



Replacement heifer development alternatives: food costs and expected reproductive performance
by Vernon Francis Fogle

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE
in Applied Economics

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Abstract:

The major capital assets of a commercial cow-calf ranch, the cows in the breeding herd, must periodically be replaced. Optimal replacement heifer development policy is jointly determined by the expected productivity of cows presently in the herd, the expected productivity of potential replacements, and the cost of providing replacements.

If the replacements are to be heifer calves produced in the herd, the rancher must decide at weaning time which heifer calves should be kept as replacements and how they should be fed from weaning until the coming breeding season.

It was hypothesized that the occurrence of puberty and thus of pregnancy in replacement heifers can be affected by postweaning feeding practices. Probability of puberty was estimated as a function of heifer age and weight. The estimated equation supports the hypothesis that heifers, if fed for high rates of gain during the wintering period, will be younger and heavier at puberty than if fed for low rates of gain.

Using linear programming techniques, least cost rations were determined for heifer calves varying in weight and fed for four alternative rates of gain. Utilizing these least cost rations, total winter feed costs were estimated for various heifer wintering alternatives, each alternative consisted of specific heifer weight at weaning and a specific rate of gain to be fed for during an 180 day wintering period.

Various replacement heifer development alternatives were then analyzed in terms of costs and expected reproductive performance.

Each alternative consisted of a state of nature, a heifer of specific age and weight at weaning, and an action, the rate of gain to be fed for during the wintering period. The results indicate that for a heifer of any state probability of pregnancy increases and expected time of pregnancy becomes earlier as rate of gain is increased.

This indicates that within limits young light heifers, if fed for higher rates of gain, can achieve the same level of expected reproductive performance as old heavy heifers. However, the benefits of higher probability of pregnancy and earlier expected pregnancy must be weighed against increased feed costs. The inclusion of an opportunity cost of sale of heifer calves at weaning changed the ranking of the alternatives, indicating that costs other than feed costs should be considered when planning replacement policy. Altering the length of the breeding season also changed the ranking, indicating that individual management practices should be considered.

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FEED COSTS AND EXPECTED REPRODUCTIVE PERFORMANCE

by

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ABSTRACT

The major capital assets of a commercial cow-calf ranch, the cows in the breeding herd, must periodically be replaced. Optimal replacement heifer development policy is jointly determined by the expected productivity of cows presently in the herd, the expected productivity of potential replacements, and the cost of providing replacements. If the replacements are to be heifer calves produced in the herd, the rancher must decide at weaning time which heifer calves should be kept as replacements and how they should be fed from weaning until the coming breeding season.

It was hypothesized that the occurrence of puberty and thus of pregnancy in replacement heifers can be affected by postweaning feeding practices. Probability of puberty was estimated as a function of heifer age and weight. The estimated equation supports the hypothesis that heifers, if fed for high rates of gain during the wintering period, will be younger and heavier at puberty than if fed for low rates of gain.

Using linear programming techniques, least cost rations were determined for heifer calves varying in weight and fed for four alternative rates of gain. Utilizing these least cost rations, total winter feed costs were estimated for various heifer wintering alternatives, each alternative consisted of specific heifer weight at weaning and a specific rate of gain to be fed for during an 180 day wintering period.

Various replacement heifer development alternatives were then analyzed in terms of costs and expected reproductive performance. Each alternative consisted of a state of nature, a heifer of specific age and weight at weaning, and an action, the rate of gain to be fed for during the wintering period. The results indicate that for a heifer of any state probability of pregnancy increases and expected time of pregnancy becomes earlier as rate of gain is increased. This indicates that within limits young light heifers, if fed for higher rates of gain, can achieve the same level of expected reproductive performance as old heavy heifers. However, the benefits of higher probability of pregnancy and earlier expected pregnancy must be weighed against increased feed costs. The inclusion of an opportunity cost of sale of heifer calves at weaning changed the ranking of the alternatives, indicating that costs other than feed costs should be considered when planning replacement policy. Altering the length of the breeding season also changed the ranking, indicating that individual management practices should be considered.

Chapter 1

INTRODUCTION

Included in Montana's agricultural sector is a large number of beef cattle operations, the most prevalent of which are commercial cow-calf ranches. The chief income-producing activity of a commercial cow-calf ranch is raising feeder cattle for sale, generally steer calves and those heifer calves which are not kept for replacement of cows to be culled from the breeding herd.

