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Published in: Livestock Science
DOI: 10.1016/j.livsci.2020.104229

Available online: 24 Aug 2020

# Simulations of feed intake, production output, and economic result within extensive and intensive suckler cow beef production systems.

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**Abstract**

The aim of the present study was to investigate the impact of and variation in both maternal and production input traits on the production economy within extensive and intensive suckler cow production systems. By use of a bio-economic model, feed intake, number of weaned calves, kilogram carcass produced, gross margin and labour costs for an average cow (including offspring) through one production cycle from one calving to the next were simulated. Several scenarios were included, changing the input traits from the average within the third of herds with the lowest performance, to the average within the third of the herds with the highest performance in the Norwegian beef cattle recording system, and compared with baseline scenarios. The results revealed that the variation in production traits had the largest influence on the economic result, but the calf mortality and the calving interval also had considerable economic importance. Both the extensive and intensive production systems were profitable, with a similar gross margin/kilogram carcass.

*Key Words: calving interval; calving difficulties; calf mortality; carcass weight; gross margin; labour costs*

## 1.0 Introduction

Over the last decades, many bio-economic models for suckler cow production have been developed. The models are used to study different aspects of suckler cow production, for instance, estimate economic values of traits in the breeding goals (e.g. Albera et al., 2004; Wolfová et al., 2007), or investigate the effect of different management strategies on farm profit (e.g. Roughsedge et al., 2003; Crosson et al., 2006; Tanure et al., 2015). Several factors influence the farm profit, such as feed resources, management strategies, breeds and current external production conditions. Traditionally, bio-economic models have focused on production traits (e.g. Koots and Gibson, 1998; Pang et al., 1999; Laske et al., 2012). Recently, bio-economic models focusing on both production and maternal traits have shown that maternal traits may have a major impact on the economy of suckler cow beef production, in some cases more important than production traits (Åby et al., 2012; Campos et al., 2014; Pravia et al., 2014). Thus, complex models, including both production and maternal traits, are necessary when evaluating the economic value of different production systems.

Due to highly varying climatic conditions and resource bases within Europe, a wide variety of production systems exist in suckler cow production (Åby et al., 2012). In contrast to intensive systems, extensive systems are characterised by low quality feed rations of pastures and roughages, in addition to no or small amounts of concentrates in the annual diet (Wetlesen et al., 2020b). Breed by environment interactions have been found for maternal, growth and carcass traits between the smaller British and the larger Continental beef breeds with varying feed intensities (e.g. Jenkins and Ferrell, 1994; McGregor et al., 2012; Wetlesen et al., 2020b). Such results suggest that British breeds are better suited for extensive systems, while Continental breeds are correspondingly better adapted to intensive systems.

Production costs may vary greatly between these contrasting production systems, where extensive systems are expected to have considerably lower feed costs (NIBIO, 2018). On the other hand, large Continental breeds have better carcass performance in intensive systems, which gives higher carcass income (Bartoň et al., 2006; Wetlesen et al., 2020a). Thus, the gross margin is essential when investigating the two systems.

The aim of the present study was to use a modified version of a bio-economic model developed by Åby et al. (2012) to investigate the impact of and the variation in maternal traits and production traits on production economy (gross margin and labour costs), within extensive and intensive suckler cow production systems. Aberdeen Angus and Charolais were used as model breeds in the extensive and intensive production system, respectively.

## 2.0 Materials and methods

### 2.1 The model

Åby et al. (2012) developed a deterministic bio-economic model to calculate economic values for functional (maternal) and production breeding goal traits in British and Continental beef breeds. The model calculates lifetime production output and estimates economic results for an average cow in extensive and intensive production systems associated with the two breed types, respectively. Thus, the model is highly applicable to study other research questions related to production and profitability in suckler cow herds.

As the approach in the present study was to evaluate the effects of variable levels of animal production efficiency on the production economy in Norwegian suckler cow herds, the model was modified accordingly. While feed intake for replacement heifers and animals for fattening was a default in the original model, the modified version simulated feed intake dependent on production level (i.e. growth rate and weights). In order to be comparable to Wetlesen et al. (2020b), the results in the modified model were expressed per production cycle for an average mature cow, instead of cow's lifetime. The calculation of production output, measured as the number of weaned calves and kilogram carcass per cow, were similar in both models, except that the original model included the production from all production cycles through the lifetime of a cow. The original model simulated the profit, including carcass income, subsidies, feed costs for all animal groups, use of veterinarian due to calving difficulty, use of claw trimmer and farmer labour costs. In the modified model, gross margin was calculated, including carcass income and all the important variable costs in suckler cow production. In addition, labour costs were calculated (i.e. not included in the gross margin as most farms in Norway are family businesses mainly operated by the family). In contrast to the original model, subsidies were not included in the gross margin. The inputs for feed and management strategies were based on the approach of Wetlesen et al. (2020b), similar to the common practice in Norwegian suckler cow production. The modified model was updated to current market prices (assessed October 2019).

#### 2.1.1 Cow production input data

Data from the Norwegian beef cattle recording system from 2010–2016 were used as input data on maternal and production traits. Traits studied were age at first calving (AFC), calving interval (CI), calving difficulty score (CDS), twinning frequency (TF), percentage calf mortality including stillbirths and dead calves after calving (CM), birth weight (BW), 200 days weaning weight (WW), 365 days yearling weight (YW), carcass weight (CW), age at slaughter (AS), EUROPE conformation score (ECS) and EUROP fat score (EFS). CDS was assessed by the farmer on a scale from 1–3 (1=no assistance, 2=some assistance by farmer or 3=major assistance by farmer and/or veterinarian). ECS was measured with the EUROP grading scheme, including 15 classes (i.e. P–, P, P+ ,…, E–, E, E+) and correspondingly, EFS measured in 15 classes (i.e. 1–, 1, 1+ ,…, 5–, 5, 5+), where P–/1– is the lowest/leanest score and E+/5+ is the highest/fattest score. Table 1 presents the full list of abbreviations.

### 2.1.2 Production output

The number of weaned calves (NWC) from the mature cow within one production cycle included adjustment for the proportion of CM and TF, as shown in equation 1. Based on the assumption that one cow needs to produce one replacement heifer during herd life of cow (HLC), the frequency of replacement heifers ($RH_{freq}$) was calculated with equation 2, including AFC and CI. The cow was assumed to produce 50% calves of each sex in one production cycle. No animal loss was assumed after weaning. The frequencies of bulls ($B_{freq}$) and surplus heifers ($SH_{freq}$) for slaughter were calculated with equations 3 and 4. Based on these proportions and carcass weights of surplus heifers ($CW_h$) and bulls ($CW_b$), the total production output (ProdO) was calculated with equation 5.

