Vol. 19 (2010): 101–115.

Tactical decisions of concentrate level, slaughter age and carcass weight of bulls of five beef breeds under Norwegian conditions

Helge Bonesmo[1]*, Leidulf Nordang[2] and Lloyd Davies[3]

[1]*Norwegian Agricultural Economics Research Institute, Statens hus, Prinsensgate 1, NO-7468 Trondheim, Norway,*
**email: helge.bonesmo@nilf.no*

[2]*Norwegian Agricultural Purchasing and Marketing Co-Operation, FK Fôrutvikling BA, NO-7005 Trondheim, Norway*

[3]*NSW Department of Primary Industries, Tocal Agricultural Centre, NSW 2421 Paterson, Australia*

Beef production based on suckler cow breeds is a relatively new production system in Norway as in most Nordic countries. To ensure the continuation of this production, profitable management practices designed for Norwegian conditions have to be established. Thus a simulation model was developed that integrates the daily feed intake, the daily live weight (LW) gain, silage net energy concentration for beef production (feed units beef (FUb) kg^{-1} dry matter) and price, concentrate level and price, and carcass price for bulls of the country's five most common beef breeds. In this work the model was combined with production statistics to find general recommendations in the finishing of beef bulls under Norwegian conditions. Among all the five breeds the Limousin bulls had the highest estimated mean daily return and the Hereford bulls the lowest estimated mean daily return from 20 g concentrate kg^{-1} LW$^{0.75}$ for the 940 FUb kg^{-1} silage dry matter, and from 40 g concentrate kg^{-1} LW$^{0.75}$ for the 800 FUb kg^{-1} silage dry matter. Our estimated optimal slaughter ages and carcass weights shows that it pays to more intensively feed during the finishing period for all five breeds. Current farming practice in Norway for the five major breeds studied is that slaughter age is at least two months later with lighter carcass weights than the results expected from following our model estimated recommendations.

Key-words: feeding, silage intake, daily live weight gain, mean daily return, simulation model

Manuscript received December 2008

Introduction

Beef production in Norway has traditionally been a sideline of the dairy industry, and cull cows and beef production from young dairy bulls still represents the major beef sources. However, the rapid decline of the dairy herd with the improvement of the milk cow's productivity has lead to an increase in the number of suckler cows. The number of dairy cows has been reduced from 322 350 in 1997 to 258 720 in 2007 and during the same time the number of beef suckler cows increased from 26 490 to 56 360 (Statistics Norway 2008). According to the Norwegian Beef Cattle Recording System (Animalia 2008) crossbreeds make up 45 % of the total number of beef cows while Angus (10%), Charolais (11%), Hereford (15%), Limousin (5%), and Simmental (4%) are the most common of the pure breeds. A typical suckler cow farm in Norway is a combined cow-calf enterprise and a bull finishing, or fattening, enterprise, and the prevailing beef finishing production system can be characterized as a grass silage system (Deblitz et al. 2008). The bull finishing enterprise will involve a number of inter-dependent decisions about the desired carcass weight, the slaughter age and silage to concentrate ratios and levels. Due to the large variation in weather conditions between sites and years (Skjelvåg 1998), the energy concentration (feed units kg^{-1} dry matter) of the grass silage, and its price, will be variable which in turn will impact on the key decisions mentioned above. Given the yearly variation in silage price and quality, decisions regarding carcass weight, slaughter age and silage to concentrate ratios and levels can be regarded as tactical as they are the decisions that are necessary in order to make the whole farm strategy work over the duration of a production season (Sørensen and Kristensen 1989).

Decision support simulation models have been developed for beef finishing in other production systems, e.g. Williams and Bennet (1995) for steers in feed lot, Kilpatrick and Steen (1999) for a wide range of breeds of steers but only Charolais bulls, Nielsen and Kristensen (2007) for steers. The availability and use of such a tool developed for the bull finishing of a grass silage production system might contribute to better feeding and management practices in the beef finishing industry in Norway. Similar approaches are also applicable to other parts of Europe with bull finishing based on silage production systems, e.g. Austria, Germany, Poland and Sweden (Deblitz et al. 2008). Thus, in order to assist the farmers to make better tactical decisions in their finishing of bulls, a simulation model that integrates the feed intake, the daily LW gain, grass silage quality and price, concentrate level and price, and carcass price was developed by the feed industry and the Norwegian Agricultural Economics Research Institute. The objective of the current work was to combine this model with production statistics, i.e. average or typical numbers, from the Norwegian beef cattle recording system with other key factors to provide a tactical feeding recipe to maximize the return per head of finishing of the five most common pure beef breed bulls in Norway. Other factors incorporated include governmental payments and the seasonal variation of the beef price.

Material and methods

Database

The database for the development of the model was:

1. The INRA feeding tables of beef bulls (Garcia et al. 2007), based on a net energy system of feed units beef (FUb) used during many years in beef production in France. The INRA tables have separate tables for bulls of Charolais and Limousin. We assumed the table of "early maturing beef cattle" to correspond to bulls of Angus and Hereford. The feeding table for Charolais was also used for Simmental bulls.

2. Measurements of silage intake and daily LW gain of bulls of Angus, Charolais, Hereford, Limousin, and Simmental at the Norwegian Breeders' Association Test Station. Data available were from the winters 2003–2004, 2004–2005, 2005–2006,

Vol. 19 (2010): 101–115.

and 2006–2007, for twelve bulls per year of each of the five breeds during 21 weeks. The overall years range of start and end weights for the bulls were from 230 kg to 645 kg for Angus, from 334 kg to 746 kg for Charolais, form 286 kg to 650 kg for Hereford, from 286 kg to 650 kg for Limousin, and from 332 kg to 760 kg for Simmental. At the test station the bulls were fed on a typical Norwegian grass silage, consisting of mainly timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*), and concentrate pellets (1090 FUb kg^{-1} dry matter) (Table 1).

3. EUROP- conformation, fatness, and weaning weights for bulls of the five breeds from The Norwegian Beef Cattle Recording System from 2001 to 2007 (e.g. Animalia 2008). Altogether 40% of the total beef cattle population in Norway is included in the recording system, and the total number of bulls recorded during the years 2001 to 2007 were 94 661 head.

Model description

The model is for Angus, Charolais, Hereford, Limousin, and Simmental beef bulls finishing within the range of weights as given in the INRA tables (Garcia et al. 2007).The model is based on the state and rate approach (Goudriaan and van Laar 1994). The time interval of the model is one day. The model reflects the dynamics in the daily

Table 1. Characteristics of the feed rations for bulls of five beef breeds at the Norwegian beef breeders test station: The silage energy concentration in feed unit beef (FUb) per kg dry matter (DM), the silage dry matter concentration, and the mean and range of the daily concentrate ratio. The silage was stored in two pits, silage pit 1 (S1) and silage pit 2 (S2), the time in weeks the bulls were fed from a silage pit is given in brackets

