Economic values for lean meat- and fat efficiency in Norwegian Landrace nucleus pig population

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Abstract

A bio-economic model was developed to estimate economic values for new efficiency traits for fattening pigs in Norwegian Landrace. These traits were lean meat - (**LME**) and fat efficiency (**FE**). In addition, days from 40 to 100/120 kg live weight (**DAYS**), lean meat percentage (**LMP**) and fat content on carcass (**FC**) were included in the model and referred to as breeding goal A. To compare LME and FE with total feed intake (**FI**), a model including FI, LMP and DAYS was developed and referred to as breeding goal B. The standardized economic values for LME and FE were 8.9 and 2.9 EUR/σa, respectively. There was a larger variation in the index for breeding goal A than B. The results suggested that the two efficiency traits had a high economic importance in pork production and that there was a big potential for increased genetic gain in profit by using breeding goal A.

Keywords: animal breeding, economic model, feed efficiency, Norwegian Landrace, standardized economic value

Introduction

The purpose of breeding programs is to improve the profitability of livestock production. Profitability is approximated by the breeding goal for the population. A breeding goal states which traits that are important to improve and could be of both economical and societal interest (Olesen et al., 2000; Kanis et al., 2005). The purpose of pig breeding is to meet the demands for high quality meat production in a sustainable way. The breeding goal should therefore include traits that increase the commercial producer's income and reduce their costs in pork production. This includes traits such as growth and feed efficiency, but also demands from the society, with traits such as meat quality, animal welfare and health (Kanis et al., 2005; Flint and Woolliams, 2008). The traits are often of different importance, and to weigh the traits in the breeding goal, their economic value needs to be estimated (De Vries, 1989). The Norwegian Landrace (**NL**) is a maternal breed and the breeding goal consists of seven trait groups with a number of traits within each group. These groups are production, carcass quality, meat quality, litter size, reproduction, maternal ability and robustness, and all have different weights in the total merit index (Norsvin, 2016). The NL is a feed efficient and lean breed with a low amount of back fat (Gjerlaug-Enger et al., 2012). This is due to extensive selection for reduced back fat, increased lean growth and reduced feed intake per kg growth (**FCR**) over 50 years. Martinsen et al. (2015) suggested that this selection was more related to resource allocation rather than selection for efficiency to utilize nutrients. The same study therefore established two new efficiency traits, indicating how well the animal utilizes the feed for lean meat and fat production. The traits were named lean meat efficiency (**LME**) and fat efficiency (**FE**) and describes how much feed needed for production of one extra kg lean meat and fat (as a deviation from the mean). The aim of this paper was to assess the economic importance of the new efficiency traits in pork production compared to a traditional feed consumption trait and estimate the economic values for the two new efficiency traits, lean meat- and fat efficiency.

Material and Methods

Model Description

The breeding company Topigs Norsvin (TN; Vught, the Netherlands) provided data from their boar test station in Norway, and this was used as input for the economic model. The model describes the income and costs in the purebred NL fattening pigs, from they are bought, as feeder pigs (40 kg) to they are slaughtered (100/120 kg).

Traits Evaluated

All traits were recorded on purebred NL boars from 40 nucleus herds in Norway at the boar test station. The boars are housed in pens with a Feed Intake Recording Equipment (FIRE) station (Osborne Industries Inc., Osborne, KS, USA), with 12 pigs in each pen. Here, individual feed intake and weight are recorded. The boars weight ~40 kg live weight when they enter the test, and about 100/120 kg when they end the test and their body composition is scanned by computed tomography (**CT**). Boars finishing the test before March 1, 2012 were CT-scanned at 100 kg live weight, while boars finishing after this date were scanned at 120 kg. Through image analysis from the CT-scans, lean meat- and fat content are registered. In total, 8,161 NL boars had information on the traits included in the bio-economic model. These traits were lean meat efficiency (**LME**) and fat efficiency (**FE**) (described in Martinsen et al. (2015)), number of days from 40 to 100/120 kg (**DAYS**), lean meat percentage (**LMP**) and fat content on the carcass (**FC**). To compare the new efficiency traits with total feed intake in the test period (**FI**), an economic model including FI, DAYS and LMP was developed. This was referred to as breeding goal B. The economic model including LME, FE, DAYS, LMP and FC was referred to as breeding goal A.