$$NWC = 1 - CM + TF \tag{1}$$

$$RH_{freq} = 1/((HLC - AFC)/CI) \tag{2}$$

$$B_{freq} = NWC*0.5 \tag{3}$$

$$SH_{freq} = NWC*0.5 - RH_{freq} \tag{4}$$

$$ProdO = (CW_h * SH_{freq}) + (CW_b * B_{freq}) \tag{5}$$

2.1.3 Carcass income

As the input data used to calculate income and costs was based on Norwegian statistics, the numbers were converted from NOK to EUR (exchange rate: 1 NOK=0.1017 EUR, assessed 10.10.19). The carcass income from bulls and surplus heifers was calculated with current prices in the Norwegian market in October 2019 (Nortura SA, 2019a). The prices were given per kilogram carcass within ECS. Furthermore, penalties per kilogram carcass were given for the leanest (score 1–2) and fattest (score 7–15) carcasses. The classification results were normally distributed, and frequencies within each ECS ($cc_i$, i=1,…,15) and EFS ($fg_i$ i=1,…,15) were calculated based on the formula:

$$fcc_{ikl} = (\text{Ø}(t_i - \mu_{kl})/\sigma_k) - (\text{Ø}(t_{i-1} - \mu_{kl})/\sigma_k) \tag{6}$$

where $fcc_{ikl}$ is the frequency of carcass category k (k=young bull and heifer), in breed group l (l=Aberdeen Angus and 2= Charolais), and conformation class i (i=1,…,15), Ø(μ, σ) is the cumulative density function, μ is the mean carcass conformation score and σ is the standard deviation. $T_i$ is the fixed thresholds in units of the standard normal liability scale, where $\text{Ø}(t_i - \mu_{kl}) - \text{Ø}(t_{i-1} - \mu_{kl})$ is the area between the thresholds, which is the frequency of carcass k within ECS and EFS.

The average price per kilogram carcass (PrA) for carcass category k, in breed group l is then calculated with the formula;

$$PrA_{kl} = (\sum^{15}_{i=1} cc_{ikl}*Pr_{ikl} - \sum^{15}_{j=1} fg_{jkl}*F_j) - fees \tag{7}$$

Where $cc_{ikl}$ is the frequency in ECS i for carcass category k in breed group l, $Pr_{ikl}$ is the price in ECS i for carcass category k, $fg_{jkl}$ is the frequency of EFS j for carcass category k in breed group l, $F_j$ is the penalty according to EFS j and fees associated with the sale of beef (0.18 EUR/kilogram carcass; Nortura SA, 2019a). Total carcass income (CINC) is then calculated based on carcass weight for heifers ($CW_h$) and bulls ($CW_b$), and frequency of surplus heifers ($SH_{freq}$) and bulls ($B_{freq}$) slaughtered;

$$CINC = (PrA_{kl} * CW_h * SH_{freq}) + (PrA_{kl} * CW_b * B_{freq}) \quad (8)$$

2.1.4 Descriptions of the production system

The performance in one production cycle (from one calving to the next) of a mature Aberdeen Angus (A) cow was simulated in an extensive system, while a mature Charolais (C) cow was simulated in an intensive system. In both systems, dates of calving and weaning were assumed 1 April and 2 October, respectively. The length of the subsequent dry period was dependent on the calving interval, unlike the original model (Åby et al., 2012), where the cow was assumed barren when the calving interval was above 14 months. A percentage of the average cow was simulated to be without calf (i.e. dry period) the whole production cycle, corresponding to the calf mortality percentage. No feed intake was calculated for the proportion of dead calves, as the majority of the lost calves dies within 14 days after calving (Storihle, 2016). The grazing season was assumed to start 15 May/1 June and lasted 140/90 days until 2 October/30 August in the extensive/intensive systems. The rest of the year, all animals were fed roughages and concentrates and kept indoors. Post-weaning, young bulls were fattened indoors until slaughter. The surplus heifers and replacement heifers were at pasture during the second summer. The length on the second pasture period was dependent on the surplus heifer age at slaughter, while the length of the third pasture period for the replacement heifer was dependent on age at first calving. Unlike the original model (Åby et al., 2012), replacement heifers were not assumed to calve at either 2 or 3 years of age, but the actual average age at first calving for A and C in the Norwegian beef cattle recording system was used, respectively.

2.1.5 Feed intake and proportion of feed sources

Feed intake was simulated for the mature cow in the dry and suckler periods, for the proportion of bull/heifers from birth to slaughter, and the proportion of replacement heifer from birth to first calving. Feed intake of bulls and heifers were calculated within weight intervals and growth rates using feed requirements based on Andersen (1990) and Berg and Matre (2001) for heifers and bulls, respectively (minus the energy from cow milk). As the cited literature gave requirements in feed units, the conversion rate to MJ NE lactation was 7.075 (Bævre, 2007). As done by Wetlesen et al. (2020b), mature cow weight was set to 600 and 750 kg (80% of the mature weight for the heifers at first calving), and milk yield was set to 1000 and 1200 litres during the suckler period for A and C, respectively (90% milk yield per calf if twins). The mature cow feed requirement was calculated based on Andersen (1990) for the suckler period (equation 9) and dry period (equation 10).

$$FeedSucP_i = (((MW_i/200 + 1.5)*SucP) + (0.4*MY_i*(1 - TF)) + (0.4*MY_i*2*0.9*TF_i))*NWC_i*CR \tag{9}$$

$$FeedDryP_i = (((MW_i/200 + 1.5)*0.8*(CI_i - SucP)* NWC_i) + ((MW_i/200 + 1.5)*0.8*CI_i*CM_i) + 3*((BW_{bi} + BW_{hi})/2)))*CR \tag{10}$$

Where $FeedSucP_i$ is the feed requirement in the suckler period for the mature cow of breed i (i=A or C), $MW_i$ is the mature cow weight of breed i, SucP in the length of the suckler period (i.e 200 days), $MY_i$ is the milk yield of breed i, $TF_i$ is the twinning frequency of breed i, $NWC_i$ is the number of weaned calves per cow of breed i and CR is the conversion rate from feed unit to MJ NE lactation. Thus, $((MW_i/200 + 1.5)*SucP)$ is the maintenance requirement in the suckler period, $(0.4*MY_i*(1 - TF))$ gives the feed requirement due to milk production for the proportion of single calves, while $(0.4*MY_i*2*0.9*TF)$ gives the feed requirement due to milk production for the proportion of twins. $FeedDryP_i$ is the feed requirement in the dry period for the mature cow of breed i, $(CI_i - SucP)$ is the calving interval minus the length of the suckler period (i.e. the length of the dry period), and $CM_i$ is the percentage of calf mortality of breed i. The first term in the formula (i.e. $(MW_i/200 + 1.5)*0.8*(CI_i - SucP)$) is the maintenance requirement in the dry period for the proportion of cows without calf loss. The second term (i.e. $(MW_i/200 + 1.5)*0.8*CI_i*CM_i$) is the maintenance requirement in the dry period for the proportion of the cows that lost calf corresponding to percentage calf mortality, as the cows were kept in the herd until next calving if the calves died. $BW_{bi}$ and $BW_{hi}$ is the birth weight for the bull and heifer calves of breed i, respectively. Thus, $(3*((BW_{bi} + BW_{hi})/2))$ gives the cow feed requirement due to foetal growth of the average bull/heifer calf.