		Silage, g FUb kg^{-1} DM[a] (time, weeks)		Silage DM concentration, g DM kg^{-1}		Concentrate, kg day^{-1}	
Year	Breed	S1	S2	S1	S2	Mean	Range
2006–2007	Angus	1017 (20)	939 (2)	522	296	3.9	[3.6–4.0]
	Charolais	1017 (22)		522	296	5.1	[3.9–6.0]
	Hereford	1017 (20)	939 (2)	522	296	3.9	[3.7–4.0]
	Limousin	1017 (22)		522	296	5.2	[3.8–5.8]
	Simmental	1017 (22)		522	296	5.0	[3.9–6.1]
2005–2006	Angus	874 (18)	770 (4)	219	240	4.6	[3.7–4.8]
	Charolais	874 (20)	770 (2)	219	240	5.2	[4.0–5.5]
	Hereford	874 (19)	770 (3)	219	240	4.6	[3.7–4.8]
	Limousin	874 (20)	770 (2)	219	240	5.4	[4.0–5.6]
	Simmental	874 (20)	770 (2)	219	240	6.6	[5.0–7.2]
2004–2005	Angus	952 (9)	978 (13)	321	367	4.4	[3.7–4.7]
	Charolais	952 (9)	978 (13)	321	367	4.8	[4.0–5.2]
	Hereford	952 (10)	978 (12)	321	367	4.4	[3.6–4.6]
	Limousin	952 (9)	978 (13)	321	367	4.8	[4.0–5.3]
	Simmental	952 (9)	978 (13)	321	367	5.1	[4.0–5.5]
2003–2004	Angus	887 (22)		263		4.2	[3.7–4.7]
	Charolais	887 (22)		263		4.7	[4.0–5.7]
	Hereford	887 (22)		263		4.1	[3.7–4.6]
	Limousin	887 (22)		263		4.9	[3.6–5.4]
	Simmental	887 (22)		263		4.8	[4.0–5.7]

[a] The silage energy concentration is determined by the use of Near Infrared Spectroscopy (NIRS), 1000 FUb = 6.9 MJ net energy beef.

silage and concentrate energy intake and the daily live weight gain, and the model also simulates the dressing percentage, the EUROP conformation and the fatness score on a daily basis (Table 2).

The silage intake model was based on the approach of dry matter (DM) intake capacity related to $LW^{0.75}$ of bulls and the energy concentration of the silage (FUb_{conc} = 0.001 × FUb kg^{-1} Silage DM) of different types of grasses (Baumont et al. 1999), combined with the effect of concentrate - grass silage substitution (McNamee et al. 2001). This combined approach offers a very simple description of the key factors that influence the silage intake.

The potential intake capacity of DM ($SDMI_{pot}$) of the silage of timothy and meadow fescue was assumed to lie between the silage of orchard grass (*Dactylus glomerata*) and perennial ryegrass (*Lolium perenne*) as given by Baumont et al. (1999) and was, by using the Proc Model routine of SAS (SAS Institute Inc 1999a), quantified to:

$$SDMI_{pot}\ (\text{g kg}^{-1}\ LW^{0.75}\ d^{-1}) = (0.07730 - 0.07538 \times FUb_{conc} + 0.07388 \times FUb_{conc}^{2}) \times LW_{t-1}^{0.75} \quad [1]$$

where LW_{t-1} is the LW the day before

The reduction index in silage DM intake related to the level of concentrate in the feed ration, f(CI), was estimated according to McNamee et al. (2001):

$$f(CI)\ (\text{dimensionless}) = 1 - 0.001888 \times CI - 0.0001102 \times CI^{2} \quad [2]$$

where CI is concentrate intake (as is) in g kg^{-1} $LW^{0.75}$ d^{-1}.

The daily actual silage DM intake ($SDMI_{act}$) was then obtained by the product of $SDMI_{pot}$ and f(CI). The combination of the $SDMI_{pot}$ (Equation 1) and the reduction index (Equation 2) implies a lower absolute reduction in silage intake (kg DM day^{-1}) for silage of a lower energy concentration, than for silage with a higher energy concentration if the bulls receive the same concentrate ration (kg d^{-1}). Differences among the five breeds in silage DM intake were accounted for by indicator variables, also called dummy variables, related to $LW^{0.75}$ estimated on the basis of the dataset from the Norwegian Breeders' Association Test Station, by using the SAS Proc Reg (SAS Institute Inc 1999b):

$$SDMI_{act}\ (\text{g kg}^{-1}\ LW^{0.75}\ d^{-1}) = SDMI_{pot} \times f(CI) + 0.00246 \times LW_{t-1}^{0.75}{}_{Angus} - 0.00265 \times LW_{t-1}^{0.75}{}_{Charolais} - 0.00611 \times LW_{t-1}^{0.75}{}_{Limousin} \quad [3]$$

In search for an appropriate equation for prediction of daily LW gain (DLWG) we chose to find a formula for all the five breeds with the least bias in the residuals, by several runs of SAS Proc Reg (SAS Institute Inc 1999b) and inspection of the deviation plots . The resultant equation, based on the LW_{t-1} and the current days total energy intake, was:

Table 2. General overview of the breed specific differences in the model components, algorithms, of silage dry matter (DM) intake, daily live weight (LW) gain, EUROP conformation (EUROP) and fatness score (FAT). The + symbol indicates a higher value than average, the – symbol indicates a lower value than average.

Breed	Silage DM intake	Daily LW gain [a]	EUROP	FAT
Angus	+	"Early maturing"	Average	+
Charolais	–	"Charolais"	+	Average
Hereford	Average	"Early maturing"	–	+
Limousin	–	"Limousin"	+	–
Simmental	Average	"Charolais"	Average	Average

[a] corresponding to the INRA tables (Garcia et al. 2007)

$$\text{DLWG (g d}^{-1}) = a_0 + a_1 \times LW_{t-1} + a_2 \times LW_{t-1}^{1.8} + a_3 \times FUb + a_4 \times FUb^{1.5} + a_5 \times FUb \times LW_{t-1} + a_6 \times LW_{t-1}^{0.75} \quad [4]$$

where FUb is the total daily net energy intake, the sum of the FUb in the $SDMI_{act}$ and the FUb in the daily concentrate ration, and the parameters a_0 to a_6 are breed dependent (Table 3). The LWs of the bulls were then obtained by integrating the respective DLWG from the typical weaning weights for the five breeds. The typical weaning weights of the bulls where derived from the Norwegian Beef Cattle Recording System: 272 kg for Angus; 294 kg Charolais; 259 kg Hereford; 287 kg Limousin and 310 kg for Simmental. The parameters in Table 3 should not be given any biological meaning beyond that the sum of the LW related variables and the sum of the FUb variables in Equation 4 reflects the diminishing return of the energy in the feed ration with increasing weight of the bull and with increasing total daily energy intake.