Days from 40 to 100/120 kg live weight

Days from 40 to 100/120 kg live weight is a measure for the individual growth. The trait is number of days between the animal is bought as a feeder pig (40 kg) and slaughtered at 100/120 kg. A reduction in this trait is preferable, as a faster growing pig would use less days to reach the end weight, and thus less feed. In addition, the farmer save costs in housing and labor per unit produced when the animals are slaughtered earlier.

Lean Meat Percentage

Lean meat percentage is a measure for carcass quality in the pig, and influences the income of the farmer. The price per kg for the carcass is influenced by LMP, as the market prefers a lean carcass (high LMP). By improving this trait, the income of the farmer will thus increase.

Fat Content on the Carcass

Fat content on the carcass represents the amount of fat on the carcass, which represents a cost for the farmer. By reducing FC on the fattening pigs, feed costs for fat deposition is reduced, and the farmers total cost decreases. This trait is included in the calculation of feed intake costs together with FE.

Total Feed Intake in the Test Period

Total feed intake in the test period is a measure of individual total feed intake during the test period. A reduction in this trait is preferable, as animals with low feed intake saves feed costs in the production.

Estimation of Lean Meat and Fat Efficiency

Both efficiency measurements were analyzed in an random regression animal model, and prediction of breeding values was performed in a univariate analysis using DMU (Madsen and

Jensen, 2013).The fixed effects used in the model were determined based on an analysis of the traits in SAS.

To estimate LME and FE, FI was analyzed as the trait with amount of lean meat and fat included through random regressions in the model. For analyzing FI the following model was used:

$$\mathbf{FI_{ijknoqrst} = HY_i + BM_j + ST_k + SEC_n + \beta_{lm} \times LMEAT_o + \beta_{fat} \times FAT_q + \beta_{amw} \times AMW_r + a_s + pen_t + a_{p_s} \times lmeat_o + a_{f_s} \times fat_q + e_{ijknoqrst}} \quad [1]$$

The fixed effects included in the model were herd-year (**HY**), birth month (**BM**), scanning time (**ST**) and section (**SEC**). Number of levels in *i* were 207 and for *j* it were 12. For *k* number of levels were two (finishing before or after March 1, 2012) and *n* had 132 levels. The boars' amount of lean meat (**LMEAT**) and fat (**FAT**) on the carcass and accumulated metabolic body weight (**AMW**) were included as fixed regression covariates. As a measure of the individual genetic potential for LME and FE, amount of lean meat (**lmeat**) and fat (**fat**) were also included as random regression covariates ($\mathbf{a}_{p_s}$ and $\mathbf{a}_{f_s}$, in the model) (Martinsen et al., 2015). Lean meat efficiency and FE represents the amount of feed needed to produce one extra kg of lean meat or fat, respectively, and are regression coefficients. The animals' breeding value ($\mathbf{a}_s$) and pen (**pen**) were included as random effects. In this model, a_s represent the genetic effect of the animal on FI that is not explained by the genetic effect of fat and lean meat efficiency and is referred to as the residual feed intake of the animal (Martinsen et al., 2015).

Since LME and FE are derived from estimates of model [1], direct phenotypic recordings are not available for these traits. The fixed regression coefficients estimated by model [1] were set as the mean for LME and FE, and are used in the profit equation to estimate the economic value of these traits. The prediction of breeding values for FI, FC, LMP and DAYS was performed in univariate models using the DMU (Madsen and Jensen, 2013). The following model was used:

$$\mathbf{Y_{ijklmn} = HY_i + BM_j + ST_k + SEC_l + a_m + pen_n + e_{ijklmn}} \quad [2]$$

Model [2] was identical to model [1], but did not include the fixed and random effect of lean meat and fat content nor the fixed effect of accumulated metabolic body weight.

Profit Function

The profit function is a function consisting of the input and output per unit, to describe the profitability of the unit. In this study, the profit was calculated per fattening pig. The input data and means are presented in Table 1.

