure can accurately be described as percentage of average herd weight (PAHW).

Two assumptions are made when using the PAHW as a proxy measurement of maturity: 1) animals in a herd are of a homogeneous weight, and 2) the herd's average weight is representative of the average mature weights of cows from that herd. These two assumptions are problematic in application, since most commercial herds contain animals of various sizes and ages, where the ages and sizes are not likely to be uniformly distributed. It would be expected that a greater percentage of younger animals would be present in a herd versus older animals and that many factors could influence the size variation within the herd. Both of these facts introduce variation error in measuring maturity.

Despite these shortcomings, this method of determining mature body weight has been widely adopted and accepted, most likely because it is convenient and provides a rough measure of heifer maturity and breeding readiness. However with the amount of information available to animal scientists and producers, it is logical to explore other means of predicting maturity. Given current technology and information, a new method of measuring maturity was developed based on a series of observable individual animal characteristics, much like an index, and thus was titled the maturity index (MI).

Procedure

Data from two experiments performed on young heifers at the Gudmundsen Sandhills Laboratory (GSL) were analyzed to determine the MI. Each of these two experiments has been published in previous Nebraska Beef Cattle Reports (*2002 Beef Cattle Report*, pp. 4-7 and *2005 Beef Cattle Report*, pp. 3-6). These studies were initiated to determine the effect of reducing the PAHW. The first experiment consisted of a study of two groups of animals fed to an average PAHW of approximately 60% and 56%. The more recent study (2005) targeted even lower maturity levels to a PAHW of 58% and 53%. The primary objective in these two trials was to compare pregnancy rates. In both of these studies feed was varied to control the pre-breeding weights of the heifers. As with most groups, individual animals deviated from the group averages. In this work, the treatment effect was considered, but variation within groups also was an important part of the result. The within-group variation made possible the use of statistical techniques to estimate differences in individual maturities. The combined data for these two studies contained information about 500 heifers.

As the studies progressed, animals that died, did not conceive or lost their calves were culled and sold, leaving only 302 at the time of maturity. The actual percentage of mature body weight (APMBW) at the time of first breeding was calculated by dividing a heifer's pre-breeding weight by her actual mature weight at the time her third calf was weaned.

A series of ordinary least squares regressions was estimated using APMBW as the dependent variable and all possible combinations of five commonly observed variables: pre-breeding weight, birth weight, dam mature body weight, pre-breeding age and nutrition level, as measured by a set of indicator variables for the four ration treatments that were part of the original experiments. The selected model was chosen on the following two criteria. First, each of the coefficient estimates had to be statistically significant at the 95% level using a student t test; and second, the selected model had to have the lowest Akaike information criterion (AIC) score. The AIC, as described in *Basic Econometrerics* by Damodar Gujarati (2003), is used to balance the explanatory power obtained from the number of coefficients included in the estimation process versus the cost of increased model complexity, and is commonly applied as a model selection criterion.

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Results

Equation 1 shows the MI model meeting the two conditions of coefficient significance and minimum AIC score. Three indicator or "dummy" variables were included to account for the four feed treatment groups. The fourth group's T4 was the baseline and required no indicator variable.

Equation 1.

$$MI = 30.508 + 0.032\,PbWt - 0.146\,BirthWt + 0.078\,Age - 0.013\,DamWt + 4.839\,T1 + 2.658\,T2 + 2.499\,T3$$

Where:

MI = Maturity index

PbWt = Pre-breeding weight

BirthWt = Birth weight

Age = Age in days for first bull exposure

DamWt = Weight of the heifer's dam at weaning when four years of age

T1 = Dummy variable for feeding treatment group resulting in a group average pre-breeding weight of 58% of mature body weight

T2 = Dummy variable for feeding treatment group resulting in a group average pre-breeding weight of 53% of mature body weight

T3 = Dummy variable for feeding treatment group resulting in a group average pre-breeding weight of 56% of mature body weight

The relationship between MI and the variables that predict it provide clues about the factors that affect maturity and breeding readiness. From Equation 1, the right side coefficients represent the magnitude and nature of the relationship that each has to the MI. For example, the coefficient for pre-breeding weight shows there is a positive 0.032 increase in MI for every pound of weight, indicating that the heavier the heifer the greater her MI, relative to other heifers with identical birth weight, dam weight, age and nutrition level. The dam's weight has a negative effect on the MI, indicating animals of equal age, birth weight, pre-breeding weight and nutrition level have a 0.013 reduction in their MI for every pound larger their dam was relative to the dams of other heifers. The same effect holds for birth weight as for dam weight: the larger the birth weight the smaller the MI would be relative to contemporaries that differ only by birth weight. Age has the opposite effect of birth weight and dam weight. For each day of age, the heifer's MI would increase by .078, holding all other variables constant, *ceteris paribus*. Nutrition level also has an effect; as the level of nutrition increases, the MI increases, given the *ceteris paribus* condition.