In the model daily values for EUROP conformation (e.g. Bohuslávek 2000) and fatness score were calculated on the basis of the daily value carcass weight (CW), expressed as the state variable LW multiplied with the daily value of the dressing percentage/ 100, and the time form birth, expressed as the slaughter age (SA).Of the 94 661 bulls in the beef cattle recording system, the crossbreeds with less then ¾ of the respective breeds were excluded from the dataset. Bulls that had higher slaughter age than 24 months and bulls with very low carcass weights compared to slaughter age were also excluded. Bulls slaughtered at greater than 24 months of age are most likely breeding bulls, and not fed specifically for finishing. The remaining numbers of bulls of each breed were then: Angus, 2026; Charolais, 4691; Hereford, 3512; Limousin, 2448; Simmental, 1002. Correlations both for EUROP-conformation (EUROP) and fatness (FAT) with carcass weight (CW) and slaughter age in days (SA) were assumed, the interaction term CW × SA was excluded from the Equations 5 and 6 at $p > 0.1$ significance level by using linear stepwise regression in SAS Proc Reg (SAS Institute Inc 1999b); and the differences among the five breeds were accounted for by indicator variables related to their respective CW:

$$\text{EUROP (dimensionless)} = 2.38788 + 0.01959 \times CW - 0.00185 \times SA - 0.00257 \times CW_{Hereford} + 0.00259 \times CW_{Charolais} + 0.00697 \times CW_{Limousin} \quad [5]$$

$$\text{FAT (dimensionless)} = 1.88954 + 0.01532 \times CW - 0.00367 \times SA + 0.00993 \times CW_{Angus} + 0.01084 \times CW_{Hereford} - 0.00161 \times CW_{Limousin} \quad [6]$$

The EUROP-conformation is scaled in integer from 1 to 15 where 1 equals to P– and 15 equals to E+. Fatness is scaled in integer from 1 to 15 where 1 equals to 1– and 15 equals to 5+.

The dressing percentage (DP) is not recorded in the Norwegian Beef Cattle Recording System. However, an equation assuming a correlation between DP and EUROP-conformation, using a continuous scale, as suggested by Clason and Stenberg (2008) was used in the model. This equation was based on data from Danish research (Tinderup and Boysen 2004).

Table 3. Parameters in an equation estimating the daily live weight gain (DLWG) for bulls of five beef breeds: $\text{DLWG (g d}^{-1}) = a_0 + a_1 \times LW_{t-1} + a_2 \times LW_{t-1}^{1.8} + a_3 \times FUb + a_4 \times FUb^{1.5} + a_5 \times FUb \times LW_{t-1} + a_6 \times LW_{t-1}^{0.75}$, LW_{t-1} is the bulls live weight the day before, and FUb is the bulls total daily net energy intake.

Breeds	a_0	a_1	a_2	a_3	a_4	a_5	a_6
Angus, Hereford	487.3	9.71	−0.001706	828.2	−118.1751	−0.1874	−70.3291
Charolais, Simmental	470.9	11.77	−0.0033334	805.8	−85.7903	−0.2152	−81.4752
Limousin	361.9	12.09	−0.004181	873.2	−107.2309	−0.1859	−83.2249

DP (%) = 1.532 × EUROP + 41.349 [7]

To estimate beef prices, premiums, and governmental payments, a standard Norwegian price table was included in the model. The base beef price used in the model is 35 Norwegian kroner (NOK) kg^{-1} CW; this price applies for a bull of 300 kg CW, EUROP-conformation of O+ and no fatness deduction. The model beef price is daily updated and varies due to the current weight classes and EUROP-conformation, and there is deduction due to fatness classes higher than 3−. For bulls with CW between 225 kg and 350 kg, and EUROP-confirmation of O− or better and no fatness deduction, a premium of 1.5 NOK kg^{-1} CW is given. At EUROP-confirmation of the R classes a premium of 1.5 NOK is given regardless of weight class, and at the UE classes a premium of 3.5 NOK is given. The model also accounts for the seasonal variation in the beef price of up to 2 NOK kg^{-1} CW reflecting the variation in supply: The peak of the seasonal beef price variation is in June and the low-points are January l and July 31. The governmental payments of 393.5 NOK per bull received on January 1 and July 31 were also included in the model.

Simulations and optimisation

An iterative search method in the computer software Powersim Solver (Saleh and Myrtveit 2004, Bonesmo 1999) was used to find the concentrate levels, slaughter ages and carcass weights that maximized the mean daily return (MDR) of the finishing period; i.e. the decision variables were: concentrate level, g kg^{-1} $LW^{0.75}$ d^{-1}, slaughter age, days, and carcass weight, kg. The mean daily return was calculated as the slaughter return minus the total feeding costs and the weaner price divided by the numbers of days of the finishing period. Standard Norwegian weaner price was used (Deblitz et al. 2008), and the extra weaner cost of 1500 NOK per bull for Charolais, Limousin and Simmental was added to the weaner cost. The concentrate price was set to 2.65 NOK kg^{-1}. As a base for the optimisation, typical numbers for birth date, March 15; weaning date, September 30; and weaning weights (Table 3) for the bulls of the five breeds were used. To reflect the on farm variation in the silage quality and the silage price, combinations of a low silage energy concentration (800 FUb kg DM^{-1}), a higher silage energy concentration (940 FUb kg DM^{-1}), a low silage price (1 NOK FUb^{-1}) and a higher silage price (2 NOK FUb^{-1}) were investigated. Stochastic simulations (Hardaker et al. 2004, 157−181), were conducted using Powersim Solver to find a probability assessment of the variation in MDR due to the variation in the EUROP-confirmation and the fatness classes as revealed from the cattle recording system. The sampling method used was Latin Hypercube and the number of iterations was 1000. An iteration represents one draw of a sequence of the two random variables: the error terms in the equations for EUROP-conformation (Equation 5) and fatness (Equation 6) represented by the standard deviations. The standard deviations were found to be non-correlated and assumed to be normal distributed with expected values = 0 and were estimated to 0.49 (dimensionless) for the EUROP conformation and 0.61 (dimensionless), for the fatness score.

To evaluate the results of the risk analysis the concept of stochastic dominance developed by Hadar and Russell (1969) and Hanoch and Levy (1969), was applied. There are several stochastic dominance criteria, associated with different sets of preference assumptions. This study used first (FSD) and second (SSD) degree stochastic dominance. The FSD implies that decision makers prefer more of an outcome to less. Statistically, the rule means that alternative A is preferred to alternative B if, for every possible level of return, the probability of getting a return that high is never better for B than for A. The second rule, SSD, states that decision makers are risk averse as well as preferring more to less. Alternative A is preferred to alternative B by SSD if the curve of the cumulative area under the cumulative distribution function (CDF) for alternative A lies everywhere below and to the right of the corresponding curve for alternative B. In order to determine whether a relation of stochastic dominance holds, the distributions have to be characterised by their CDFs.

Vol. 19 (2010): 101–115.

Results

The combined silage intake model gave an applicable estimation of the silage intake (Fig. 1), the root mean square error (RMSE) between measured and estimated silage intake ranged from 0.45 kg d^{-1} to 0.78 kg d^{-1}. This was lower than the RMSE between measured and estimated silage intake of 0.99–1.0 achieved on the same data by using the silage intake equation of the AFRC (AFRC 1993); the better performance can be attributed to the adjustment of the equation of potential silage DM intake (Equation 1) to the timothy and meadow fescue based silage. The silage intake model performed best on the data of the feeding seasons 2004−2005 and 2006−2007; the silage used in those feeding seasons had higher energy concentration than the silage used in the other two seasons (Table 1).