Income

In fattening pig production in Norway, the revenue comes from the value of the fattening pig and subsidies. The value of the fattening pig is dependent on the settling price, which is associated with the SEUROP carcass grading system for pigs. The system organizes the carcasses into categories (S to R), depending on their LMP (Norwegian Meat and Poultry Research Center, 2012). During recent years, the average LMP has been above 60%, and in category S. The farmer is paid a bonus if LMP in the carcass is above 60% or given a reduced price if LMP is lower. This bonus was set to +/-0.03 EUR per LMP above/below 60% (Table 2). The settling price depends on the carcass weight. The settling price for the carcass weight was collected from Norsvin SA's economic analysis of pork production in 2014 (M. Narum, Topigs Norsvin, Hamar, Norway, personal communication). The subsidies for this given situation were set to 1.8 EUR/fattening pig (Table 2) and treated as a fixed income. The income (**I**) of a fattening pig (**fp**) was calculated with the following model:

$$\mathbf{I_{fp} = CW \times (Pr_{kg} + (LMP_{fp} - 60) \times AdPr) + S_{fp}} \quad [3]$$

where CW represents the carcass weight, Pr_{kg} is the settling price per kg. AdPr is the additional bonus per LMP above or below 60 % and S_{fp} is the fixed subsidies.

Costs

The costs included in the fattening pig production were the costs for feed for production and maintenance, costs to labor, machines and housing and fixed non-feed costs. The following model was used to calculate the costs (**C_{fp}**) of a fattening pig:

$$\begin{aligned}\mathbf{C_{fp}} &= \mathbf{P_{feed} \times (\beta_{lm} \times \mu_{lmc}) + P_{feed} \times (\beta_{fat} \times \mu_{fc}) + P_{feed} \times (MAIN_{day} \times DAYS_{fp})} \\ &\mathbf{+ (LAB_{day} \times DAYS_{fp}) + (HOU_{day} \times DAYS_{fp}) + FNF_{fp}}\end{aligned} \qquad [4]$$

The feed costs for maintenance per day (MAIN) were calculated based on the equation for standard maintenance requirement given in NRC (2012), and multiplied by the number of feed days (DAYS). To calculate feed used for production of lean meat and fat, the fixed regression coefficients derived from model [1] ($\beta_{lm} = \mathrm{LME}$ and $\beta_{fat} = \mathrm{FE}$) were used with the amount of lean meat (μ_{lmc}) and fat (μ_{fc}) (Table 1). All feed requirements were multiplied by the cost per kg feed (P_{feed}) (Table 2). In addition, a fixed non-feed cost (FNF_{fp}) per fattening pig was included. This cost includes piglet price, veterinary, insurance, mortality and interests per fattening pig for all traits (Table 3). Since machines/buildings (HOU) and labor (LAB) were dependent on DAYS, these costs are not included in FNF. The cost function described in model [4] was related to breeding goal A. The estimated cost for breeding goal B (FI is analyzed instead of LME and FE) is identical to model [4], but parameters associated with feed intake estimation ($\beta_{lm}, \beta_{fat}, \mu_{lmc}, \mu_{fc}$ and MAIN) were replaced by FI multiplied with the feed price (P_{feed}). The profit per fattening pig was the difference between total income per fattening pig (I_{fp}) and total costs per fattening pig (C_{fp}) in both breeding goal A and B.

Economic Values

Economic values for the traits were estimated by improving the mean of the trait by 1%, while the other traits remained constant. The following formula was used to estimate the marginal economic value of the traits.

$$\textbf{Marginal economic value}_n\,\textbf{(MEV)} = \frac{P(\mu_n + \Delta n) - P(\mu_n)}{\Delta n} \quad [5]$$

The difference in profit (P) between the original (μ_n) and the improved ($\mu_n + \Delta n$) mean was divided by the change in the trait (Δn) and represented the marginal economic value of the trait per trait unit. The marginal economic value was standardized by multiplying with the additive genetic standard deviation (σ_a) for each trait.

