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Biological efficiency for venison production in red deer

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ABSTRACT

The use of computer models to predict the ratio of outputs to inputs can be of considerable assistance in developing breeding objectives and assessing research priorities and evaluating the impact of changes in management on efficiency of production in the deer industry. Therefore we have developed a model (based on Parks (1982)) which quantifies the inputs of feed and the output of carcass to calculate the biological efficiency of the hind/calf unit over the lifetime of the breeding hind.

The model has been used to examine the effects of reproductive lifespan (age of culling), calving rate, twinning, changes in sex ratio and changes in calving date on efficiency. In all cases there was a peak in efficiency at 62-64 weeks of age. In terms of reproductive lifespan, the most efficient sustainable system involved slaughtering hinds after only 3 calvings, although the overall impact of this factor on efficiency was small. Changes in calving rate (proportion of hinds calving) had a marked effect with efficiency declining by 5 to 7% for a 10% decline in the calving rate. Twinning also had a major effect with about a 3% change for a 10% change in twinning rate although the higher pre-weaning mortality of twins compared with singles would markedly reduce real gains. Changes in the sex ratio also altered the efficiency of the system by 3 to 4% per 10% unit change in the proportion of males. In contrast, advancing the calving date by 3 or 6 weeks did not change efficiency or live weight of progeny at the same age but did result in a 2.8% increase in live weight at the same date for every 3 weeks advancement in calving.

Keywords Venison; lifespan; calving rate; twinning; sex ratio; calving date; efficiency

INTRODUCTION

Research into the control of reproduction and management of red deer has the potential to provide new options whereby reproductive performance may be manipulated. These include twinning, altering the sex ratio and advancing the breeding season. Fennessy (1982, 1987) produced estimates of the impact of hybridisation between species, increasing mature size, and changes in reproductive and mortality rates on efficiency (expressed in both biological and economic terms) using a simple metabolisable energy intake model based on published estimates of feed requirements (Fennessy *et al.*, 1981). However, recent developments in the analysis of feed intake and growth data offer an alternative approach (Parks, 1982) and it is this which forms the basis of the model described in this paper. The model involves a simple output/input ratio based on a series of feeding and growth equations (Parks, 1982). Using the model, Fennessy and Thompson (1988) examined the impact of changes in the genetic options including both selection within strains for increased size, and hybridisation between strains or subspecies (eg, wapiti x red deer hybridisation).

In this paper we examine the potential impact of these new reproductive technologies on the biological efficiency of venison production in red deer. The impact of the combination of hybridisation and twinning is also examined along with the effect of changes in calving rate and the age of culling which also have the potential to alter the biological efficiency of the system.

MATERIALS AND METHODS

Lifetime biological efficiency of meat production for the hind/calf unit was calculated as the ratio of predicted outputs and inputs for both the hind and her lifetime progeny. The assumptions used to calculate biological efficiency have been previously described by Fennessy and Thompson (1988). The equation to calculate biological efficiency (BE) was

$$BE = (CW_P + CW_H) / (ME_P + ME_H)$$

where

BE = lifetime biological efficiency for meat production of the hind/calf unit,

W_P = carcass weight of sale progeny,

CW_H = carcass weight of the hind at slaughter,

ME_P = ME consumed by the progeny to slaughter (excluding replacement female) and

ME_H = ME consumed by the hind.

Post-weaning metabolisable energy intake for both the hind and her progeny were described as an exponential function of age (Parks, 1982). Superimposed on this basic intake function were two sine oscillations, resulting from daylength and climate/environmental factors, respectively. This function did not incorporate the depression in intake associated with the first rut starting at about 68 weeks in males. The parameters for the basic metabolisable energy (ME) intake function and the sine function resulting from daylength oscillations were estimated from Fennessy (1981 and unpublished data) and Suttie (1987) while those for lactation and for the environmental oscillation were from Fennessy *et al.* (1981).

Live weight from weaning to maturity was described as an exponential function of cumulative ME consumed and a factor for the efficiency of conversion of ME to live weight (Parks, 1982). From body weight and ME intake data for individual stags and hinds from about 6 to 18 months of age, an oscillation in the efficiency of conversion of ME to live weight was apparent and included in the model as a sine curve.

