Economic values for performance and functional traits in dairy sheep

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ABSTRACT

In order to establish a total merit index, the relative economic values of the traits considered must be known. Hence, the objective of this study was to derive economic values, defined by the value of one unit of superiority of a trait, for essential traits in dairy sheep based on a herd model. These traits included dairy (milk carrier = water, lactose and mineral nutrients, fat and protein yield), fattening (daily gain, dressing percentage, and EUROP grading score) and functional traits (stillbirth rate, losses until first mating, litter size, lambing interval, and functional longevity). To avoid double counting, the economic value for each trait was derived while keeping all other traits constant. A sheep herd with milk production, lamb fattening and rearing of young sheep for replacement was modelled. The following economic values (in €) per ewe place and year and genetic standard deviation were derived: 21.45 (milk carrier yield), 11.73 (fat yield), 16.87 (protein yield); 3.62 (daily gain), 1.62 (dressing percentage), 1.45 (EUROP-grading score), -0.28 (functional longevity), 3.00 (litter size), 1.77 (stillbirth), 5.92 (losses before first mating), and 5.35 (lambing interval). When setting functional longevity to zero, relative economic values for the trait complexes in % were as follows: dairy:meat:functional traits = 68.8:9.2:22.0, respectively.

Key words: Dairy sheep, Breeding objectives, Economic values, Herd model, Functional traits.

RIASSUNTO

VALORI ECONOMICI PER PARAMETRI PRODUTTIVI E FUNZIONALI NELLA PECORA DA LATTE

Quando si stabilisce un indice di merito totale, occorre conoscere i valori economici relativi dei parametri che vengono presi in considerazione. Quindi, obiettivo di questo studio era ottenere valori economici, definiti dal valore di superiorità di una unità per un parametro, per i parametri essenziali nella pecora da latte sulla base di un modello di gregge. I parametri considerati comprendevano quelli di lattazione (“carrier” del latte = acqua, lattosio ed elementi minerali, produzione di grasso e proteine), di accrescimento (incremento ponderale giornaliero, resa alla macellazione e punteggio EUROP) e funzionali (mortalità neonatale, perdite fino al primo accoppiamento, numero di nati, interparto e longevità funzionale). Per evitare doppi conteggi, il valore economico per ogni parametro è stato ottenuto mantenendo costanti tutti
gli altri parametri. È stato creato un modello di gregge di pecore con produzione di latte, accrescimento degli agnelli e allevamento delle agnelle da rimonta. Sono stati ottenuti i seguenti valori economici (in €) per posto-pecora ed anno e deviazione standard genetica: 21,45 (produzione di “carrier” del latte), 11,73 (produzione di grasso), 16,87 (produzione di proteina); 3,62 (incremento ponderale giornaliero), 1,62 (resa alla macellazione), 1,45 (punteggio EUROP), -0,28 (longevità funzionale), 3,00 (numero di nati), 1,77 (mortalità neonatale), 5,92 (perdite fino al primo accoppiamento) e 5,35 (interparto). Quando è stata posta uguale a zero la longevità funzionale, i valori economici relativi per i parametri complessi sono stati, in %: latte:carne:parametri funzionali = 68,8:9,2:22,0, rispettivamente.

Parole chiave: Pecora da latte, Obiettivi selettivi, Valori economici, Modello di gregge, Parametri funzionali.

Introduction

Currently, approximately 32,000 purebred herd book ewes of about 30 different breeds are kept in Austria (ÖBSZ, 2006). Only 4.5% of these herd book ewes are dairy sheep with an average of 40 ewes per breeder. The main dairy breed is the East Friesian milk sheep, originating in Northern Germany and The Netherlands, with about 1000 herd book ewes. An additional 450 dairy sheep belong to the French Lacaune breed. Due to the federal structure of animal breeding in Austria, performance data were recorded and maintained by eight different breeding organisations conducting their own breeding programmes for many years. However, in 2004 a central data base for all Austrian sheep and goats was implemented. At the same time, the respective breeding organizations started to revise breeding objectives aiming to establish nationwide breeding objectives for the different breed groups of sheep (dairy, meat, mountain and endangered).