Indexes and Profit

To compare the two breeding goals for production an index was calculated for both breeding goals described below:

$$\textbf{Index}_i = \sum \textbf{MEV}_i \times \textbf{EBV}_{ij} \quad [6]$$

The index was calculated as the summation of the product of the marginal economic value for each trait (*i*) (MEV_i) and the estimated breeding value for the trait (EBV_{ij}) for each animal (*j*). An economically weighted phenotype including the traits in breeding goal B was estimated for each animal as showed in model [7].

$$\textbf{PROFIT}_j = \sum \textbf{MEV}_i \times \textbf{phenotype}_{ij} \quad [7]$$

Individual profit for animal (j) was calculated based on their phenotype for trait (*i*) included in breeding goal B and the economic value of the trait (j). This trait was named PROFIT and breeding values were calculated with model [2].

Results

Economic Values

Table 1 gives the production means for NL pigs on the test station. The average carcass weight of a purebred NL boar was 79.1 kg and LMP of 67.9%. The average fat content on carcass was 16 kg, and the boars used on average 66 days from 40 to 100/120 kg live weight at the test. The marginal economic values (EUR per trait unit) are presented in Table 3. The marginal economic value of FI was estimated to 0.3 EUR/kg feed. A 1% improvement of LME increased the profit by 0.005 EUR, and feed used for lean meat production was reduced by 0.0015 kg. This gave LME the highest marginal economic value of 18.3 EUR/kg feed/kg lean meat deposited (unit regression coefficient). For FE, the 1% improvement gave a reduced use of feed for fat production of 0.3 kg, which increased the profit by 0.12 EUR. The marginal economic value for FE was 5.6 EUR/kg feed/kg fat deposited. In terms of carcass payment, LMP was an important trait (Table 2). By improving LMP by 1%, to 68.5%, the profit increased by 1.7 EUR. The marginal economic value for LMP was 2.5 EUR/percentage. Fat content on the carcass affected feed intake in this economic analysis of breeding goal A. A 1% improvement in the trait was assumed (from 15.99 kg to 15.83 kg), and resulted in increasing the profit by 0.12 EUR. The marginal economic value for FC was 0.8 EUR/kg fat. For growth in the fattening period, DAYS was included in the analysis. By reducing DAYS by 1% (0.7 days), profit increased by 0.6 EUR per fattening pig and the marginal economic value was 0.9 EUR/day.

Table 3 also include standardized economic values (SEV), which makes it possible to compare the economic values on the same scale i.e. change in profit from one genetic standard deviation increase in each included trait (EUR/σ_a). Among the traits, LME was the trait that had the highest economic importance (8.9 EUR/σ_a), whereas FE (2.9 EUR/σ_a) was the third most important trait after LMP (4.5 EUR/σ_a). For DAYS, the standardized economic value was 2.6 EUR/σ_a. The trait FC was least important (1.1 EUR/σ_a). The trait FI had the second lowest economic importance out of all six trait in the analyses (1.6 EUR/σ_a).

Breeding Goals

Table 4 shows the descriptive statistics for the EBV's for PROFIT and the indexes for breeding goal A and B. The standard deviation of the EBV's for PROFIT was 23.3, while for the index for breeding goal B the standard deviation was 36.3. For the index for breeding goal A, the standard deviation was estimated to 52.2. The standard deviation suggested that the index for breeding goal A had two times as high variation as the index for breeding goal B. The high variance indicates that there is a bigger variation in the genetic potential for profit using breeding goal A. Breeding goal A included LME and FE as feed efficiency measures, while breeding goal B included FI. The rank correlation between the two indexes was 0.77. There was a complete re-ranking of the ten best sires when breeding goal B was used instead of breeding goal A, with no overlap among the ten best boars for the two breeding goals. The best animals in breeding goal A had overall lower phenotypic FI than the best animals for breeding goal B. However, the animals had poorer growth (higher DAYS).

Discussion

The study found economic values for LME and FE, together with directly observed traits DAYS, LMP, FC and FI. Higher variance was observed in the index containing LME and FE as feed consumption traits (breeding goal A) compared to the index for breeding goal B, containing FI as the feed consumption trait. The results suggested that both efficiency traits are important for profit and an inclusion of the traits in the breeding goal improves genetic gain, since the index of breeding goal A shows a substantially higher variance.

The model constructed for breeding goal A in this study was only dependent on five boar traits, as the aim was to estimate the economic value of LME and FE and not to describe the overall complexity of the pork production in Norway. Therefore, the model constructed was simple, but included the traits that are important regarding feed consumption and growth in pork production.