Both inputs (MJ of ME consumed for both the hind and her progeny) and outputs (g carcass for both the hind and her progeny) were calculated for an enterprise producing venison in which all progeny (both male and female animals, minus one female calf to be used as a replacement hind) were sold for slaughter. Biological efficiency was calculated for the period from weaning of progeny to slaughter at ages up to 70 weeks.

RESULTS

TABLE 1 Live weights of hinds and stags from birth to 65 weeks of age derived from the model.

Time	Age (weeks)	Date	Live weight (kg) Hinds	Stags
Birth	0	1 Dec	8.6	10.0
Weaning	13	2 Mar	43.6	48.0
Start winter	26	1 Jun	53.2	62.2
Start spring	39	31 Aug	58.8	72.7
Summer	52	30 Nov	71.8	102.1
Autumn	65	1 Mar	81.4	127.9
Maturity			100.0	200.0

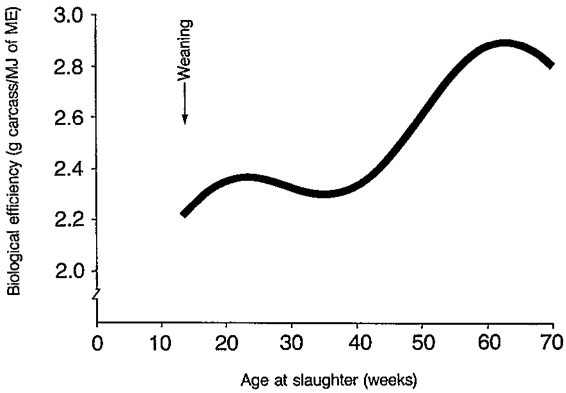

FIG 1. Relationship between biological efficiency and age at slaughter in the "standard "red deer system (10 calvings, first mating at 16 months, calving 1 December, 98% calving rate, 1:1 sex ratio, 5% pre-weaning mortality, weaning at 13 weeks, 2% annual mortality thereafter).

Liveweight patterns for hinds and stags up to 65 weeks of age derived from the model show low liveweight gain over winter and high rates of gain during the following spring-summer from 9 to 15 months of age (Table 1). At 65 weeks, hinds had attained 81% of their mature weight while stags had attained 64%.

The effects of changes in some of the model parameters on biological efficiency of the hind/calf unit were then considered. In all cases there were two peaks in BE; a minor peak at about 22-24 weeks and a more substantial peak at 62-64 weeks (Fig. 1). With the "standard" red deer system (10 calvings with first mating at 16 months, 1:1 sex ratio, calving date of December 1 with weaning at 13 weeks, 98% calving rate, a 5% pre-weaning mortality and a 2% annual mortality thereafter), the second peak was 22% higher than the first.

TABLE 2 The effect of number of calvings (reproductive lifespan) of hinds on lifetime biological efficiency of the hind/calf unit (g carcass/MJ of ME) with progeny slaughtered at 23 or 63 weeks of age.

Number of calvings	Biological efficiency- slaughter at- 23 weeks	63 weeks
2[1]	2.70	3.08
3	2.59	3.02
5	2.47	2.96
10	2.36	2.89
15	2.32	2.87
20	2.30	2.86

[1] Non-sustainable system

Varying the age of culling, ie the reproductive lifespan of the breeding hind, (Table 2) showed that the most efficient sustainable system involved culling hinds after 3 calvings (2 calvings was not a sustainable system). However the overall difference in efficiency between 3 calvings and 20 was small (only 5%).

TABLE 3 The effect of calving rate (% of hinds calving) on lifetime biological efficiency of the hind/calf unti (g carcass/MJ of ME).

Calving rate	Biological efficiency- slaughter at- 23 weeks	63 weeks
100	2.39	2.92
98	2.36	2.89
95	2.31	2.85
90	2.23	2.78
85	2.15	2.70
80	2.06	2.62
75	1.97	2.53
70	1.88	2.44

Lower calving rates resulted in lower BE (Table 3). A 10% unit decrease in calving rate caused a decline of 5 to 7% in efficiency with slaughter of the progeny at 63 weeks of age and a 7 to 9% decline with slaughter at the earlier age of 23 weeks.