The definition of breeding objectives is among the first and most important steps when defining a breeding programme (e.g. Ponzoni, 1986). A general definition of breeding objectives is provided byFewson (1993) as ‘development of vital animals ensuring profit under future commercial conditions,’ implying the inclusion of several traits in an aggregate genotype. The index selection theory (Hazel and Lush, 1943) established the basis for optimal combination of traits when selecting for more than one trait. Within this theory the aggregate genotype may be defined as a linear function of traits multiplied by their economic value. Economic values are defined by the value of one unit superiority of a trait keeping all other traits in the aggregate genotype constant (Hazel, 1943). While the terms economic value and economic weight are often used synonymously, they may also be defined as the absolute and the relative benefit of improving a trait, respectively (Amer et al., 2001). Correct relative levels of economic values of breeding objective traits must be known for establishing a total merit index (Hazel, 1943) and should result in optimum levels of genetic improvement according to future production scenarios (Groen et al., 1997). Fewson (1993) suggests the inclusion of 10 to 15 most important traits. According to Groen et al. (1997) these traits may either be characterized as production traits that increase the output or functional traits that reduce costs. While in dairy sheep the main emphasis is still placed on dairy production traits (Carta and Ugarte, 2003), an EAAP working group specifically considering functional traits in breeding goals of dairy cattle was already established in the Nineties (Groen et al., 1997). Generally, little attention was paid to the derivation of economic values in dairy sheep. In two recent studies (Legarra et al., 2007a, 2007b) marginal utilities were derived for some
selected traits by profit functions. However, milk components or fattening traits, for example, were not covered in this study. In an older study (Kominakis et al., 1997) some marginal utilities are mentioned though without presenting the methodology of their derivation.

Hence, the objective of this study was to derive economic values for a combination of dairy, meat and functional traits in Austrian dairy sheep enabling the set-up of a modern breeding programme based on selection index theory. The sensitivity of economic values to changes in the proportion of sold breeding rams was also investigated.

**Material and methods**

**Model**

For the derivation of economic values, a computer program originally designed to optimise management-related decisions on cattle farms (Amer et al., 1996) and modified for the estimation of economic values in cattle by Miesenberger (1997) was adapted. The underlying herd model is based on a deterministic approach. A dairy sheep herd with milk production, lamb fattening and rearing of young sheep for replacement was simulated in a steady state over an infinite planning term according to Miesenberger (1997) and Reinsch (1993). The economic value of a trait was derived by calculating the difference in herd profit before (reference scenario) and after a genetic change. For these purposes daily results weighted by the proportion of the respective ewe class were summarised over the lambing interval or until culling. The proportion of ewes in different lactations depended on the percentage of culling for infertility, for involuntary or voluntary reasons. Within scenario, the herd distribution stayed constant over time. All relevant revenues and costs were calculated per day. Revenues resulted from selling milk, fattened lambs and animals for replacement. As in the original program (Miesenberger, 1997) all costs (including fixed costs) were regarded as variable according to Smith et al. (1986). All results were expressed per average ewe place and year as Reinsch (1993) showed that economic values per herd place and year estimated by Markov chains are independent of discount rate and initial state of herd when assuming an infinite planning term. To avoid double counting (Dempfle, 1992) economic values were derived separately for each trait keeping all other traits constant. For each trait, the result was expressed as marginal utility in € referring to an improvement by one unit (e.g. 1 kg milk, 1% stillbirth) and as economic value in € per genetic standard deviation ($s_a$).

**Assumptions**

To describe the dairy sheep population as accurately as possible, the following data sources were used for deriving input parameters: the recently implemented central data base for all Austrian sheep and goats, data of the Federal Research Institute for Alpine Regions Raumberg-Gumpenstein, results of questionnaires sent out to breed representatives and literature values. In Table 1 the assumed herd distribution is shown. Voluntary culling was only assumed until the 4th lactation. Culling for infertility, for involuntary or voluntary reasons generally occurred at lactation days 490, 150 and 150, respectively. In Table 2 an assortment of assumptions and in Table 3 a fraction of prices and revenues considered are stated. For the calculation of milk yield in higher lactations, the average milk yield of the first lactation was multiplied by ageing factors. Highest yields were assumed for the 4th lactation with an ageing factor of 1.39. The functions of Wood (1967) and Gompertz (Fitzhugh, 1976) were used to estimate daily
milk, fat and protein yield and live weight and daily gain, respectively.