The quality of the input data used for the base situation are important when calculating economic values for traits. This study used input data from the boar test station, on purebred NL. These data are used for the genetic evaluation of the boars and are a part of the higher genetic level of the NL population as they are selected for the test station. This may influence the input data through high LMP and short growth period, but should not influence the economic value of the traits. The feed price and carcass price were market averages from 2014.

Economic Values

The marginal economic values in this study were presented per trait unit per fattening pig. Other studies have estimated economic values for production traits in different breeds, countries and with a different definition of production efficiency in the economic model (Hermesch et al. 2003; Houska et al. 2004; Serenius et al. 2007; Houska et al. 2010). Economic values across countries, breeding companies and breeds are difficult to compare due to different definitions of production efficiency, different market and management conditions across countries and different economic models (Houska et al., 2004). The standardized economic values estimated for DAYS and LMP in this study were higher than the economic values TN use. For FI, the economic value was slightly lower than what TN use. Still, the trait definitions are not exactly the same, and our economic model is not very complex.

Serenius et al., (2007) mentioned the importance of what a realistic change in the trait is, when marginal economic values are investigated. This study found a marginal economic value for LME of 18.3 EUR/kg feed/ kg lean meat, which is high. However, it may not be realistic to reduce the amount of feed used for one kg lean meat deposition by one kg. In 2014, the feed used for one kg growth in Norwegian commercial fattening pigs was 2.74 kg (Ingris, 2014). Feed for growth includes feed for deposition of fat, lean meat and other tissues as well as feed for maintenance (Schinckel and de Lange, 1996). To reduce the amount of feed for production of a kg lean meat by one kg might be unlikely, as there obviously is a biological limit for how efficient a pig could be.

The genetic standard deviation of LME was low (0.5), and the standardized economic value of the trait was 8.9 EUR/σ_a. Lean meat efficiency is not a phenotype that is observed, but a regression coefficient estimating the estimated cost for production of one additional kg lean meat (as a deviation from the mean). Lean meat efficient animals use less feed per kg lean meat deposited, i.e., the breeding value is negative and low. Even though the marginal economic value of LME was high per kg feed/kg lean meat, a small change in the trait was observed when improved by 1%. This small change reduced the feed cost and made a change in profit. This change in profit was big compared to the change in the trait and thus a high economic value per trait was calculated. The high economic value for LME is also dependent on the amount of lean meat on the fattening pig. As the trait is a result of FI as a function of amount of lean meat on the fattening pig, the trait is expressed as kg feed/kg lean meat. The same situation occurs for FE. The lower economic value is related to the lower amount FC on the carcass compared to lean meat. For both FE and LME, the economic value is dependent on the production level (amount of lean meat and fat), which makes it even more difficult to compare to other studies (Hermesch et al. 2003).

All feed related traits had high economic values, and a significant influence on the pork production profit. These economic values are highly dependent on the feed price, and a market change in the feed price would influence the economic importance of feed consumption traits in the breeding goal. The current situation in Norway is low feed prices and the importance of feed efficiency traits is expected to increase as feed prices rise.

Breeding Goals

The two breeding goals defined in this study contained few, but important, production traits in pig breeding. Breeding goal A represented the new traits LME and FE, established in Martinsen et al. (2015), while breeding goal B represented a more traditional breeding goal with FI, DAYS and LMP included. Profit as a trait (PROFIT) was the summation of the phenotypes of the traits included in breeding goal B multiplied with the economic value of each trait. This was a simple way of modelling profit (by phenotypes), but Meuwissen and Goddard (1997) concluded that profit was a quite robust trait for selection and Pérez-Cabal and Alenda (2003) suggested that profit as a trait should be implemented in the genetic evaluation of Spanish Holstein. As the standard deviation of the EBVs for PROFIT was lower than the standard deviation for the indexes for both breeding goal A and B, it seemed like more complex modelling of feed consumption increased the standard deviation. The index resulting from breeding goal A had the highest variance, which suggested that inclusion of LME and FE in the breeding goal would result in bigger genetic gain for profit. Still, it is important to take into consideration the use of univariate analyses of the traits. No genetic correlations among the traits are accounted for in the prediction of breeding values, and hence some breeding values might be over- or underestimated which might affect the index (Smith, 1983). The reason for not performing multitrait analyses was problems with convergence. Breeding goal A also included more traits in the index, which might influence the variation in the index. In addition, the traits included in breeding goal A have a considerably higher economic value than FI in breeding goal B.