Assuming the same mortality rate for both singles and twins, a 10% increase in the proportion of hinds twinning (Table 4) caused an increase in BE of about 0.09 g carcass/MJ ME (about 3.1%). However in practice, twins have a higher perinatal mortality than singles. With a 20% pre-weaning mortality rate for twins and 5% for singles, the change in efficiency was about 0.07 per 10% change in the proportion of hinds twinning (ie, 2.4%). That is the expected higher mortality of twins reduced the efficiency gains from twinning by about one quarter.

TABLE 4 The effect of twinning rate (hinds twinning/hinds calving) on lifetime biological efficiency of the hind/calf unit (g carcass/MJ of ME). Pre-weaning mortality=5% for singles: 5% or 20% for twins.

Twinning rate	Biological efficiency (slaughter at 63 weeks) Twin pre-weaning mortality 5%	20%
0	2.89	2.89
25	3.12	3.06
50	3.34	3.23
75	3.57	3.40
100	3.79	3.57

With a slaughter age of 63 weeks, an increase in the proportion of males born increased BE by 0.10 g carcass/MJ ME (about 3.5%) per 10% unit increase (Table 5). This was about 3 times greater than the change at a slaughter age of 23 weeks, the reason being the relatively greater rate of growth in males than females in the spring-summer period from 9 to 15 months of age.

TABLE 5 The effect of sex ratio on lifetime biological efficiency of the hind/calf unit (g carcass/MJ of ME)

Percentage of males	Biological efficiency- slaughter at- 23 weeks	63 weeks
0	2.22	2.41
25	2.29	2.66
50	2.36	2.89
75	2.43	3.12
88[1]	2.47	3.24

[1] This is a sustainable system with 10 calvings per hind

The combined effects on BE of twinning rate and hybridisation were examined (Table 6).

Hybridisation of red deer females with males from strains 50% and 100% heavier than red stags resulted in increases of 11 and 21% in BE. Compared with a straight red deer system without twinning, hybridisation plus 50% twinning increased BE by 23 and 32% respectively.

While changes in calving date (Table 7) had little or no effect on BE or live weight at the same age, the effects on live weight at the same time (1 March) were marked, particularly for the males with 2.8 and 5.6% increases in live weight for 3 and 6 week advances in calving date respectively.

TABLE 6 The effect of twinning rate and hybridisation on biological efficiency of the hind/calf unit (g carcass/MJ or ME).

Mature live weight of parental strains (male/female)		Bioloical efficiency (slaughter at 63 weeks) Twinning rate	
Sire strain	Dam strain	0%	50%
200/100	200/100	2.89	3.23
300/160	200/100	3.22	3.55
400/220	200/100	3.49	3.81

[1] Pre-weaning mortality rate of 5% for singles and 20% for twins.

DISCUSSION

The patterns of liveweight change derived from the model are similar to those published for red deer in New Zealand (Moore *et al.*, 1988) although the high 16 month weights of stags are generally achieved only in situations of very good nutrition such as when stags are fed indoors on high quality diets (Fennessy, 1981). In practice such high live weight gains for stags are seldom achieved on pasture during the summer mainly because of problems of both feed quality and supply. However average growth rates over a 13-week winter of 62 g/day for hinds and 115 g/day for stags are similar to those achieved with good nutrition in practical situations (Moore *et al.*, 1988). The twin peaks in BE are functions of the changes in the pattern of live weight gain (low gains in winter) and the sinusoidal oscillations in both the energy requirements due to the environmental/-climatic factors (highest in winter) and in the efficiency with which food is converted to liveweight gain (highest in autumn). The maximum BE is achieved at about 15 months of age when males had reached about 65% of mature weight and females about 80%. Comparison of the efficiency of deer with other farmed species is difficult although Taylor *et al.* (1985) estimated that in a normal beef cattle breeding system the BE was about 2.3-2.6 g lean tissue per MJ of ME. In this paper the efficiency of the standard deer system (where deer are run outdoors with additional feed costs due to the environment) was about 3 g carcass or about 2 g lean tissue per MJ of ME. If the environmental oscillation was omitted (comparable to the situation with the beef system of Taylor *et al.*(1985)), the efficiency of the deer system increased to about 2.3 g lean tissue per MJ of ME. Therefore it appears that the efficiencies of beef and deer systems in terms of meat production are very similar.