Daily energy and protein requirements were calculated according to AFRC (1993), GfE (1996, 2001) and Kirchgessner (2004). Maximum daily dry matter intake was $0.103 \times \text{live mass}^{0.75}$ according to National Research Council (1987). However, as this restriction was critical with respect to younger animals, the factors multiplied by the metabolic live mass were set to 0.115 and 0.110 for animals with less than 15 kg

| Lactation | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----------|---|---|---|---|---|---|---|---|---|
| Involuntary | 2.39 | 5.89 | 3.83 | 2.76 | 2.06 | 2.04 | 1.19 | 0.49 | 0.43 |
| Fertility | 0.92 | 0.75 | 0.51 | 0.35 | 0.62 | 0.50 | 0.41 | 0.18 | 0.00 |
| Voluntary | 2.10 | 1.23 | 0.83 | 0.46 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Survivors | 24.53 | 16.67 | 11.49 | 7.92 | 5.24 | 2.69 | 1.10 | 0.43 | 0.00 |
| Total | 29.94 | 24.53 | 16.67 | 11.49 | 7.92 | 5.24 | 2.69 | 1.10 | 0.43 |

Table 2. Assortment of assumptions.

| Trait | Unit | Value |
|-------|------|-------|
| Standard lactation | d | 240 |
| Age at first lambing | " | 450 |
| Minimum days dry | " | 55 |
| 1st lactation yield (standard lactation) | kg | 390 |
| Protein percentage in first/higher lactations | % | 4.90/4.88 |
| Fat percentage in first/higher lactations | " | 5.62/5.66 |
| Proportion of single/twin/triple births | " | 30/53/17 |
| Birth weight of single/twin/triple lambs | kg | 5/4/3 |
| Stillbirth rate | % | 5 |
| Male lambs fattened | " | 95.1 |
| Working time/d ewes dry/ewes in milk | min | 2.5/4.5 |
| Working time milking per 100 l | " | 12.5 |
| Working time milking/d independent from milk yield | " | 3 |
| Working time/d lambs reared/fattened | " | 0.95/0.5 |
| Fattening period | kg | 18-40 |
| Proportions grading scores E/U/R/O/P | % | 0/30/60/8/2 |
and between 15 and 20 kg, respectively. Available feed stuffs for summer and winter feeding based on the reports of Resch et al. (2006), Buchgraber et al. (1997) and Miesenberger (1997) are shown in Table 4. A linear planning algorithm was used to select a least cost ration that meets the protein and energy requirements (Press et al., 1986) for each day. Differences in requirements because of live weight changes (growth and mobilization of body reserves) and gestation were taken into account. Revenues and costs for wool were neglected as they are approximately balanced. Of all lambings, 85% were considered as easy, 10% as difficult while in 5% veterinarian assistance was necessary at €50/lambing. Further veterinary costs were €1 per lamb and €10 per replacement animal. Approximately 5% of male lambs were considered as breeding rams and sold at an age of 260 days and €500. Only first inseminations resulted in costs. As artificial insemination is not practiced in Austria, costs for natural service rams (difference between purchase and retail price of rams, costs per barn unit, labour, veterinary costs and feed) were assumed. To enable the calculation per insemination, costs were split to a theoretical number of 40 ewes in the herd. Of all lambings, 38% and 36% were assumed to occur in January and February, respectively. All newborn lambs were assumed to suckle during the first week of life. Subsequently, the lambs were fed according to an early weaning plan usually practiced in Austria. From the second to the fourth week lambs received 2 l, in weeks five and six 2.5 l of milk replacer (0.2 kg/l at €1.7/kg) per day, respectively, and in total an average of 4.12 kg lamb concentrate at €0.25/kg. From the 7th week onwards lambs were fed according to their requirements using the feedstuffs shown in Table 4. Contrary to dairy cattle, sheep milk production is not constrained by legislated quota. Thus, no quota scenarios were considered. More detailed descriptions are provided in the Appendix and by Fürst-Waltl et al. (2006).