The major capital asset used in producing cattle for beef is the beef cow herd. As is the case with most productive assets, beef cows are periodically replaced. Cows in the herd may be replaced by females of any age. However, it is common practice to replace cows with heifers which are bred as yearlings to produce their first calves as two-year-olds. Optimal replacement policy is jointly determined by the expected productivity of cows presently in the herd, the expected productivity of potential replacements, and the cost of providing replacements.

Replacement heifers can be purchased or raised. There is risk associated with both methods of providing replacements. Heifers that are available for purchase have in most cases been culled from other herds. This would indicate that they are either relatively poor performers or too young to be economically bred as yearlings.

In addition, there is some degree of uncertainty concerning the possible introduction of disease into the herd. Consequently, the common practice is for ranchers to raise their own replacements.

Raising replacements is also subject to conditions of risk and uncertainty. Among the decisions a rancher must make at weaning time are two interrelated decisions concerning replacement policy: Which heifer calves should be kept as replacements? How should the heifers be fed from weaning through breeding? In order to make these decisions the rancher must be able to predict the effects of various feeding alternatives on the future reproductive performance of the replacements and to estimate the costs associated with the feeding alternatives.

Future reproductive performance, as it is used in this research, is defined as weight of calf weaned each year during the heifer's productive life. Future reproductive performance is affected to a large extent by first calf performance. Heifers which calve early in their first calving season tend to calve early in subsequent years, and thus tend to wean older and therefore heavier calves throughout their lifetimes (Lesmeister, et.al. (1973), pp. 3-4). In order to calve early as a two-year-old a heifer must reach puberty and become pregnant by the early part of the breeding season when she is a yearling.

It is hypothesized that the occurrence of puberty and thus of first pregnancy in replacement heifers can be hastened by feeding for high rates of gain during the post weaning period. There is a trade-off involved, however; high rates of gain result in high feed costs.

Purpose of the Study

Replacement policy decisions could more easily be made if there existed a decision model which would enable ranchers to relate the effects of various post weaning feeding alternatives on the occurrence of puberty and pregnancy to the costs associated with the feeding alternatives. The purpose of this research is to construct such a model.

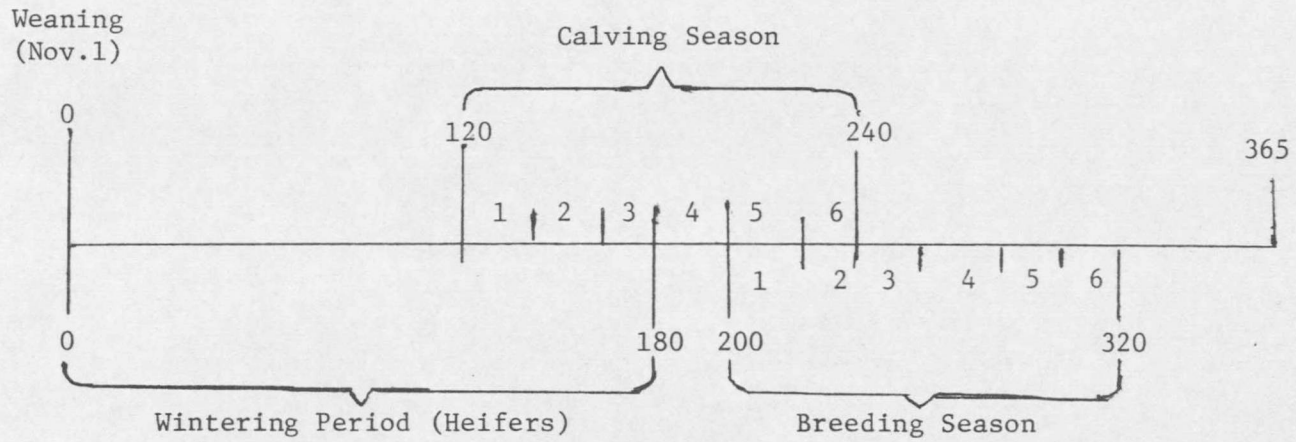
The objectives of this research are:

1. To estimate a probability distribution for the occurrence of puberty in Hereford heifers;
2. To estimate winter feed costs for heifer calves varying in weight at weaning and fed for alternative rates of gain;
3. To estimate probability distributions of pregnancy during the breeding season for heifers of various ages and weights at weaning which are fed for alternative rates of gain; and
4. To evaluate the resulting replacement heifer policy alternatives in terms of cost per bred heifer and expected time of breeding.