From a statistical perspective, this model is ideal, but the important question is how well it performs. The true test for this model would be to compare its performance to that of the PAHW in predicting the actual percentage mature body weight and — most importantly — ability to successfully breed and become pregnant. Unfortunately, in creating the MI, all of the observations were used to construct the model, making it impossible to perform an out-of-sample test. A second option, which was used in this case, was to compare the two methods using the current data in an in-sample test. In addition, an *ad hoc* method of describing a heifer's maturity was included to provide breadth. This measure, referred to as the percent of mature dam weight (PMDW), was obtained by dividing a heifer's pre-breeding weight by her dam's mature body weight. The mature weight of the dam is expected to have a large influence on the mature weight of the heifer. It would be expected that the dam's weight would be a better predictor of a heifer's mature weight than the herd's average weight, but not as good a predictor as the MI. The Mean Absolute Percent Error (MAPE) method was used to compare the three methods.

Table 1. Comparing MI, PAHW and PMDW as predictors of APMBW using a MAPE.

Forecaster	MAPE
MI	5.7%
PAHW	12.3%
PMDW	8.9%

The MAPE is a weighted measure of the average amount of error observed over the sample space. The method with the smallest calculated MAPE is the method with the least amount of error and is therefore the most accurate predictor over the sample space. Table 1 shows the calculated MAPE values for MI, PAHW and PMDW when used to predict APMBW. These results indicate that over the sample space, the MI is the best predictor of percent of mature body weight. MI out-performs both other prediction methods, with more than 3% less error than PMDW and more than 5% less error than PAHW.

The next step in evaluating the usefulness of the MI was to determine how accurately it predicted pregnancy. The MI was compared to two other methods of expressing a heifer's maturity at breeding. The first of these methods was the APMBW, the individual animal's pre-breeding weight as a percentage of her actual mature weight. As discussed earlier, the heifer's actual mature weight is not available at the time of the breeding decision, thus making the APMBW unavailable for practical use, but it does serve as a base point of comparison, being an individually calculated measure of maturity. The second measure is the commonly used PAHW, the heifer's weight relative to the herd's average weight.

Each of the three measures was used as the independent variable in a Probit regression on pregnancy rate. Pregnancy is measured as occurring, 1, or not occurring, 0. This type of information, where the dependent variable is limited, is best handled by a limited dependent variable regression such as the Probit. A model of this type is estimated by maximum

Table 2. Comparison of student t tests for the PAHW, APMBW and MI as predictors of the rate of first pregnancy using a Probit regression.

Independent Variables Used	Constant	X	X^2
PAHW	-1.612	1.779	-1.663
APMBW	0.861	-0.788	0.863
MI	-1.880	1.923	-1.871

likelihood. The coefficient estimate is the part of the normal distribution equation that represents the mean and standard deviation, assuring that the Probits' results are translated into probabilities, regardless of the value of the coefficient estimates. The Probit regression equations were modified to reflect the diminishing returns of pregnancy rate to maturity, by including the quadratic term.

Table 2 shows the results of these Probit regressions. The greater the absolute value of the student t tests, the greater the chance that the coefficient is statistically significant. These findings indicate that MI is a statistically superior predictor of first pregnancy as compared to the PAHW and the APMBW.

Discussion

MI is a more accurate and statistically superior predictor of first time pregnancy in replacement beef heifers studied at GSL than the currently used PAHW, the commonly accepted method of stating heifer size at pre-breeding. Logically these results are not unexpected, since the MI is derived entirely from individual animal information, while the PAHW is based partially on herd information. The MI is also superior to the true measure of mature stature, APMBW. While at first this seems counter-intuitive, careful thought reveals why this is so. The MI contains information in addition to the heifer's mature stature including age, nutrition and birth weight.

It is possible to use the relationships found from estimating the MI to increase the probability of a higher pregnancy rate among replacement females. Relatively older calves with a smaller birth weight, smaller dam weight, and of a higher pre-breeding weight fed at a higher level of nutrition would have a relatively higher MI than herd mates and would thereby have a greater probability of becoming pregnant.

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