Table 3. Assortment of revenues and prices (€).

| Trait (unit)                                      | €/unit       |
|-------------------------------------------------|--------------|
| Milk carrier (kg)                                | 0.37         |
| Fat (%)                                         | 0.0443       |
| Protein (%)                                      | 0.0741       |
| Lamb carcass weight for E/U/R/O/P grading score (kg) | 5.50/5.00/4.80/4.40/4.00 |
| Ewe carcass weight (kg)                          | 1.5          |
| Replacement female carcass weight (kg)           | 4.35         |
| Labour costs (h)                                 | 10           |
| Veterinary costs per lamb born/fattened/reared  | 1/1/10       |
| First inseminations                              | 8.94         |
| Barn unit costs (ewe/year)                       | 21           |
| Barn costs (fattening lamb/day)                  | 0.03         |
| Barn unit costs (replacement stock/year)         | 12           |
Appendix

Description of the herd model (Miesenberger, 1997)

For the simulation of a dairy sheep herd in a steady state over an infinite planning term the maximum number of lactations (n) and the number of reasons for disposal (k) need to be known. Accordingly, the number of different ewe classes is calculated by n(k+1). For this simulation n=9 and k=3 (culling for infertility, for voluntary and for involuntary reasons) were assumed resulting in 36 different ewe classes. In lactation number 9 all ewes were disposed for involuntary reasons.

For all classes the probability of realization P(i,j), defined by the maximum number of lactations and the probability of disposals c(i,j) may be calculated with i=lactation number and j=fate of a ewe within lactation. The sum of all P(i,j) is 1.

The probability for a ewe to reach lactation 1 is denoted by p_i. In the first lactation, p_1=1, in higher lactations p_i is calculated by

\[ p_{i+1} = \frac{\sum_{j=1}^{k} p_i \cdot c_{i,j}}{n} \quad i = 1, 2, ..., n-1 \quad j = 1, 2, ..., k \]

The proportion in each lactation (P_i) is therefore calculated by

\[ P_i = \frac{p_i}{\sum_{i=1}^{n} p_i} \quad i = 1, 2, ..., n \]

By multiplication with the respective probabilities for disposal c_{i,j} the proportions of ewe classes by lactation and fate for the reference herd are calculated.

(3) \[ P_{i,j} = a \cdot b \cdot c_{i,j} \quad i = 1, 2, ..., n \quad j = 1, 2, ..., k \]

For particular values of i and j the following formulas are applied

(4) \[ P_{i,j} = P_{i+1} \quad \text{for} \quad i = 1, 2, ..., n-1 \quad j = k+1 \]

(5) \[ P_{i,j} = 0 \quad \text{for} \quad i = n \quad j = k+1 \]

Calculation of milk yield and live mass

Daily milk yield and milk contents were calculated by the exponential function described by Wood (1967)

\[ y_t = a \cdot b \cdot e^{ct} \]

with yt being milk, fat or protein performance on day t, where a, b, and c are constants that specify the shape of the lactation curve. The parameter a is calculated by the given milk production potential (MP) and the shape of the lactation curve:

(7) \[ a = \frac{MP}{\sum_{t=1}^{240} t^b \cdot e^{ct}} \]

The average milk production of the second and higher lactations is calculated by applying multiplication factors describing the relative production level in different lactations due to the ageing process.

Probabilities for different reasons for disposal (c_{i,j}) in the reference scenario.

| Lactation number | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    |
|------------------|------|------|------|------|------|------|------|------|
| **Reason for disposal** |      |      |      |      |      |      |      |      |
| Involuntary culling | 0.08 | 0.24 | 0.23 | 0.24 | 0.26 | 0.39 | 0.44 | 0.45 |
| Infertility       | 0.03 | 0.03 | 0.03 | 0.03 | 0.08 | 0.10 | 0.15 | 0.16 |
| Voluntary culling | 0.07 | 0.05 | 0.05 | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 |
The live mass of a female animal is described by the function

\[ \text{LM}_t = \text{MM} - (\text{MM} - \text{BM}) \cdot e^{-0.006t} \]

with \( \text{LM} \), \( \text{MM} \) and \( \text{BM} \) denoting the live, mature (\( \text{MM} = 70 \) kg) and birth mass, respectively, and \( t \) being the age in days. For breeding rams the exponential parameter was changed to 0.004 with an assumed mature mass of 100 kg.