Proportions of energy intake (MJ NE) from different feed sources used through the production cycle were based on the commercial feeding strategies reported by Wetlesen et al. (2020b). No concentrates were assumed to be fed to the cows in the dry period, but C cows were offered concentrates in the suckler period when housed indoors (1 April until 1

June and 30 August until 2 October). The percentage of concentrate fed cows, bulls, and heifers during the indoor feeding period (indoor suckler period for cows), is presented in Table 2. No animals were fed concentrates on pasture. The calf concentrate intake from birth until weaning was set to 10% and 20% of the total feed intake in the whole suckler period (excluded cow milk) for the A and C calves, respectively. Feed energy from roughages was assumed to be the feed requirement minus the feed energy from concentrates. Charolais grazed only at infield pastures (i.e. fertilised or cultivated fields) for approximately three months, while A grazed approximately 2.5 months in outfield pastures (i.e. natural grassland, mountain or forest areas), with one month at infields at the start and one month at the end of the grazing season. The percentage of infield and outfield pastures in the production cycle was calculated based on the assumption that feed requirements were met in the pasture period. Within one production cycle, the number of days at pasture was dependent on the calving interval for cows, age at slaughter for surplus heifers, and age at first calving for replacement heifers. Thus, these factors influenced the proportion of different feed sources used within the whole production cycle.

2.1.6 Economic result

The prices for outfield pasture ($p_{out}$), infield pasture ($p_{in}$), roughage ($p_{rou}$) and concentrates ($p_{con}$) were 0.007, 0.015, 0.011, and 0.045 EUR/MJ NE, respectively (Asheim, 2019). The feed costs (FeedC) were calculated based on total feed intake (TFI) for animal group m (m=cows, bulls, surplus heifers or replacement heifers), frequencies of animals in group m ($freq_m$; where cows=1 and frequencies of bulls, surplus heifers and replacement heifers are given in equation 2–4), and the proportion of outfield pasture ($out_{pct}$), infield pasture ($in_{pct}$), roughage ($rou_{pct}$), and concentrate ($con_{pct}$) given animal group m (as described in Section 2.1.5).

$$FeedC_m = TFI_m * freq_m \, (out_{pct} * p_{out} + in_{pct} * p_{in} + rou_{pct} * p_{rou} + con_{pct} * p_{con}) \quad (11)$$

The variable veterinary costs related to calving difficulties were 246 EUR (Røros dyreklinikk, 2019) multiplied by the percentage of major calving difficulties. Other variable costs included were claw trimmer, consumables, medicine, veterinary costs due to insemination and diseases. These costs were based on results from Norwegian agriculture

(NIBIO, 2018), and expressed per cow and year. Thus, these costs were dependent on the length of the calving interval.

Gross margins (GM) were calculated based on carcass income (CINC) minus all variable costs (VarC) including feed costs, veterinary costs, medicine, claw trimmer, and consumables (equation 12).

$$GM = CINC - VarC \tag{12}$$

The input data used in the calculation of labour was set to 45 hours per suckler cow ($h_{cow}$) and 30 hours per bull/heifer ($h_{heif/bull}$) per year, based on interviews of suckler cow farmers in Wetlesen et al. (2020b; unpublished). The total hours of labour ($LH_{tot}$) during the production cycle were dependent on calving interval (CI), age at slaughter (AS), and age at first calving (AFC). Similar to the original model (Åby et al., 2012), three and five hours of labour were included when calving difficulties occurred, based on relative proportions of some ($CDS_2$) and major ($CDS_3$) calving difficulties (equation 13). Labour costs (LC) were calculated with an hourly salary of 17.3 EUR (equation 14) (Landbrukstjenester Østfold SA, 2019).

$$LH_{tot} = (h_{cow}*(CI/12)) + (h_{heif/bull}*(AS_{bull}*B_{freq} + AS_{SH}*SH_{freq} + AFC*RH_{freq})/12) + (CDS_2*3) + (CDS_3*5) \tag{13}$$

$$LC = LH_{tot}*17.3 \tag{14}$$

2.2 Choice of scenarios

The overall average and the standard deviation for maternal and production traits of all herds in the Norwegian beef cattle recording system during the period 2010–2016 (baseline) demonstrate a considerable variation in all registered traits (Table 3). Thus, the averages within the third of herds with the lowest and the highest performance were calculated for calving interval, calving difficulties, calf mortality, and production traits (PT) (including WW, YW, CW, AS, ECS, and EFS). Although WW is found to be correlated with cow milk yield in the literature (Beal et al., 1990), milk yield was held constant in the model, as this is very difficult to simulate dependent on WW due to little data available. Only calf feed intake increased with a higher WW in the model. Thus, the WW was defined as a production trait. The Norwegian beef cattle recording system data were based on 23 615 and 50 299 calvings and 5190/1582 and 10324/3243 bulls/heifers' carcasses of A and C, respectively. Table 3 presents the number of herds and the average and standard deviation within the herds.

Eleven scenarios for each breed (A and C) were studied. The overall average of all herds within breed was called the baseline (BL) scenario and represented the average mature A and C cow and her calf production until slaughter/first calving. Then each of the traits CI, CDS, CM, and the group of PT were changed to the average within the third of herds with the lowest performance (LCI, LCD, LCM, and LPT) and the highest performance (HCI, HCDS, HCM, and HPT). The group of PT were all changed simultaneously because they are highly correlated. Furthermore, an overall low-performance case (LC) and an overall high-performance case (HC) scenario were simulated, changing all the traits (CI, CDS, CM, and PT) to the average within the third of herds with the lowest and the highest performance, respectively. The age at first calving, herd life of cow, and twinning frequency were held constant at 26.7 mo., 90.9 mo., and 2.3% for A, and 27.4 mo., 86.7 mo., and 4.5% for C, respectively. The birth weight was held constant at 39/37 kg and 46/43 kg for the bull/heifer calves of A and C, respectively.

## 3.0 Results

### 3.1 The extensive production system

The feed intake and proportion of different feed sources simulated in each scenario are presented in Table 4, while Table 5 presents the production output and economic result for Aberdeen Angus in the extensive production system.

#### 3.1.1 Calving interval

In the LCI scenario, A cows had 2.3 months longer CI than the average of all A herds in the Norwegian beef cattle recording system (BL; Table 3), resulting in a 28% (1786 MJ NE) higher dry period feed intake (Table 4). Thus, the feed costs/kilogram carcass increased by 0.10 EUR in the LCI scenario compared to the BL scenario. The gross margin was reduced by 76% (54 EUR). The labour per production cycle increased by 8.6 hours, which increased costs by 149 EUR compared to the A BL scenario (Table 5).

The CI was slightly below one year in the HCI scenario for A (Table 3), 1.8 months shorter than the A BL scenario. The dry period feed intake was reduced by 22% (1399 MJ NE) in this scenario compared to BL scenario (Table 4). Thus, the feed costs/kilogram carcass decreased by 0.08 EUR, and the gross margin increased by 62% (44 EUR; Table 5). Additionally, labour was reduced by 6.8 hours, and these costs were thus 118 EUR lower than A BL scenario.

### 3.1.2 Calving difficulties

The veterinary costs increased by approximately 1 EUR in the LCDS scenario compared to A BL. However, in the HCDS scenario, the proportion of calving difficulties was zero (Table 3). The veterinary costs for birth help were small relative to the total costs, and the influence on the gross margin was low (Table 5). Although the amount of labour was dependent on the proportion of major calving difficulties, the change in labour and appurtenant costs were inconsiderable.