The simulations of live weight (LW) were also very convincing for the feeding seasons 2006−2007 and 2004−2005 (Fig. 2), for those seasons the RMSE ranged from 4.0 kg to 13.0 kg among breeds. For these seasons there was a tendency to underestimate the LW of the Angus and Hereford bulls, the LW of the Charolais bulls were slightly overestimated. Over all four feeding seasons the simulated LW of the Limousin bulls corresponded best to the measured value. The Limousin bulls had the lowest silage DM intake relative to LW (Equation 3), thus the error in the silage DM intake would be less notable for bulls of this breed. There were considerable underestimations of LW of the Charolais bulls for the feeding seasons of 2003−2004 and 2005−2006 and for Simmental bulls the feeding seasons of 2005−2006. For these years the DM intake, hence LW gain, was underestimated because it is suspected there are errors in the silage DM intake simulations. Thus, the INRA feeding tables based equation of LW gain (Equation 4) might be considered as reliable for the Norwegian bull phenotypes of the five beef breeds. The overall performance of the model to simulate the LW of the bulls was good. However, for all years there was a tendency to underestimate the LWs of Angus and Hereford bulls at higher weights; the INRA tables (Garcia et al. 2007) of the early maturing breeds do not fully reflect the growth pattern of Angus and Hereford bulls.

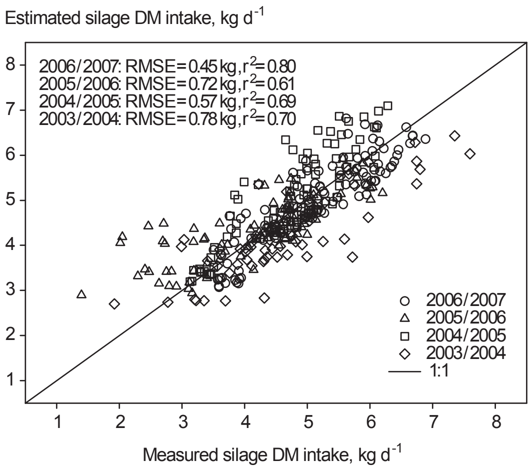

Fig. 1. Measured and simulated silage dry matter (DM) intake during four 21 weeks feeding periods for beef bulls of the breeds Angus, Charolais, Hereford, Limousin, and Simmental.

For bulls of all the five breeds an optimal concentrate level to maximise average daily return for both silage energy concentrations and both prices was determined (Table 3). Among all the five breeds the Limousin bulls had the highest estimated mean daily return and Hereford bulls the lowest estimated mean daily return from 20 g concentrate kg^{-1} $LW^{0.75}$ for the 940 FUb kg^{-1} silage DM, and from 40 g concentrate kg^{-1} $LW^{0.75}$ for the 800 FUb kg^{-1} silage DM (Fig. 3). The difference between the bulls of Angus and Hereford may mainly be caused by the 13 kg lower weaning weight of the Hereford bulls (Table 3), but may also be attributed to the higher silage intake capacity (Equation 3) and the somewhat better confirmation (Equation 5) of Angus bulls than of the Hereford bulls. For both the silage qualities the main difference in average daily return in relation to the feed ration concentrate level (kg^{-1} $LW^{0.75}$) among the breeds was between bulls of Angus, Hereford and bulls of Charolais, Limousin, Simmental, where the latter group over a larger range of concentrate levels have considerable higher mean daily return. Note that that the lines between the points in Figure 3 are

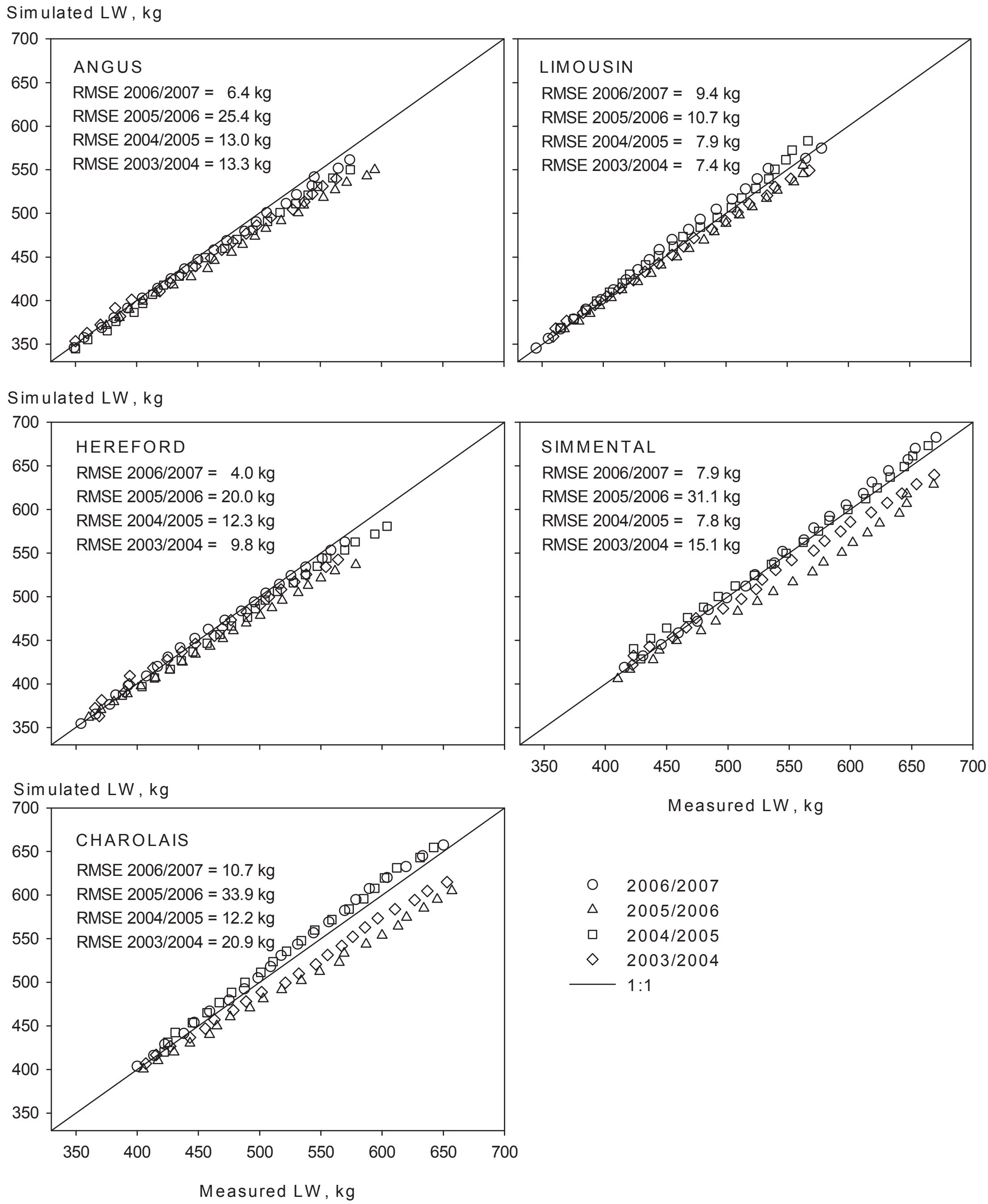

Fig. 2. Measured and simulated live weights (LW) of bulls of five beef breeds at four 21 weeks feeding periods

Vol. 19 (2010): 101–115.