The rank correlation between the indexes for the breeding goal was low (0.77), and suggested that the two breeding goals are not the same. The re-ranking of the sires suggested that the new efficiency traits contribute new information, not described in breeding goal B with FI as feed consumption trait. No sires were selected in common for the two breeding goals. The efficiency traits does not necessarily say which animals that have lowest feed intake or highest growth, but who deposit lean meat and fat most efficient. The animals with highest feed intake does not necessarily have to be less efficient. However, when comparing the best boars for the two breeding goals, the boar selected with breeding goal A had lower FI and poorer growth than the animals selected with breeding goal B. This highlights the importance of including genetic relationships between the traits in the breeding value estimation.

Conclusions

Both of the new efficiency measures had an economic importance in pork production. Lean meat efficiency had a high economic value compared to other production traits in NL. When comparing the breeding goals, including LME and FE in the breeding goal could potentially give a bigger genetic gain for profit than the breeding goal including FI. The rank correlation between the breeding goals proved that the new efficiency traits does not describe the same as FI, and includes additional information to improve the genetic evaluation of boars.

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Table 1. Input data, mean performance from purebred Norwegian Landrace boars at test station.

Variable	Performance mean
Carcass weight (kg)	79.1
Days in test (days)	66.3
Total feed intake in the test period (kg)	152.1
Maintenance requirement/day (kg)	1.2
Lean meat percentage (%)	67.9
Average fat percentage (%)	20.4
Lean meat content (kg)	52.3
Fat content on the carcass (kg)	15.9
Average lean meat efficiency (kg feed/kg lean meat)	-0.03
Average fat efficiency (kg feed/kg fat)	2.24

Table 2. Market prices related to costs and income in fattening pig production (M. Narum, Topigs Norsvin, Hamar, Norway, personal communication). The currency was set at April 13, where 1 EUR = NOK 9.3.

Variable	EUR(€)
Price/kg carcass weight	2.75
Additional price per kg if lean meat percentage above or below 60 %	0.03
Subsidies per fattening pig	1.83
Cost /kg feed	0.34

Table 3. Marginal economic values (MEV) expressed in EUR (€), genetic standard deviation (σ_a) and standardized economic values (SEV) for the five traits; Total feed intake in the test period (FI) Lean meat efficiency (LME), fay efficiency (FE), days from 40 to 100/120 kg live weight (DAYS), lean meat percentage (LMP) and fat content on the carcass (FC). All traits are expressed on a fattening pig-basis. The currency was set at April 13, where 1 NOK = 9.3 EUR

Trait	MEV (€)	σ_a	SEV (€/σ_a)
FI (kg)	0.3	4.7	1.6
LME (kg feed)	18.3	0.5	8.9
FE (kg feed)	5.6	0.5	2.9
DAYS (days)	0.9	2.8	2.6
LMP (%)	2.5	1.8	4.5
FC (kg)	0.8	1.4	1.1

Table 4. Number of observations (n), standard deviation (SD), minimum value (Min) and maximum value (Max) for index calculated for breeding goal A, breeding goal B and breeding values for profit as a trait (EBVprofit). Breeding goal A contain lean meat efficiency (LME), fat efficiency (FE), fat content on the carcass (FC), lean meat percentage (LMP) and days between 40 to 100/120 kg live weight (DAYS). Breeding goal B contains total feed consumption in the test period (FI), lean meat percentage (LMP) and days from 40 to 100/120 kg live weight (DAYS). Profit as a trait was the summation of the product of the phenotypes for the traits included in breeding goal B and the economic value of each trait.

	Breeding goal A	Breeding goal B	EBVprofit
n	8161	8161	8161
Mean	41.9	21.1	9.6
SD	52.2	36.3	23.2
Min	-137.9	-135.8	-89.7
Max	311.3	160.4	135