### 3.1.3 Calf mortality

In the LCM scenario, 0.10 fewer calves per cow were weaned compared to the BL scenario (Table 5). Thus, kilogram carcass produced per cow was reduced by 20 kg, and the total carcass income was 83 EUR lower. Compared to the A BL scenario, the cow feed intake decreased (–952 MJ NE) in the suckler period but increased in the dry period (+525 MJ NE) (Table 4). Although the total feed intake was lower (–427 MJ NE), feed costs/kilogram carcass increased by 0.15 EUR. Thus, the total gross margin was reduced by 75% (–53 EUR) compared to the BL scenario (Table 5).

No occurrence of calf mortality existed in HCM scenario for A (Table 3), which resulted in 0.07 more weaned calves per cow compared to the BL scenario. Thus, kilogram carcass increased by 14 kg and the carcass income by 60 EUR (Table 5). The cow feed intake increased in the suckler period (+683MJ NE) and decreased in the dry period (–377 MJ NE) when comparing the two scenarios (+306 MJ NE in total cow feed intake; Table 4). This caused 0.07 EUR lower feed costs/kilogram carcass (Table 5). The gross margin was 52% higher (+37 EUR) in LCM scenario compared to BL scenario.

3.1.4 Production traits

The production trait scenarios (LPT and HPT), including changes in the WW, YW, CW, AS, ECS, and EFS, had a large impact on kilogram carcass produced (Table 5). In the LPT scenario for A, the amount of carcass produced was 29 kg lower compared to the BL scenario, resulting in 134 EUR lower carcass income per cow. The bull/heifer feed costs were 12% (39 EUR) lower than in the BL scenario. Reductions in feed costs and income per kilogram carcass resulted in a negative gross margin (–24 EUR; Table 5).

In the HPT scenario for A, the carcass weight was 24 kg higher and carcass income 98 EUR higher compared to the BL scenario (Table 5). Although the bull/heifer feed intake increased (Table 4), resulting in 16% (49 EUR) higher bull/heifer feed costs, the gross margin was 49 EUR higher than in the BL scenario (Table 5). The income per kilogram carcass was nearly at the same level, but both feed costs and the margin per kilogram carcass improved.

3.1.5 The overall low- and high-performance case scenarios

When comparing the overall low-performance case and high-performance case scenarios in the extensive production system, A weaned 0.18 more calves and produced 85 kg more carcass weight in the HC than the LC scenario (Table 5). Although the bull/heifer feed costs were lower in the LC scenario, the high cow feed costs and the low carcass weight resulted in a 0.76 EUR higher total feed costs per kilogram carcass weight in the LC scenario compared to the HC scenario. The income and the margin per kilogram carcass were 0.06 and 1.82 EUR lower in the LC scenario than the HC scenario, respectively. Furthermore, the difference in labour hours and costs were 13.5 hours and 234 EUR, respectively.

3.2 The intensive production system

The feed intake and proportion of different feed sources simulated in each scenario are presented in Table 6, while Table 7 presents the production output and economic result for Charolais in the intensive production system.

3.2.1 Calving interval

In the LCI scenario, the C cow had 2.3 months longer CI than the BL scenario (Table 3), and the dry period cow feed intake increased by 2085 MJ NE (Table 6). The feed costs per kilogram carcass increased by 0.14 EUR, which resulted in 66 EUR lower gross margin in the LCI scenario compared to the BL scenario (Table 7). Additionally, labour (+8.6 hours) and appurtenant costs (+149 EUR) both increased correspondingly.

A CI of 11.7 months in the HCI scenario (high performance; Table 3) reduced the feed intake by 1631 MJ NE in the dry period compared to the BL scenario (Table 6). This gave 0.08 EUR lower feed costs/kilogram carcass and a 47 EUR higher gross margin in the HCI scenario than the BL scenario (Table 7). In addition, with fewer hours worked (–6.8 hours), labour costs were 118 EUR lower.

3.2.2 Calving difficulties

The veterinary costs increased by approximately 4 EUR in the LCDS scenario compared to the BL scenario (Table 7). No calving difficulties occurred in the high-performance scenario (Table 3). The veterinary costs for birth help were low relative to the total costs, and the influence on the gross margin was negligible in both LCDS and HCDS scenarios compared to the BL scenario. Furthermore, the influence on labour costs was low (±3.5 EUR; Table 7).

3.2.3 Calf mortality

In the LCM scenario, C cows weaned 0.12 fewer calves, resulting in 29 kg less carcass produced, and a 134 EUR lower carcass income compared to the BL scenario (Table 7). The feed intake in the suckler versus dry period changed, resulting in a lower (614 MJ NE) total feed intake (Table 6). Additionally, the gross margin was only slightly positive, 93% lower in the LCM scenario compared to BL scenario (Table 7).

No calf mortality occurred in the high-performance scenario for C (Table 3). The number of weaned calves per cow (+0.08), and carcass production (+19 kg) were higher, and carcass income increased by 91 EUR when comparing the HCM scenario to the BL scenario (Table 7). Although the total cow feed intake increased by 418 MJ NE (Table 6), the gross margin was 62 % higher (+54 EUR; Table 7).

3.2.4 Production traits

The lowest production performance scenario (LPT) for C was characterised by less carcass weight produced (–25 kg) and lower carcass income (–137 EUR) compared to the BL scenario (Table 7). The corresponding bull/heifer feed intake was reduced (Table 6), which gave a 11% (–42 EUR) reduction in bull/heifer feed costs (Table 7). The gross margin turned negative, i.e. 95 EUR lower than the BL scenario. Per kilogram carcass, the feed costs increased, while the income and gross margin decreased.

The carcass output and income were 20 kg and 117 EUR higher in the HPT than in the BL scenario for C, respectively (Table 7). Although the bull/heifer feed costs were elevated (+ 9%; 52 EUR), the gross margin was also higher (+65 EUR). In total, feed costs, income, and margin per kilogram carcass improved substantially (Table 7).

#### 3.2.5 The overall low- and high-performance case scenarios

When comparing the overall low-performance case and the overall high-performance case scenarios in the intensive production system, C weaned 0.21 more calves and produced 91 more kilogram carcass in the HC scenario (Table 7). The feed cost per kilogram carcass was 0.89 EUR higher in the LC than the HC scenario, but the income (+0.19 EUR) and gross margin (+1.85 EUR) per kilogram carcass were substantially higher in the HC scenario. The difference in labour was 14.6 hours, and the related costs 253 EUR.

## 4.0 Discussion

### 4.1 The model

The Norwegian beef cattle recording system represents the greater part of the Norwegian suckler cow population, including 60% of herds in 2010, increasing to 86% of herds in 2016 (Animalia, 2017). For carcass traits, the percentage of records was high, as these data are automatically transferred from abattoirs. However, other traits such as weaning weight, yearling weight, and calf loss are voluntarily recorded by the farmer, resulting in a lower recording percentage for these traits. Still, a large number of herds were included in the average for each trait (Table 3).

Approximately 70% of calves were born in the spring, from February to May, showing that seasonal calving is the common practice in Norwegian suckler cow herds. When seasonal calving is utilised, the optimum calving interval is approximately 12 months, which requires the cow to conceive approximately three months after calving. However, the post-partum interval extends if the cow fertility is reduced, resulting in a longer calving interval.

Although the calving interval is influenced by the seasonal mating practice, prolonged calving intervals (> 12 months) indicate poor cow fertility. In the present study, the extended calving interval is mainly reflected in the extra costs related to poor cow fertility.