Assumptions and Delimitations

Although it would be desirable to include other breeds in this study, the data required for their inclusion are not available. As a result, this study is restricted to Hereford cattle.

The major activities in the production of feeder cattle are winter feeding, calving, breeding, summer grazing, and weaning. The specific timing and duration of the activities varies from ranch to ranch. For purposes of this research, the timing and duration of the activities are assumed to be as presented in Figure 1.1. All calves are weaned at one time in the fall. The first calendar period is a wintering period which for the mature cow herd is assumed to be 120 days in length and 180 days for heifer calves kept as replacements. Cows and heifers are bred during a 120 day breeding season beginning on day 200. The breeding season is divided into six 20-day periods. The 20 day period corresponds to the average length of the estrous cycle in cattle. Calves are born during a 120 day calving season beginning on day 120 of the next year, 285 days after the beginning of the breeding season, which corresponds to the average length of the gestation period for beef cattle. The calving season is divided into six 20-day periods corresponding to the six 20-day periods of the breeding season. If a cow (or heifer) is bred during period 3 of the breeding season, her calf is born during period 3 of the following calving season.



5

Figure 1.1 Cow-Calf Calendar

Outline of Procedures

In Chapter 2 a probability distribution will be estimated for the occurrence of puberty by age and weight in Hereford heifers. In Chapter 3, winter feed costs will be estimated for heifers of various weights at weaning and fed for alternative rates of gain. In Chapter 4, the estimated probability distribution of puberty (Chapter 2) will be combined with the assumptions of the Cow-Calf Calendar (Figure 1.1) to estimate probability distributions of pregnancy during the breeding season for heifers of various ages and weights at weaning which are fed for alternative rates of gain. The winter feed cost estimations (Chapter 3) will then be applied to the estimated pregnancy distributions and the replacement heifer policy alternatives will be evaluated in terms of cost per bred heifer and expected time of pregnancy.

Chapter 2

ESTIMATION OF A PROBABILITY DISTRIBUTION FOR THE OCCURRENCE OF PUBERTY IN HEIFERS

In Chapter 1 it was hypothesized that the onset of puberty in heifers, a precondition for pregnancy, can be affected by postweaning feeding practices. In this chapter literature concerning the factors affecting the onset of puberty will be reviewed and a method will be developed for estimating a probability distribution for the occurrence of puberty.

Prediction of Puberty

The onset of puberty in heifers is affected by many factors, both genetic and environmental.

Laster et.al. (1972) showed that average age and weight at puberty varied significantly among breeds and breed crosses (Table 2, page 1033).

A heifer must reach a certain minimum age and a certain minimum weight before puberty can occur (Wiltbank (1973) page 3, and Table 4, page 4).

This relationship between age and weight and the onset of puberty is affected by the growth pathway¹ by which a heifer grows to

¹A growth pathway is the relationship of heifer weight to age from birth to maturity.

maturity. One important component of the growth pathway is the postweaning rate of gain achieved by a heifer during the winter feeding period which is determined by postweaning feeding practices and level of nutrition provided. Wiltbank et.al. (1969), in a study of 74 heifers (16 Hereford, 24 Angus, 15 Angus-Hereford crossbreds, and 19 Hereford-Angus crossbreds) found that, for heifers within all breed groups, heifers fed at high nutritional levels from weaning until puberty were significantly younger and heavier at puberty than heifers fed at low nutritional levels during the same period (Table 4, page 604). Short and Bellows (1971) confirmed these findings (Table 2, page 128). In their study 89 heifers (50 Angus-Hereford cross breeds and 39 Hereford-Angus crossbreds) were assigned at random within breed to three feed groups at weaning time. The groups were fed to gain 0.23, 0.45, and 0.68 kg./da., respectively, through the wintering period, and all heifers were put on pasture in the spring of the year.

In addition to confirming the findings of the Wiltbank study, Short and Bellows observed the phenomenon of compensatory growth. That is, heifers fed at low nutritional levels during the wintering period achieved higher rates of gain on pasture than heifers fed at high nutritional levels during the wintering period. The compensatory gains achieved by the heifers fed at low nutritional levels were insufficient, however, to allow them to reach the same weight by the

following fall as the heifers fed at high nutritional levels (Table 1, page 128). The phenomenon of compensatory growth demonstrates that winter feeding practices affect heifer growth pathways later in life as well as during the winter feeding period.