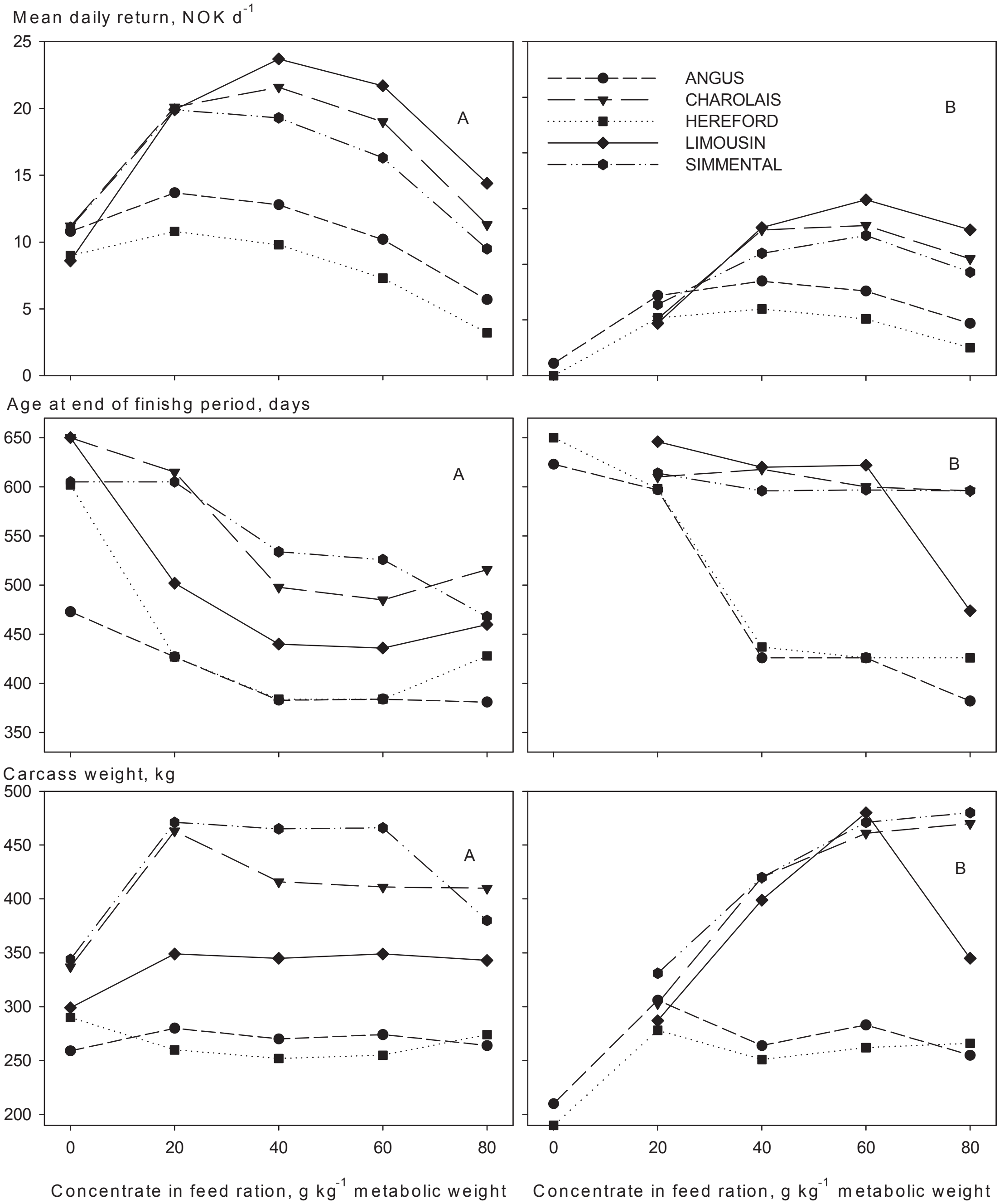

Fig. 3. Estimated optimal values of mean daily return in Norwegian kroner (NOK d^{-1}), age at end of finishing, and carcass weights of bulls of five beef breeds for five concentrate levels related to metabolic weight ($LW^{0.75}$) for two silage energy concentrations and one silage price, A: 940 feed unit beef (FUb) kg^{-1} dry matter (DM) silage and 1.0 Norwegian kroner (NOK) 1000 FUb^{-1}, B: 800 FUb kg^{-1} DM silage and 1.0 NOK 1000 FUb^{-1}

interpolations, due to stepwise change in price due to discrete variables as weight classes, EUROP-conformation classes and seasonal change in base beef price the change in mean daily return in relation to concentrate level will not actually be a continuous line.

For the 940 FUb kg^{-1} DM silage the highest estimated mean daily return was at 22 g concentrate kg^{-1} LW$^{0.75}$ for the Angus bulls and 26 g concentrate kg^{-1} LW$^{0.75}$ for the Hereford bulls, for the bulls of those breeds an increase in concentrate level above 50 g concentrate will result in a greater reduction in mean daily return than a situation where there was no concentrate in the feed ration. For the bulls of Charolais, Limousin and Simmental the highest estimated mean daily return was from 34 to 43 g concentrate kg^{-1} LW$^{0.75}$.

For all breeds and all concentrate levels (g kg^{-1} LW$^{0.75}$) the mean daily return was substantially lower for the the 800 FUb kg^{-1} DM silage than for the 940 FUb kg^{-1} DM silage; the mean daily return was even negative at 0 g concentrate kg^{-1} LW$^{0.75}$ for Charolais, Limousin and Simmental (Fig. 3). For Angus and Hereford bulls the highest mean daily return was achieved slightly above 40 g concentrate kg^{-1} LW$^{0.75}$. However, the mean daily return for these breeds was relatively stable between 20 and 60 g concentrate kg^{-1} LW$^{0.75}$. For Limousin bulls, the optimum mean daily return was close to 60 g concentrate kg^{-1} LW$^{0.75}$, and for Charolais or Simmental bulls the optimum was slightly below 55 g concentrate kg^{-1} LW$^{0.75}$. For these Euro breeds the mean daily return will be considerably lower with a small change in concentrate level. Going from 1 to 2 NOK 1000 FUb^{-1} for the 800 FUb kg^{-1} DM silage, the mean daily return for bulls of all the breeds except for Limousin will be 3 NOK lower, for the Limousin bulls it will be lowered by 1 NOK only. This is caused by the lower silage intake capacity of the Limousin bulls compared to the bulls of the other breeds. Compared to the highest quality silage the 800 FUb kg^{-1} DM results in a higher slaughter age and higher carcass weights for Charolais, Limousin and Simmental, whereas Angus and Hereford had the same slaughter age but lower carcass weights (Table 3). A doubling of the silage price for the lowest quality silage resulted in a slightly higher daily live weight gain but lower carcass weights, i.e. a less intensive production.

When the effect of variation in EUROP confirmation and fat was assessed for the optimal strategies (Table 3), the 940 FUb kg^{-1} DM silage of 1 NOK 1000 FUb^{-1} had first degree stochastic dominance for all five breeds (Fig. 4), because at every possible probability level the value of returns of the 940 FUb kg^{-1} DM silage of 1 NOK 1000 FUb^{-1} is greater than that of the other combinations of silage prices and energy concentrations. The highest quality silage of 2 NOK 1000 FUb^{-1} dominated the lower quality silage of 1 NOK 1000 FUb^{-1} for Limousin bulls with first degree dominance and for Charolais with second degree dominance. Although quite similar in risk, the less expensive lower quality silage resulted in second degree stochastic dominance for Angus and Simmental bulls when compared to the more expensive higher quality silage. For Hereford bulls the same comparison resulted in first degree stochastic dominance. The optimal strategy for the higher quality silage of 1 NOK for Limousin bulls had the smallest variation in mean daily return (4.4 NOK), whereas the higher quality silage of 2 NOK had the largest variation (8.7 NOK).