Calving difficulties are associated with a higher proportion of calf mortality (Nix et al., 1998; Johanson and Berger, 2003; Heringstad et al., 2007), poorer cow fertility (López de Maturana et al., 2007; Gaafar et al., 2011), and shorter cow longevity (Szabó and Dákay, 2009). Based on a survey of UK dairy farms, the major costs associated with calving difficulties were labour due to birth help, the increase in the number of days open, deaths of cows and calves, and culling of cows (McGuirk et al., 2007). Only costs due to birth help (i.e. veterinary costs and labour costs) were directly dependent on calving difficulties in the present study. However, the economic results of the varying aspects of cow fertility (calving interval) and calf mortality were investigated separately in different scenarios.

Other variable costs may vary between breeds, such as costs for claw trimming and veterinary assistance due to diseases. Limited data were available on the prevalence of claw disorders and other diseases in the Norwegian beef cattle recording system. As animal health is overall high and use of antibiotics is low in Norwegian cattle (Animalia, 2019), the assumption of equal veterinary and claw trimmer costs for both breeds in the present study is appropriate.

Subsidies constitute about 60% of farmers' income in the Norwegian suckler cow industry (OECD, 2019). This study aimed to investigate the importance of biological traits in the profitability of suckler cow production systems. Subsidies, which are incentives dependent on broad political motives, were thus not included in the calculations of economic results.

Several studies show that Aberdeen Angus is the most suitable breed in extensive feed regimes, as the breed tends to allocate high feed levels to body fat rather than increased production (e.g. Jenkins and Ferrell, 1994; Brauner et al., 2011). However, Charolais has large responses in production performance such as fertility and production output when feed intensity increases, showing that Charolais is the most suitable breed in intensive feed regimes (e.g. Morris et al., 1993; Nugent et al., 1993). Hence, A was selected as a model breed in the extensive production system, while C was selected in the intensive production system. Although breed and environment are confounded, comparing breeds within environments is done by several other studies, indicating that A in an intensive production system and C in an extensive production system have low production performance and thus low profitability (e.g. McGregor et al., 2012; Wetlesen et al., 2020b). Furthermore, the main objective of the present study was to investigate the profitability of the different production systems with the most suitable breed.

4.2 Simulated scenarios

The proportion of energy intake from different feed sources used for cows was influenced both by the calving interval and calf mortality (Tables 4 and 6). The percentage of pasture increased by changes in calving interval both in the low- and high-performance scenario (LCI and HCI). When the CI was 15.8 months in the LCI (Table 3), the pasture period next year started 13.5 and 14.0 months after calving (15 May and 1 June) for A and C, respectively. Thus, a longer CI in the LCI scenario extended the dry period to the next pasture period. In contrast, when the CI was 11.7 months (HCI) (Table 3), the pasture period with the calf, and the proportion of energy intake from pasture, constituted a larger part of the total production cycle compared to the BL scenario. Cows with suckling calves have higher feed intake than barren cows. Thus, an increase in energy intake from the pasture was also observed when calf mortality was reduced to zero (the HCM versus BL scenarios; Tables 4 and 6).

In the HCM scenarios, the number of weaned calves was above one (1.02–1.05) due to the twinning frequency and no occurrence of calf losses. When comparing LCM and HCM scenarios, the difference in kilogram carcass was large (i.e. 34 kg and 48 kg for A and C; Tables 5 and 7), showing the large impact of reduced calf mortality on kilogram carcass produced. The corresponding differences in kilogram carcass between LPT and HPT scenarios were 53 kg and 45 kg for A and C, respectively. Thus, for C in the intensive production system, the variation in calf mortality had a larger impact on kilogram carcass produced than the variation in production traits.

In the HPT scenario, a higher carcass conformation score resulted in higher income per kilogram carcass for C in the intensive system (Table 7). However, the carcass fat score also increased, where penalties resulted in slightly lower carcass income per kilogram for A in the extensive system (Table 5). Nevertheless, the overall gross margin/kilogram carcass improved in the HPT scenario compared to BL scenario for both breeds (Tables 5 and 7).

The differences in total gross margin per suckler cow between the low- and high-performance scenarios for CI, CDS, CM, and PT were 98, 1.23, 90, 144 EUR in the extensive system and 113, 6, 135, and 160 EUR in the intensive system, respectively (Tables 5 and 7). In both production systems, the variation in production traits had the largest impact on gross margin. Secondly, calf mortality scenarios were important for the gross margin in the intensive system, while the calving interval had a greater influence on gross margin in the extensive system. However, the variation in calf mortality was larger for C in the intensive system than for A in the extensive system. Although growth and carcass traits had the highest impact on gross margin in both systems, reducing calf mortality is crucial, due to the direct effect on the kilogram carcass produced.

The salary level in Norway is high compared to other European countries (Eurostat, 2019), thus, labour costs were high (Tables 5 and 7). The results highlight the value of labour provided either by the farmer or employees. The labour costs were dependent on the length of the production cycle (CI and AS), calving difficulties due to birth help, and calf mortality due to the number of bulls and heifers available for fattening. Prolonged calving interval and higher age at slaughter in LCI and LPT scenarios clearly had the largest negative impact on labour costs (Tables 5 and 7).

### 4.3 Comparisons of the extensive and intensive production systems

The feed ration with higher proportions of concentrates and infield pastures in the intensive system resulted in higher total feed costs (Table 7) compared to the extensive system (Table 5). Although the feed costs per kilogram carcass were highest in all intensive system scenarios, carcass income/kilogram were higher as well, resulting in equal gross margins per kilogram carcass between the extensive and the intensive system in the BL scenarios. Additionally, overall small differences were revealed between the other scenarios studied.

The overall higher number of labour hours (1–2 hours) in the intensive system (Tables 5 and 7) may be explained by the 0.7 months higher age at first calving for C compared to A (Section 2.2). However, the differences in labour were smaller with a higher feed level in the HPT scenarios, due to a lower age at slaughter for C bulls and surplus heifers compared to A (Table 3).

4.4 Comparisons with other studies

Comparing results from various studies using bio-economic models is difficult as different breeds, production systems, management strategies, and traits are investigated (Åby et al., 2012). Syrucek et al. (2017) studied the profit of selling calves after weaning, including subsidies and fixed costs in the Czech Republic. This study showed that reducing the calving interval by 20% had a larger effect on the profit, than increased prices of calves or calf loss. The break-even points for the calving interval and calves weaned per mated cow were 14.2 months and 0.81 calves, respectively. In the present study, the gross margin was only slightly positive when the calving interval was 15.8 months and 0.85 and 0.84 calves were weaned per mated cow for A and C, respectively. However, subsidies and fixed costs were not included, and the price levels between Norway and the Czech Republic are very different, making a comparison between the studies difficult. Raboisson et al. (2016) estimated that the costs of low colostrum intake causing increased calf mortality was 80 EUR per calf in beef herds. Furthermore, Santos et al. (2019) concluded that calf diarrhoea, respiratory disease, and sudden, unexplained deaths are common causes of calf mortality and have a large impact on the farm economy. Several other studies have also confirmed that calf survival has high economic importance (Koots and Gibson, 1998; Phocas et al., 1998; Wolfová et al., 2005a).