The results of the Wiltbank et.al. and Short and Bellows studies lead one to hypothesize that there is some degree of tradeoff between age and weight in influencing the onset of puberty. This tradeoff, if it exists, can be exploited through the choice of winter feeding practices. Within limits, a heifer will reach puberty earlier and at a heavier weight if she is fed for a high rate of gain during the wintering period than if she is fed for a low rate of gain during the wintering period.

Varner et.al. (1977) demonstrated that benefits can be obtained by wintering replacement heifers in groups that are similar in certain characteristics, in this case weaning weight. In this study 59 crossbred heifers (one-half Charolais one-fourth Angus, one-fourth Hereford) were divided into three groups at weaning time: heavies (heifers heavier than the group average at weaning), lights (heifers lighter than the group average at weaning), and a control group composed of both heavies and lights. All groups were fed over the winter to achieve the same target weight at the end of the winter feeding period, and all were put on pasture in the spring. The

results show that both heavy and light heifers tended to reach puberty sooner when fed in separate groups than when fed in one group (Table 6, page 170). In addition, the phenomenon of compensatory gain was observed in this study (Table 4, page 169), confirming the findings of Short and Bellows.

In a study of 510 Hereford heifers Arije and Wiltbank (1971) used simple regression analysis and correlation analysis to determine what factors are significantly related to age at puberty and weight at puberty. The results of the regression analysis indicated that age at puberty is affected by day of birth ($p < 0.005$) and postweaning rate of gain ($P < 0.005$), and weight at puberty is affected by day of birth ($P < 0.005$), 205 day adjusted weaning weight ($P < 0.005$), actual weaning weight ($P < 0.005$), and postweaning rate of gain ($P < 0.005$). The correlation analysis indicated that age at puberty is related to weight at puberty ($P < 0.01$), day of birth ($P < 0.01$), rate of gain from birth to weaning ($P < 0.01$), postweaning rate of gain ($P < 0.01$), and weaning weight ($P < 0.01$), and that weight at puberty is related (in addition to age at puberty) to rate of gain from birth to weaning ($P < 0.01$), postweaning rate of gain ($P < 0.01$), day of birth ($P < 0.01$), and weight at weaning ($P < 0.01$). Generally, these relationships are consistent with and are what would be expected from the tradeoff between age and weight in determining the onset of puberty. The exceptions are the relationships between day of birth and age and

weight at puberty. According to the authors, these seeming relationships were due to abnormal local conditions, and thus are not indicative of any true functional relationship.

Arije and Wiltbank (1974) used multiple regression analysis to develop predictive equations for age and weight at puberty for heifers of various breeds. For the 52 Hereford heifers included in this study the following regression equations were estimated:

$$\text{Age-P} = 585 - 0.21B - 0.38W - 200.83A \quad R^2 = 0.414$$

(0.37) (0.35) (110.01)

$$\text{Wt-P} = 67 + 0.71B + 0.83W + 31.58A \quad R^2 = 0.386$$

(0.37) (0.28) (85.51)

Where Age-P = age of puberty

Wt-P = weight at puberty

B = birthdate (day of year, Jan 1 = 1, Feb. 1 = 32, etc.)

W = weight at weaning

A = average daily gain during the winter feeding period.

Numbers in parentheses are the standard errors of the respective parameters.

The statistical tests ($P < 0.05$) indicated that none of the estimated parameters in the age equation were significant, and that in the weight equation only the estimated coefficient for weight at weaning was significant. R^2 measures the proportion of the variation in the dependent variable which is explained by the variables in the

regression equation. The R^2 values, 0.414 and 0.386 for the age and weight equations, respectively, indicate that these equations have relatively weak predictive ability. Part of the problem with this approach is that age at puberty and weight at puberty are interdependent as shown by Arije and Wiltbanks' earlier correlation analysis. This difficulty could possibly be overcome by including both age and weight considerations, complete with interaction terms describing the tradeoff between age and weight at puberty in a single equation, or by using simultaneous equation techniques.

In summary, this review of past research suggests that to predict the onset of puberty in heifers, breed, age, weight, and growth pathway from birth through puberty should be considered.

Past research has concentrated on predicting point values for heifer age and weight at the onset of puberty. In contrast, this study will estimate a probability distribution for the occurrence of puberty at various ages and weights for Hereford heifers. The effect of growth pathway on the onset of puberty will not explicitly be considered in the estimation. The inclusion of age and weight in the estimation will to some degree capture the effect of growth pathway on the onset of puberty. The growth pathway is the relationship of weight to age from birth through maturity, and different growth pathways result in different combinations of age and weight through time. Two representative growth pathways are illustrated in Figure 2.1.