Discussion

The supply of locally produced beef has been decreasing in Norway for the last 10 years. Despite increases in suckler cow based beef production, this boost to production has not been enough to account for the decrease in the dairy based beef production (Statistics Norway 2008). One reason that could explain the lack of growth in suckler cow based beef production is that the profitability of that production is too low. A tool that can assist farmers in improving the management practices and increase the profitability of beef production under Norwegian conditions could help halt the decline in beef production. This paper describes such a tool that has been developed to simultaneously optimise feeding and timing of slaughtering in beef finishing. The tool is

Vol. 19 (2010): 101–115.

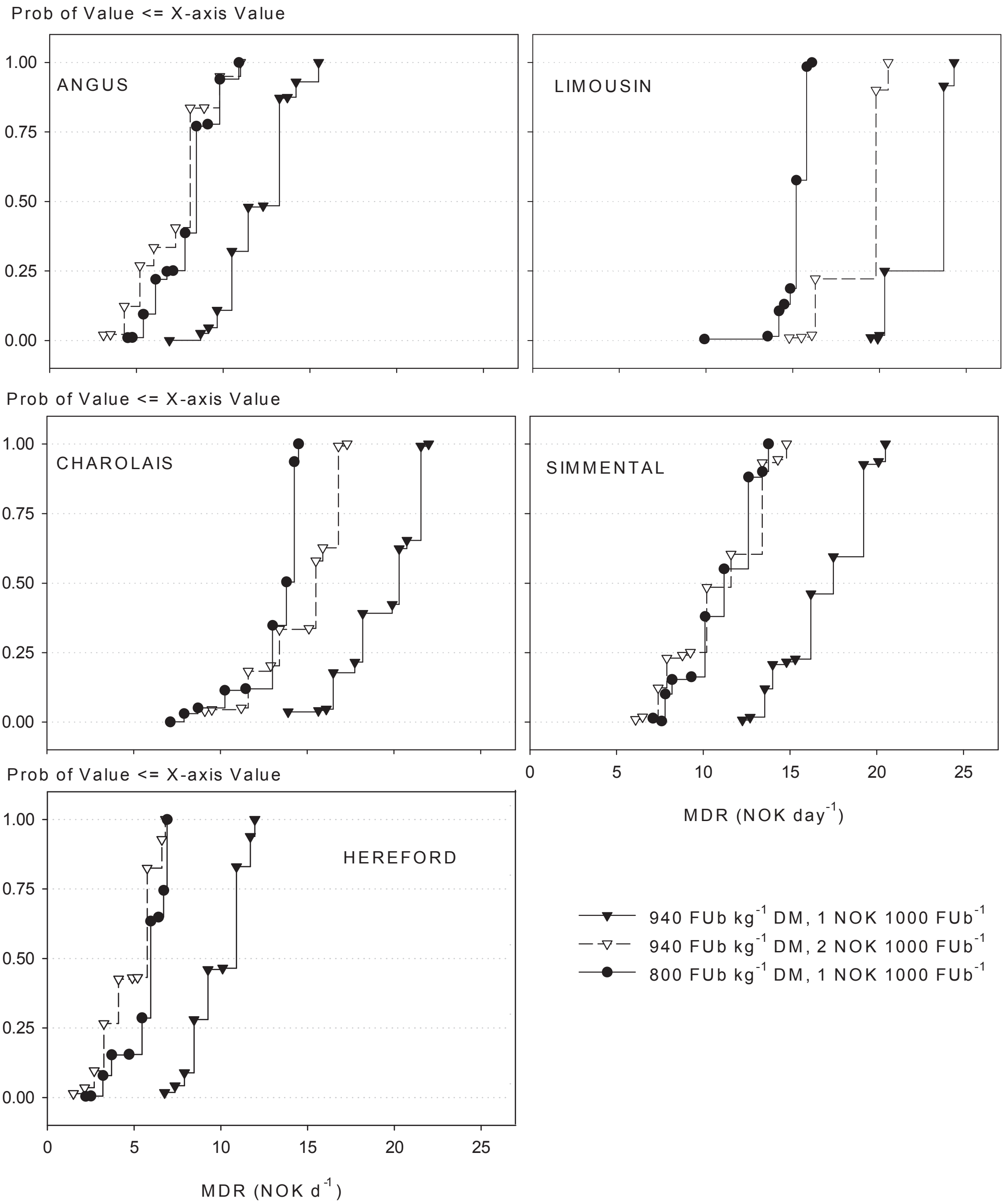

Fig. 4. Risk analysis, cumulative distribution functions: the variation in mean daily return (MDR) in Norwegian kroner (NOK) of finishing of bulls of five breeds due to variation in EUROP and fat conformations scores for higher silage energy concentration and lower price silage, 940 feed unit beef (FUb) kg^{-1} dry matter (DM) silage of 1 NOK 1000 FUb^{-1}, compared with the risk at either lower silage energy concentration (800 FUb kg^{-1}) or higher price (2 NOK 1000 FUb^{-1}).

Table 4. Conditions for optimization (to the left): two levels of silage energy concentration in g feed unit beef (FUb) per kg dry matter (DM), two silages prices in Norwegian kroner (NOK) per FUb, and breed specific live weight (LW) at weaning. Estimated optimal characteristics (to the right): Mean daily return (MDR) in NOK per day, concentrate level in g concentrate per kg $LW^{0.75}$, slaughter age in months, carcass weight (CW) in kg, average daily live weigh gain of the finishing period (DLWGavg) in kg per day, dressing percentage, beef price in NOK kg^{-1}, and EUROP conformation (EUROP) and fatness score (FAT) in integer.

Silage Conditions		Breed	LW at weaning[a]	Estimated Beef Production Characteristics[b]								
Energy concentration	Price			MDR	Concentrate level	Slaughter age	Carcass weight	DLWGavg	Dressing percentage	Beef price	Confirmation	
FUb kg^{-1} DM	NOK FUb^{-1}		kg	NOK d^{-1}	g kg^{-1} $LW^{0.75}$ d^{-1}	Months	kg	kg day^{-1}	%	NOK kg^{-1}	EUROP	Fat
940	1	Angus	272	13	22	13.9	283	1.20	52	38.7	7	7
		Charolais	294	22	43	16.1	413	1.45	58	43.8	11	6
		Hereford	259	11	26	14.2	273	1.18	51	38.6	6	7
		Limousin	287	24	38	14.7	349	1.27	58	46.3	11	5
		Simmental	310	19	34	17.9	466	1.45	58	42.3	11	7
	2	Angus	272	8	37	12.5	268	1.33	52	38.7	7	7
		Charolais	294	17	46	16.1	416	1.46	58	43.8	11	6
		Hereford	259	6	27	14.0	270	1.20	51	38.6	6	7
		Limousin	287	20	48	14.4	349	1.33	58	46.3	11	5
		Simmental	310	14	44	17.3	465	1.51	58	42.3	11	7
800	1	Angus	272	9	43	14.0	268	1.08	52	39.2	7	7
		Charolais	294	14	53	19.5	444	1.18	58	43.8	11	6
		Hereford	259	6	42	14.2	251	1.03	51	38.6	6	7
		Limousin	287	16	58	20.3	462	1.09	60	44.8	13	6
		Simmental	310	13	54	20.1	472	1.24	55	41.8	9	6
	2	Angus	272	5	51	14.0	276	1.14	52	39.2	7	7
		Charolais	294	11	65	15.3	349	1.25	58	43.8	11	6
		Hereford	259	3	53	14.0	258	1.10	51	38.6	6	7
		Limousin	287	15	66	20.0	465	1.13	57	44.8	11	5
		Simmental	310	10	61	19.5	471	1.28	56	41.8	9	6