A varying proportion of calving difficulties had a relatively low impact on the economic results in the present study. Other studies investigating traits in beef breeding objectives have shown that calving difficulties have relatively low economic value (Amer et al., 2001; Wolfová et al., 2005b). However, in these studies, cow fertility and calf losses were evaluated separately from calving difficulties, implying that the economic value of calving difficulties did not take into account correlations with these traits.

High age at slaughter, in combination with low carcass weight in the LPT scenarios, resulted in the overall highest feed costs per kilogram carcass. Topcu and Uzundumlu (2009) also reported that increased length of the fattening period and reduced daily live weight gain had a negative effect on production costs. Due to the current price system (Nortura SA, 2019b), a lower carcass conformation score resulted in lower carcass income per kilogram, while the actual carcass weight was important for the total carcass income in the present study. High economic importance of dressing percentage and carcass weight was reported in several other studies (e.g. Amer et al., 2001; Wolfová et al., 2004; Wolfová et al., 2005a; Rewe et al., 2006).

## 5.0 Conclusion

Using input data equal to the average within the third of herds with the lowest and the highest performance in the Norwegian beef cattle recording system showed that a suboptimal production level had significant impacts on the gross margin and labour costs per suckler cow. The variation in production traits had the largest influence on the gross margin in both extensive and intensive production systems. However, the calf mortality was crucial for the number of calves weaned for further fattening and was of major economic importance. The gross margin was also clearly negatively influenced by increased feed costs with a prolonged calving interval. The labour costs reflecting the farmer effort per cow was considerable and increased by a prolonged calving interval and higher age at slaughter. Although the total gross margin was slightly higher for Charolais in the intensive system, compared to Aberdeen Angus in the extensive system, the gross margin/kilogram carcass was similar in the baseline scenarios. In conclusion, when utilising model breeds with suitable production potential according to natural feed resources, both intensive and extensive production systems are profitable.

## Acknowledgments

The authors would like to thank Animalia, the Meat and Poultry Research Centre for data from the Norwegian Beef Cattle Recording System.

## Funding

The project (Optibeef – Increased meat production from beef cattle herds; Grant no. 233683/E50) is a cooperation between Norwegian University of Life Sciences (NMBU), Norwegian Institute of Bioeconomy (NIBIO), and Nord University, financially supported by the Agriculture and Food Industry Research Funds (FFL/JA), Geno Breeding, and AI Association, the Norwegian Beef Breeders Association, Animalia Meat and Poultry Research Centre, Nortura SA (a Norwegian agricultural cooperative that operates slaughterhouses and other processing related to meat and eggs), KLF (the Meat and Poultry Industry Federation), and Nord University (Grant no. 244836/E50).

**Declaration of Competing Interest**

None.

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Table 1. List of abbreviations.

| Abbreviations | |
|---|---|
| A | Aberdeen Angus |
| AFC | Age at first calving |
| AS | Age at slaughter |
| BL | Baseline |
| BW | Birth weight |
| C | Charolais |
| CI | Calving interval |
| CDS | Calving difficulty score |
| CM | Calf mortality |
| CW | Carcass weight |
| ECS | Europ conformation score |
| EFS | Europ fat score |
| EUR | Euro |
| HC | High-performance case |
| HCD | High calving difficulties |
| HCI | High calving interval |
| HCM | High calf mortality |
| HLC | Herd life of cow |
| HPT | High production traits |
| LC | Low-performance case |
| LCD | Low calving difficulties |
| LCI | Low calving interval |
| LCM | Low calf mortality |
| LPT | Low production traits |
| NOK | Norwegian krone |
| NWC | Number of weaned calves |
| PT | Production traits |
| TF | Twinning frequency |
| WW | Weaning weight |
| YW | Yearling weight |

Table 2. Proportion (%) of energy intake from concentrates fed during the indoor period for mature cows (only indoor suckler period), bulls, surplus heifers (SH) and replacement heifers (RH) for Aberdeen Angus (A) and Charolais (C) in the extensive and intensive production systems, respectively.

| Breed | Mature cow[1] (indoor suckler period) | Bull (200-365 days) | Bull (>365 days) | Heifer (200-365 days) | SH and RH (>365 days) |
|---|---|---|---|---|---|
| A | 0 | 54 | 44 | 23 | 20 |
| C | 37 | 65 | 55 | 33 | 30 |

[1]Percentage of concentrate in the indoor suckler period with calf (1 April until 1 June and 30 Aug until 2 October for Charolais cows). No concentrate was fed to Aberdeen Angus cows in both suckler and dry period or Charolais cows in the indoor dry period.

Table 3. Input data on maternal and production traits for Aberdeen Angus and Charolais. Number of herds (N), means and (SD) for the baseline (all herds), and the third of herds with the lowest and highest performance in the Norwegian beef cattle recording system from 2010-2016.

| Input data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Aberdeen Angus | | | | Charolais | | | |
| | N | Baseline[1] | Low[2] | High[2] | N | Baseline[1] | Low[2] | High[2] |
| Cow maternal traits | | | | | | | | |
| Calving interval, months | 556 | 13.5 (2.4) | 15.8 | 11.7 | 994 | 13.5 (2.4) | 15.8 | 11.7 |
| No calving difficulties[3] % | 544 | 98.5 (8) | 95.4 | 0 | 1040 | 96.3 (10) | 89.4 | 0 |
| Some calving difficulties[3] % | 544 | 1.3 (7) | 4.1 | 0 | 1040 | 2.9 (8) | 8.2 | 0 |
| Major calving difficulties[3] % | 544 | 0.2 (3) | 0.5 | 0 | 1040 | 0.8 (5) | 2.4 | 0 |
| Calf mortality % | 68 | 6.1 (9.1) | 18.0 | 0 | 87 | 8.1 (10.1) | 20.8 | 0 |
| Bull production traits | | | | | | | | |
| Weaning weight, kg (200d) | 61 | 255 (40) | 219 | 293 | 121 | 302 (50) | 264 | 338 |
| Yearling weight, kg (365d) | 61 | 438 (60) | 366 | 514 | 121 | 540 (64) | 460 | 614 |
| Carcass weight, kg | 426 | 272 (51) | 233 | 306 | 740 | 340 (47) | 306 | 370 |
| Age at slaughter, months | 426 | 17.2 (2.7) | 18.3 | 16.1 | 740 | 17.0 (2.4) | 18.6 | 15.6 |
| Europe conformation score[4] | 426 | 6.8 (1.2) | 6.0 | 7.4 | 740 | 8.8 (1.3) | 7.8 | 9.5 |
| Europe fat score[4] | 426 | 7.2 (1.7) | 6.1 | 8.2 | 740 | 5.7 (1.1) | 5.1 | 6.2 |
| Heifer production traits | | | | | | | | |
| Weaning weight, kg (200d) | 54 | 233 (27) | 207 | 265 | 117 | 269 (40) | 241 | 297 |
| Yearling weight, kg (365d) | 54 | 363 (42) | 303 | 430 | 117 | 428 (47) | 364 | 491 |
| Carcass weight, kg | 290 | 201 (46) | 162 | 232 | 525 | 242 (42) | 209 | 267 |
| Age at slaughter, months | 290 | 17.8 (3.1) | 18.4 | 16.4 | 525 | 18.0 (3.0) | 19.4 | 16.1 |
| Europe conformation score[4] | 290 | 5.6 (1.2) | 4.8 | 6.5 | 525 | 7.0 (1.2) | 6.1 | 7.8 |
| Europe fat score[4] | 290 | 8.0 (2.3) | 6.3 | 9.4 | 525 | 6.5 (1.9) | 5.3 | 7.6 |

[1]Overall average for all herds.