For fattening animals \( \text{LM} \) on day \( t \) was defined according to the Gompertz function (Fitzhugh, 1976)

\[ \text{LM}_t = a \cdot e^{-be^{-kt}} \]

with \( a \) being the asymptote, while \( b \) and \( k \) denote slope and point of inflexion, respectively.

Energy and protein requirements, energy deficit (AFRC, 1993; GfE 1996, 2001; Kirchgessner, 2004).

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### Parameters of the Wood curve for dairy sheep in first, second and higher (3+) lactations.

| Lactation | b  | c  | b  | c  | b  | c  |
|-----------|----|----|----|----|----|----|
| 1         | 0.180 | -0.0087 | -0.0469 | 0.00120 | -0.09862 | 0.00133 |
| 2         | 0.167 | -0.0108 | -0.0536 | 0.00210 | -0.11732 | 0.00156 |
| 3+        | 0.116 | -0.0930 | -0.1893 | 0.00370 | -0.13098 | 0.00171 |

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### Assumed average first lactation milk yield as well as ageing factors for higher lactations.

| Milk yield | 1<sup>st</sup> lactation (kg) | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|------------|-------------------------------|----|----|----|----|----|----|----|----|
| 390        | 1.27                          | 1.36 | 1.39 | 1.36 | 1.30 | 1.19 | 1.14 | 1.12 |

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The live mass of a female animal is described by the function

\[ \text{LM}_t = \text{MM} - (\text{MM} - \text{BM}) \cdot e^{-0.006t} \]

For fattening animals \( \text{LM} \) on day \( t \) was defined according to the Gompertz function (Fitzhugh, 1976)

\[ \text{LM}_t = a \cdot e^{-be^{-kt}} \]

with \( a \) being the asymptote, while \( b \) and \( k \) denote slope and point of inflexion, respectively.

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### Parameters of the Gompertz function for fattening lambs for the reference situation and for deriving economic weights.

| Gompertz parameters | a       | b       | k       |
|---------------------|---------|---------|---------|
| 54.465<sup>1</sup>  | 2.169   | 0.0130  |
| 54.465              | 2.119   | 0.0135  |
| 54.465              | 2.069   | 0.0140  |
| 54.465              | 2.019   | 0.0145  |

<sup>1</sup>Reference situation.
Model calculations were based on the following requirements (LM=live mass (kg), BM=birth mass (kg), LMZ=gain in live mass (g/d)):

- **Energy requirements:**
  - **Maintenance:**
    - (10) 0.43 MJ ME/kg LM^{0.75} including medium movement and wool growth
  - **Milk production:**
    - Energy content of milk (LE) is calculated by
      - (11) LE(MJ/kg)=0.38 fat%+0.21 protein%+0.95
  - Efficiency factor for calculation of requirements =0.60
  - **Gestation:**
    - Energy content of the gravid uterus (CE)
      - (12) CE(MJ/d)=0.25 · BM · (10^{x}) · 0.07372 · e^{-0.00643t} with
        - x=3,322-4,979 · e^{-0.00643 · t} with t=day of gestation
    - Efficiency factor for calculation of requirements =0.20.
  - **Growth:**
    - (13) ME_g=0.141LM+0.0273LMZ+0.0001(LM · LMZ)

- **Protein requirements:**
  - **Maintenance:**
    - (14) Maintenance requirements (gXP/d)=3.0kg LM^{0.75}+15 (including medium wool growth)
  - **Milk production:**
    - (15) Milk production protein requirements (g XP)=(protein per kg milk in g)/0.42
  - **Gestation:**
    - Protein requirements during gestation
      - (16) (g XP)=(10.5/0.83)(energy requirements for maintainance and gestation)
  - **Growth:**
    - Protein requirements for growth (g XP/d)=1.708LM+0.4316LMZ

A possible energy deficit is defined by the difference between energy requirements and maximum energy consumption. The maximum loss of live mass was assumed to be 8% at a maximum rate of 7.77g per kg LM^{0.75}. For a possible additional energy deficit the milk production was reduced accordingly. A linear weight gain at the same maximum rate was modelled until the next lambing as soon as the energy balance for maintenance, production and gestation was positive.