[a]The Beef Cattle Recording System (typical numbers for the years 2001–2007)
[b]Optimization range: 350–650 d, 0–80 g concentrate kg^{-1} $LW^{0.75}$

Vol. 19 (2010): 101–115.

already used by advisers in the feed industry, which in collaboration with the farmer and his knowledge of the production data for his farm, can indicate the optimal tactical decisions regarding quantity of feed, the duration of the finishing period, and the carcass weight for bulls of the five most common beef breeds in Norway. As with the model for Irish beef finishing of Kilpatrick and Steen (1999) our model of the beef cattle production process also comprises two components: the feed intake and the effects of feed energy intake on growth rate. The satisfactory prediction by our approach of these two components, demonstrated in this paper, provides the necessary basis for the estimation of the most economic level of concentrate feeding to achieve the growth and quality of carcass composition required. Although the model was developed for use as a tactical decision support tool at individual farm level, the model in this work is used in combination with typical numbers of birth dates, weaning dates and weights of the bulls of the five breeds to find general recommendations or "rules of thumb" in beef finishing under Norwegian conditions.

Our estimated optimal slaughter ages and carcass weights indicates that a substantial intensification of the feeding in the finishing period is warranted for the bulls of all the five breeds. Current farming practice in Norway for the five major breeds studied was for the slaughter age to be more than two months longer with carcass weights lighter than what the results of our optimisation recommend (Animalia 2008). However, our estimated slaughter ages for bulls of Angus, Hereford and Limousin are in accordance with the Danish practice (Dansire 2006). Our estimated optimal slaughter weights of Angus and Hereford bulls are also close to those of Danish practice, whereas the estimated optimal slaughter weight for Limousin bulls is somewhat higher. The estimated optimal slaughter ages and carcass weights for bulls of Charolais and Simmental were somewhat longer and considerable higher than the Danish average figures for those breeds; the Danish bulls of Charolais and Simmental seems to achieve better EUROP-conformation scores at lower carcass weights than what could be found for the bulls of those breeds in the Norwegian Cattle Recording System. As noted by Pihamaa and Pietola (2002) the optimisation procedure detects the break points: "the optimal timing of slaughter is at the point where the bull reaches the quality adjustment (price increase) after reaching the minimum weight class". The estimated carcass weights and slaughter ages must thus be considered as limits. As examples: Based on statistics of the Norwegian cattle recording system, the Limousin bulls reach the highest quality premium at carcass weights lower than 350 kg; the Limousin bulls can achieve both the premium for optimal carcass size (<350 kg) and the highest quality premium and should thus be slaughtered before the carcass weight exceeds 350 kg. In contrast Norwegian Charolais bulls do not reach the highest quality premium until carcass weight is greater than 350 kg, and must thus be slaughtered later. The estimated high carcass weight and long finishing period for the Charolais bulls is also determined by the seasonal variation in price. Our optimisation is based on a typical calving date, and at the time the Charolais bull reaches the highest quality premium, the seasonal price is at its lowest, thus the finishing period has to be prolonged to achieve a higher price. However, the similarity of the ranking among the breeds in slaughter age and carcass weight between our estimated values for bulls and the values for steers estimated by Williams and Bennet (1995) suggest that there are some general and simple "rules of thumb". Bulls and steers of Angus and Hereford breeds should have lower carcass weights and slaughter ages than bulls and steers of Simmental breeds that should have a high carcass weight. Bulls and steers of Limousin breeds should be somewhere between Angus/ Hereford and Simmental in carcass weight. Both the estimated values of steers (Williams and Bennet 1995) and the Danish values for bulls (Dansire 2006) suggest that the carcass weight and slaughter age of Charolais should be close to those of Limousin. Our estimated values for Charolais bulls are, however, closer to those of the Simmental bulls than to those of Limousin bulls.

Similar to the conclusion of Pihamaa and Pietola (2002) our optimisation results show that the price of silage in general does not affect the optimal slaughter age and carcass weights but it affects farmer returns and animal feeding. When the price of silage is doubled from one to two NOK per FUb the optimal carcass weights and slaughter ages remains practically unchanged but the farmers mean daily returns decreased by 40 to 50 % for the Angus and Hereford bulls, 20 to 25 % for the Charolais and Simmental bulls, and 5 to 15 % for the Limousin bulls. The ranking in the decrease in mean daily return among the breeds reflects the different ratios of silage to concentrate in the feed rations of the breeds. The differences among the breeds optimal silage to concentrate ratios is a consequence of differences in silage intake capacity, potential daily live weigh gain, and deposition of fat.

Looking at the finishing period only, our work implies that bulls of Limousin origin are the best choice of breed based on profit per day. The finishing of Limousine bulls also had the lowest variation in EUROP-conformation and fatness. However, at the silage of 800 FUb kg DM^{-1} and 1 NOK FUb^{-1} the finishing of Charolais bulls could generate the similar level of return per day (Fig. 4), indicating the potential for similar performance in the finishing phase of the breeds Charolais and Limousin as found by Williams and Bennet (1995).

Although bulls of Limousin origin achieved the highest profit per day in our simulations, our work does not disqualify the other breeds as suitable under Norwegian conditions. The fact that all the five breeds are present in significant numbers in Norway today indicates that they all have valuable qualities for our conditions. Beef production based on suckler cow breeds has been established in Norway as well as in Finland and Sweden for the last twenty years (Statistics Norway 2008, Tike 2007, Jordbruksverket 2005). Thus it is a relatively new production system in most of the Nordic countries. The farmers dealing with beef production based on suckler cow breeds thus have to find the best management system and the best choice of breed, or cross breeding system, based on knowledge generated for other environmental conditions. Among several factors that have to be taken into account is the cow-calf part of the production. Thus, decision support systems for the cow-calf part, as for example the model of Tess and Kolstad (2000) should also be develop for our conditions. The intensification of the finishing phase as recommend in the current work is, however, a requisite of profitable beef production under our conditions. In a Nordic production environment the standard is that cattle are raised indoors for most of the time and the matured animal has to be culled to enable stable space for a new calf. Beef production using steers is regarded as an extensive alternative to bull feeding, but if the capacity of the barn will be the main constraint, the farm income is optimized by maximisation of net returns per steer per time unit in the barn. Under such circumstances Nielsen and Kristensen (2007) recommended an intensive finishing even on steers.