[2]The average within the third of herds with the lowest and the highest performance.

[3]Percentage of no, small or major calving difficulties for the mature cows, scored on a scale from 1-3 by the farmer.

[4]EUROP carcass conformation and fatness scored on a scale from 1-15.

Table 4. Feed intake (MJ NE) and percentage of feed sources through one production cycle for each scenario simulated[1] for Aberdeen Angus in the extensive production system.

| Feed intake and proportion feed sources for Aberdeen Angus | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BL | LCI | HCI | LCDS | HCDS | LCM | HCM | LPT | HPT | LC | HC |
| Mature cow feed intake through one production cycle | | | | | | | | | | | |
| Feed intake dry period | 6426 | 8212 | 5027 | 6426 | 6426 | 6951 | 6049 | 6426 | 6426 | 8737 | 4650 |
| Feed intake suckler period | 8822 | 8822 | 8822 | 8822 | 8822 | 7870 | 9505 | 8822 | 8822 | 7870 | 9505 |
| Outfield pasture[2] % | 22 | 26 | 24 | 22 | 22 | 20 | 23 | 22 | 22 | 25 | 25 |
| Infield pasture[3] % | 18 | 22 | 20 | 18 | 18 | 17 | 19 | 18 | 18 | 21 | 21 |
| Roughage % | 6 | 52 | 56 | 6 | 6 | 63 | 58 | 60 | 60 | 54 | 54 |
| Concentrate % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fattening bull[4] feed intake from birth to slaughter | | | | | | | | | | | |
| Feed intake | 7584 | 7584 | 7584 | 7584 | 7584 | 6763 | 8175 | 6755 | 8379 | 6030 | 9032 |
| Outfield pasture[2] % | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 11 | 09 | 11 |
| Infield pasture[3] % | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 5 | 6 |
| Roughage % | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 45 | 43 | 45 | 43 |
| Concentrate % | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 40 | 41 | 40 |
| Surplus heifer[4] feed intake from birth to slaughter | | | | | | | | | | | |
| Feed intake | 3529 | 3529 | 3529 | 3529 | 3529 | 3153 | 3805 | 2780 | 4333 | 2487 | 4672 |
| Outfield pasture[2] % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 26 | 22 | 26 | 22 |
| Infield pasture[3] % | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 18 | 12 | 18 | 12 |
| Roughage % | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 42 | 50 | 42 | 50 |
| Concentrate % | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 16 | 14 | 16 |
| Replacement heifer[4] feed intake from birth to first calving | | | | | | | | | | | |
| Feed intake | 4687 | 4687 | 4687 | 4687 | 4687 | 4687 | 4687 | 4273 | 5652 | 4273 | 5652 |
| Outfield pasture[2] % | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 20 | 18 | 20 | 18 |
| Infield pasture[3] % | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 17 | 15 | 17 | 15 |
| Roughage % | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 48 | 51 | 48 | 51 |
| Concentrate % | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 16 | 15 | 16 |

[1]Scenarios simulated for the overall average of all herds (BL=baseline) and the average within the third of herds with lowest and highest performance (LCI=low-performance on calving interval, HCI=high-performance on calving interval, LCDS= low-performance on calving difficulty scores, HCDS= high-performance on calving difficulty scores, LCM= low-performance on calf mortality, HCM= high-performance on calf mortality, LPT= low-performance on production traits, HPT=high-performance on production traits, LC=overall low-performance case for all the traits and HC=overall high-performance case for all the traits).

[2]Natural grassland, mountain or forest areas.

[3]Fertilised or cultivated fields.

[4]Feed intake minus energy from cow milk, adjusted to the frequency of bulls, surplus heifers and replacement heifers produced in an average cow production cycle. In one production cycle 50% of the weaned calves were bulls (adjusted for calf mortality percentage and twinning frequency), 23% were assumed to be replacement heifers, while the rest were surplus heifers.

Table 5. Production output, costs, income and economic result (EUR) from one production cycle of one mature Aberdeen Angus cow in each simulated scenario[1] in the extensive production system.

| Production output and economy in the extensive production system | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BL | LCI | HCI | LCDS | HCDS | LCM | HCM | LPT | HPT | LC | HC |
| Production output | | | | | | | | | | | |
| Number of weaned calves | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.85 | 1.02 | 0.95 | 0.95 | 0.85 | 1.02 |
| Kg carcass | 181 | 181 | 181 | 181 | 181 | 161 | 195 | 152 | 205 | 136 | 221 |
| Income | | | | | | | | | | | |
| Total carcass income | 767 | 767 | 767 | 767 | 767 | 684 | 827 | 633 | 865 | 565 | 932 |
| Income/kg carcass | 4.24 | 4.24 | 4.24 | 4.24 | 4.24 | 4.24 | 4.24 | 4.16 | 4.22 | 4.16 | 4.22 |
| Costs | | | | | | | | | | | |
| Feed costs cow | 169 | 188 | 154 | 169 | 169 | 165 | 173 | 169 | 169 | 184 | 157 |
| Feed costs bulls, SH and RH[2] | 316 | 316 | 316 | 316 | 316 | 290 | 335 | 277 | 365 | 254 | 387 |
| Feed costs/kg carcass | 2.68 | 2.78 | 2.60 | 2.68 | 2.68 | 2.83 | 2.61 | 2.93 | 2.60 | 3.22 | 2.46 |
| Veterinary costs for CD[3] | 0.3 | 0.3 | 0.3 | 1.2 | 0.0 | 0.3 | 0.3 | 0.3 | 0.3 | 1.2 | 0.0 |
| Other variable costs[4] | 211 | 246 | 182 | 211 | 211 | 211 | 211 | 211 | 211 | 246 | 182 |
| Economic result | | | | | | | | | | | |
| Gross margin[6] | 71 | 17 | 115 | 70 | 71 | 17.8 | 108 | –24 | 120 | –120 | 206 |
| Gross margin/kg carcass | 0.39 | 0.09 | 0.63 | 0.39 | 0.39 | 0.11 | 0.55 | –0.16 | 0.58 | –0.88 | 0.93 |
| Labour (hours) | 99.2 | 107.8 | 92.4 | 99.3 | 99.1 | 95.7 | 101.6 | 100.9 | 97.0 | 106.0 | 92.5 |
| Labour costs[7] | 1716 | 1865 | 1599 | 1718 | 1714 | 1656 | 1758 | 1746 | 1678 | 1834 | 1600 |

[1]Scenarios simulated for the overall average of all herds (BL=baseline) and the average within the third of herds with lowest and highest performance (LCI=low-performance on calving interval, HCI=high-performance on calving interval, LCDS= low-performance on calving difficulty scores, HCDS= high-performance on calving difficulty scores, LCM= low-performance on calf mortality, HCM= high-performance on calf mortality, LPT= low-performance on production traits, HPT=high-performance on production traits, LC=overall low-performance case for all the traits and HC=overall high-performance case for all the traits).

[2]SH=surplus heifer and RH=replacement heifer.

[3]Veterinary costs for the percentage of major calving difficulties (=3, scale 1-3).