An increase from 3 to 10 calvings resulted in a decrease in BE of approximately 9 and 4% at 23 and 63 weeks respectively. This decrease is much smaller than that for cattle where in a pure breeding system, the change was 13-15% (Taylor *et al.*, 1985). The number of calvings has a major effect on BE in cattle because the dam is still

TABLE 7 The effect of calving date on biological efficiency with slaughter at 63 weeks and on the live weight at 65 weeks of age and at 1 March.

Claving date	Biological efficiency	Live weight at 65 weeks Females	Live weight at 65 weeks Males	Live weight on 1 March Age(weeks)	Live weight on 1 March Females	Live weight on 1 March Males
1 Dec	2.89	81.4	127.9	65	81.4	127.9
10 Nov	2.88	81.5	128.2	68	82.6	131.3
20 Oct	2.84	81.1	126.8	71	83.8	134.9

growing during the first pregnancy and in this sense assumes the role of offspring for slaughter with food being used for both growth and maintenance, in contrast to the situation with mature cows where food consumed during pregnancy is being used for maintenance only. Consequently as the number of calvings increase, the advantages that occurred during the first pregnancy are defrayed and lifetime efficiency declines. Calving number has less impact in deer since the red hind has attained a higher proportion of her mature body weight at the time of first mating (about 80%) than is the case with the cow (60-70%).

The obvious method for defraying the high maternal cost in species with a low reproductive rate is to increase the latter. Because deer, like cattle, have a very low incidence of twinning under natural conditions, we have examined the consequences of changes in reproductive rate. While red deer in farmed conditions generally have a high fertility with calving rates of over 95% and weaning rates of 90% being achieved regularly, the consequences of declines in calving rate are considerable. The decline in BE amounted to a 5 to 7% per 10% unit change in the calving rate with slaughter at 63 weeks. This decline is similar to that calculated for cattle (Taylor *et al*., 1985) where the decline was about 12% in BE for a 25% drop in calving rate. With slaughter at 23 weeks of age, the effect of changes in the calving rate of deer is greater than at 63 weeks. This is expected since, with earlier slaughter, BE of the system is lower as the feeding costs of hinds comprise a greater proportion of the total feed costs. Therefore any decrease in output will have a proportionately greater effect on the output/input ratio.

Twinning offers an increase in efficiency of about 3% per 10% increase in the twinning rate. Successful induction of twinning on a reasonable scale in red deer has been achieved only when the breeding season is advanced with hinds being treated with pregnant mares serum gonadotrophin (PMSG) and the stags being treated with melatonin (Moore, 1987). In practice, the increased perinatal mortality (Bringans and Lawrence, 1988) associated with low birth weights (Fennessy, Moore and Littlejohn, pers. comm.) can have a very marked effect on efficiency gains. The impact of combining twinning with hybridisation is very large but this strategy has not been researched to quantify the extent of possible problems of fertility and perinatal mortality.

Manipulation of the sex ratio through semen sexing is the aim of numerous research programmes throughout the world (eg, Reed, 1985). Since males have a greater mature size and faster growth rates than females, an increase in the proportion of males could be expected to increase the BE of meat production. While this is apparently the case for red deer where a 10% unit increase in the proportion of males increases efficiency by about 3.5%, it is much less so for cattle (Taylor *et al*., 1985) in that the efficiency gain with deer is about twice the change predicted for cattle. The major difference between the deer and cattle systems is the greater sexual dimorphism of deer.

There have been major developments in techniques to advance the calving season in red deer over the last few years with combinations of melatonin and progesterone/PMSG systems (Fisher and Fennessy, 1987) now offering practical approaches in some situations. Not unexpectedly, changes in the calving date have little effect on BE or weight at the same age. However, at a set date, animals born earlier are heavier. This is particularly so for males which are less mature and growing at a faster rate than females. In practice, the higher quality and the availability of spring pasture gives advantages to early calving. This highlights the point that incorporating feed quality/supply relationships would improve the applicability of the model.

The model is still under development and new data from current feeding trials and analysis of other data will result in further refinements. However the basic principles apply and this paper indicates the power of this approach in predicting the impact of changes in reproduction and management on the biological efficiency of meat production. Building on the basic feeding/growth relationships, the model could be expanded to include feed supply, economic or genetic components.

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