High net return in beef finishing is also valuable in the production of public goods. The beef production is the base for the multi-functionality of European grasslands (Sarzeaud et al. 2008). Grassland-cattle systems can be carbon sinks (Soussana et al. 2007). In France the sequestering of carbon in grassland is estimated to compensate for half of the ruminant emissions of methane, nitrous oxide and nitrogen related to the livestock transforming grass to meat (Sarzeaud et al. 2008). Further, the role of grasslands appears significant in the maintenance of biodiversity and landscape management. Most of the meadows have a good vegetation diversity compared with mono-cropping. This is due to the long-term pastoral practices, which guarantee the maintenance of a large variety of grass species but also insects, micro-organisms, and other fauna such as earthworms. To ensure the continuation of these positive public good features, high profitability in beef finishing is vital. Thus, our model may also contribute to the production of goods available for everyone and without special quantitative or qualitative limits.

Acknowledgements. The authors are grateful to Dr. Ola Flaten and Dr. Gudbrand Lien for advice during the study.

Vol. 19 (2010): 101–115.

References

AFRC 1993. *Energy and Protein Requirements of Ruminants. An advisory manual prepared by the ARFC Technical Committee on Responses to Nutrients.* CAB international, Wallingford, UK. 159 p.

Animalia 2008. *Storfekjøttkontrollen årsmelding 2007.* Oslo, Norway. 40 p. (in Norwegian)

Baumont, R. P., Champciaux, J., Agabriel, J., Andrieu, J., Aufrère, J., Michalet-Doreau, B. & Demarquilly, C. 1999. Une démarche intégrée pour prévoir la valeur des aliments pour les ruminants: PrévAlim pour INRAtion. *INRA Productions Animales* 12: 183–194. (in French)

Bohuslávek Z. 2000. Estimation of EUROP-Conformation and Fatness of Beef Carcasses by Bioelectrical Impedance Analysis. *CIGR Electronic Journal* II: 1–10.

Bonesmo, H. 1999. Modelling spring growth rates of timothy and meadow fescue by an expolinear growth equation. *Acta Agriculturæ Scandinavica, Section B. Soil and Plant Sciences* 49: 216–224.

Clason, C. & Stenberg, H. 2008. *Slaktutbyte något att räkna med?* Taurus Köttrådgivning AB, Kalmar, Sweden. 11 p. (in Swedish)

Dansire 2007. *Dansk kødkvæg, Årsrapport 2006.* Dansire, Skjeby, Denmark 55 p. (in Danish)

Deblitz, C. Minihuber, J., Brüggemann, D., Reyes, E., Kinsella, A., Sarzeaud, P., Becherel, F., Topliff, M., Bonesmo, H., deRoest, K., Montanari, C., Salevid, P., Switlyk, M., Wilczynski, A., Szabo, K., Borbely, C., Richardson, J., Herbst, B., Klein, K., Roy, D.L., Ostrowski, B., Ras, C., Gomez, C.A., deZen, S., Carvalho, T., Moncada, A., Wang, J., Wang, D., Hadi, P.U., Nair, N., Davies, L., Taljaard P. & Jooste, A. 2008. *Beef Report. Benchmarking Farming Systems Worldwide.* vTI Braunschweig, Germany. 111 p.

Garcia, F., Agabriel, J. & Micol, D. 2007. *Alimentation des bovins en croissance et à l'engrais* In : *Alimentation des bovins, ovins et caprins. Besoins des animaux – Valeurs des aliments. Tables Inra 2007. Éditions Quæ.* Versailles Cedex, France: 89–120. (in French)

Jordbruksverket 2005. *Statistik från jordbruksverket. Statistikrapport 2005:5.* 21 p. (in Swedish)

Goudriaan, J., and van Laar, H.H. 1994. *Modelling Potential Crop Growth Processes.* Kluwer Academic Publishers, Dordrecht, The Netherlands. 240 p.

Hadar, J., and Russell, W.R. 1969. Rules for ordering uncertain prospects. *American Economic Review* 59: 25–34.

Hanoch, G., and Levy, H. 1969. The efficiency analysis of choices involving risk. *Review of Economic Studies* 36: 335–346.

Hardaker, J.B., Huirne R.B.M., Anderson J.R and Lien, G. 2004. *Coping with Risk in Agriculture. Second edition.* CABI Publishing, Oxfordshire, UK. 333 p.

Kilpatrick, D.J. & Steen, R.W.J. 1999. A predictive model of beef cattle growth and carcass composition. *Agricultural Systems* 61: 95–107.

McNamee, B.F., Kilpatrick, D.J., Steen R.W.J., & Gordon F.J. 2001 The prediction of grass silage intake by beef cattle receiving barley-based supplements. *Livestock Production Science* 68: 25–30.

Nielsen B.K. & Kristensen, A.R. 2007. Optimal decision inorganic beef production from steers – Effects of criterion of optimality and price changes. *Livestock Science* 110: 25–32.

Pihamaa, P. & Pietola K. 2002. Optimal beef cattle management under agricultural policy reforms in Finland. *Agricultural and Food Science in Finland* 11: 3–12.

Saleh M. & Myrtveit M. 1999. Designing a rational process for risk-taking. In *Proceedings of the 16th International Conference of the System Dynamics Society.* Wellington, New Zealand. 5 p.

Sarzeaud, P., Pflimlin, A., Perrot C. & Becherel, F. 2008. Diversity of beef farming systems and grassland use in Europe. *Grassland Science in Europe* 13: 693–705.

SAS Institute Inc. 1999a. *SAS/ETS User's Guide, Version 8*, Cary, NC: SAS institute Inc., 1546 p.

SAS Institute Inc. 1999b. *SAS/STAT User's Guide, Version 8*, Cary, NC: SAS institute Inc., 3884 p.

Skjelvåg A.O. 1998. Climatic conditions for crop production in Nordic countries. *Agricultural and Food Science in Finland* 7: 149–160.

Soussana, J.F., Allard, V., Pilegaard, K., Ambus, P., Amman, C., Campbell, C., Ceschia, E., Clifton-Brown, J., Czobel, S. & Domingues, R. 2007. Full accounting of the greenhouse gas (CO_2, N_2O, CH_4) budget of nine European grassland sites. *Agriculture, Ecosystems and Environment* 121: 121–134.

Sørensen, J.T. & Kristensen E.S. 1989. Alternative forskningsmetoder: Styringsteori og systematisk forskningsmetodikk. Relevans i jordbrugsforskningen. *Ugeskrift for Jordbrug* 25: 375–380. (in Danish)

Statistics Norway 2008. Statistikkbanken. Homepage. Updated 15 December 2008. Cited 22 January 2010. Available on the internet: http://statbank.ssb.no/statistikkbanken/Default_FR.asp?PXSid=0&nvl=true&PLanguage=0&tilside=selectvarval/define.asp&Tabellid=03802 (in Norwegian)

Tess M.W. & Kolstad B.W. 2000. Simulation of cow-calf production system in a range environment: II Model evaluation. *Journal of Animal Science* 78: 1170–1180.

Tike 2007. *Antalet dikor fortsätter att öka*. Homepage. Updated 20. February 2007. Cited 22 January 2010. Available on the Internet: http://www.mmmtike.fi/sv/index/meddelanden/e-tiketti/artiklar/antalet_dikor.html (in Swedish)

Tinderup, M. & Boysen, B. 2004. *Slagteresultater for kødkvægsracer 2000–2004,* Dansk Landbrugsrådgivning, Landscentret. 5p. (in Danish)

Williams C.B. & Bennett G.L. 1995. Application of a computer model to predict optimum slaughter end points for different biological types of feeder cattle. *Journal of Animal Science* 73: 2903–2915.