[4]Other variable costs=claw trimmer, veterinary costs due to insemination and disease, medicine and consumables.

[6]Gross margin=carcass income minus all variable costs.
[7]Labour costs=number of labour hours multiplied with an hourly salary at 17.3 EUR.

Table 6. Feed intake (MJ NE) and percentage of feed sources through one production cycle for each scenario simulated[1] for Charolais in the intensive production system.

| Feed intake and proportion feed sources for Charolais | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BL | LCI | HCI | LCDS | HCDS | LCM | HCM | LPT | HPT | LC | HC |
| Mature cow feed intake through one production cycle | | | | | | | | | | | |
| Feed intake dry period | 7433 | 9518 | 5802 | 7433 | 7433 | 8165 | 6934 | 7433 | 7433 | 10250 | 5303 |
| Feed intake suckler period | 10573 | 10573 | 10573 | 10573 | 10573 | 9227 | 11490 | 10573 | 10573 | 9227 | 11490 |
| Outfield pasture[2] % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Infield pasture[3] % | 26 | 33 | 29 | 26 | 26 | 24 | 28 | 26 | 26 | 31 | 30 |
| Roughage % | 66 | 60 | 62 | 66 | 66 | 68 | 64 | 66 | 66 | 62 | 61 |
| Concentrate % | 8 | 7 | 9 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 9 |
| Fattening bull[4] feed intake from birth to slaughter | | | | | | | | | | | |
| Feed intake bull | 8679 | 8679 | 8679 | 8679 | 8679 | 7594 | 9403 | 8462 | 9156 | 7404 | 9918 |
| Outfield pasture[2] % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Infield pasture[3] % | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 7 | 10 | 7 | 10 |
| Roughage % | 39 | 39 | 39 | 39 | 39 | 39 | 39 | 40 | 39 | 40 | 39 |
| Concentrate % | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 53 | 51 | 53 | 51 |
| Surplus heifer[4] feed intake from birth to slaughter | | | | | | | | | | | |
| Feed intake | 4326 | 4326 | 4326 | 4326 | 4326 | 3786 | 4687 | 3343 | 5258 | 2925 | 5696 |
| Outfield pasture[2] % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Infield pasture[3] % | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 25 | 21 | 25 | 21 |
| Roughage % | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 51 | 53 | 51 | 53 |
| Concentrate % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 24 | 26 | 24 | 26 |
| Replacement heifer[4] feed intake from birth to first calving | | | | | | | | | | | |
| Feed intake | 6876 | 6876 | 6876 | 6876 | 6876 | 6876 | 6876 | 6158 | 7742 | 6158 | 7742 |
| Outfield pasture[2] % | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Infield pasture[3] % | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 23 | 20 | 23 | 20 |
| Roughage % | 54 | 54 | 54 | 54 | 54 | 54 | 54 | 53 | 54 | 53 | 54 |
| Concentrate % | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 24 | 26 | 24 | 26 |

[1]Scenarios simulated for the overall average of all herds (BL=baseline) and the average within the third of herds with lowest and highest performance (LCI=low-performance on calving interval, HCI=high-performance on calving interval, LCDS= low-performance on calving difficulty scores, HCDS= high-performance on calving difficulty scores, LCM= low-performance on calf mortality, HCM= high-performance on calf mortality, LPT= low-performance on production traits, HPT=high-performance on production traits, LC=overall low-performance case for all the traits and HC=overall high-performance case for all the traits).

[2]Natural grassland, mountain or forest areas.

[3]Fertilised or cultivated fields.

[4]Feed intake minus energy from cow milk, adjusted to the proportion of bulls, surplus heifers and replacement heifers produced in an average cow production cycle. In one production cycle 50% of the weaned calves were bulls (adjusted for calf mortality percentage and twinning frequency), 23% were assumed to be replacement heifers, while the rest were surplus heifers.

Table 7. Production output, costs, income and economic result (EUR) from one production cycle of one mature Charolais cow in each simulated scenario[1] in the intensive system.

| Production output and economy in the intensive system | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | BL | LCI | HCI | LCDS | HCDS | LCM | HCM | LPT | HPT | LC | HC |
| Production output | | | | | | | | | | | |
| Number of weaned calves | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.84 | 1.05 | 0.96 | 0.96 | 0.84 | 1.05 |
| Kg carcass | 222 | 222 | 222 | 222 | 222 | 193 | 241 | 197 | 242 | 172 | 263 |
| Income | | | | | | | | | | | |
| Total carcass income | 1049 | 1049 | 1049 | 1049 | 1049 | 915 | 1140 | 912 | 1166 | 796 | 1267 |
| Income/kg carcass | 4.73 | 4.73 | 4.73 | 4.73 | 4.73 | 4.73 | 4.73 | 4.63 | 4.82 | 4.63 | 4.82 |
| Costs | | | | | | | | | | | |
| Feed costs cow | 271 | 302 | 253 | 271 | 271 | 262 | 278 | 271 | 271 | 293 | 259 |
| Feed costs bull, SH and RH[2] | 478 | 478 | 478 | 478 | 478 | 434 | 508 | 436 | 530 | 396 | 560 |
| Feed costs/kg carcass | 3.37 | 3.51 | 3.29 | 3.37 | 3.37 | 3.61 | 3.26 | 3.59 | 3.31 | 4.01 | 3.11 |
| Veterinary costs for CD[3] | 2.0 | 2.0 | 2.0 | 6.0 | 0.0 | 2.0 | 2.0 | 2.0 | 2.0 | 6.0 | 0.0 |
| Other variable[4] | 211 | 246 | 182 | 211 | 211 | 211 | 211 | 211 | 211 | 246 | 182 |
| Economic result | | | | | | | | | | | |
| Gross margin[6] | 87 | 21 | 134 | 83 | 89 | 6.0 | 141 | –8 | 152 | –145 | 266 |
| Gross margin/kg carcass | 0.39 | 0.09 | 0.60 | 0.37 | 0.40 | 0.03 | 0.59 | –0.04 | 0.63 | –0.84 | 1.01 |
| Labour (hours) | 100.3 | 108.9 | 93.5 | 100.5 | 100.1 | 96.3 | 103.0 | 103.0 | 97.4 | 107.6 | 93.0 |
| Labour costs[7] | 1735 | 1884 | 1618 | 1739 | 1732 | 1666 | 1782 | 1782 | 1685 | 1861 | 1609 |

[1]Scenarios simulated for the overall average of all herds (BL=baseline) and the average within the third of herds with lowest and highest performance (LCI=low-performance on calving interval, HCI=high-performance on calving interval, LCDS= low-performance on calving difficulty scores, HCDS= high-performance on calving difficulty scores, LCM= low-performance on calf mortality, HCM= high-performance on calf mortality, LPT= low-performance on production traits, HPT=high-performance on production traits, LC=overall low-performance case for all the traits and HC=overall high-performance case for all the traits).

[2]SH=surplus heifer and RH=replacement heifer.

[3]Veterinary costs for the percentage of major calving difficulties (=3, scale 1-3).

[4]Other variable costs=claw trimmer, veterinary costs due to insemination and disease, medicine and consumables.

[6]Gross margin=carcass income minus all variable costs.
[7]Labour costs=number of labour hours multiplied with an hourly salary at 17.3 EUR.