**Traits**

Subsequent to intensive discussions with representatives of breeding organisations, the following breeding objective traits were determined for the derivation of economic values:

- **Dairy traits** - Carrier (water, lactose and mineral nutrients), fat yield and protein yield: For deriving economic values for the carrier, the daily milk yield was increased for the same absolute value during the whole lactation. Thus the shape of the lactation curve remained constant. At the same time fat and protein content had to be reduced to achieve constant fat and protein yields. For fat and protein yields, economic values were derived by increasing the respective content while keeping the total milk yield constant.
ECONOMIC VALUES IN DAIRY SHEEP

Table 4. Costs per kg dry matter (€/kg DM) and protein, energy (MJ ME) and fibre content for available feed stuffs¹.

| Feed stuff                      | €/kg DM | Crude protein (g) | MJ ME | Fibre (%) |
|---------------------------------|---------|-------------------|-------|-----------|
| Hay, 2nd cut                    | 0.13    | 148               | 9.39  | 23.6      |
| Grass (summer)                  | 0.09    | 169               | 10.97 | 24.0      |
| Grass silage, 1st cut (winter)  | 0.12    | 169               | 10.04 | 23.2      |
| Corn silage                     | 0.11    | 85                | 10.8  | 19.9      |
| Barley                          | 0.12    | 120               | 12.93 | 3.3       |
| Soy bean                        | 0.28    | 513               | 13.02 | 6.5       |

¹The following feed restrictions were applied: Concentrate max 40%, fibre min 16%, corn silage max 10%, grass silage max 50%.

Fattening traits - Daily gain, dressing percentage and EUROP grading score: An improved performance of daily gain (live mass/age at slaughter) resulted in a shortened fattening period to derive economic values. To increase daily gain, the parameters of the Gompertz curve (Fitzhugh, 1976) were altered in lambs (see Appendix) without changing adult ewe size. For dressing percentage (slaughter mass/live mass), the performance was increased by one percent. As EUROP grading score is a categorical trait, the economic value was calculated assuming a standard normal distribution with E=5, U=4, R=3, O=2, and P=1 and proportions of animals in these categories as shown in Table 2 following the method described by Miesenberger (1997). Class limits (u-values) were then assigned. Subsequently, shifting by approximately one genetic standard deviation towards the desired grade (E) resulted in new u-values and thus new class ratios. Both u-values and class ratios may be found in the u-table for standard normal distribution (e.g. Essl, 1987). From the original and new ratios weighted means for EUROP grading score and price were calculated. The differences between original and new mean prices and scores enabled the calculation of approximated economic weights. As costs are not considered, these values are not marginal utilities in the narrow sense. However, costs for breeding, keeping and marketing may be assumed to be rather similar.

Functional traits - Length of productive life, stillbirth rate (including lambs born dead and losses until 48h after birth), losses before 1st mating (of all lambs surviving until 48h a fixed percentage was assumed to die on day 21), lambing interval, and litter size: For length of productive life, economic value was derived by decreasing the probability of involuntary culling by one percent in all lactations. This resulted in a change in herd distribution and thus in a different profit. The derivation of economic values for litter size followed the method described for EUROP grading score, while for stillbirth rate and losses before 1st mating the traits were improved by 1 percent according to dressing percentage. The economic value for lambing interval was derived by reducing days to first service rather than improving the conception rate.

Genetic parameters

As genetic parameters were only available for dairy traits (Fuerst-Waltl et al., 2005), literature values from other popula-
tions had to be used for meat and functional traits (e.g. Wessels, 2003; De Vries, 2004; ZuchtData, 2007) to calculate $s_a$.

**Results and discussion**

Table 5 provides an overview of the reference situation. A profit of €135.36 per average ewe place and year was achieved. However, for the appraisal of results it has to be considered that this result does not really represent the actual profit as some effects which are presumably neutral with regard to economic values were not taken into account (e.g. wool production, claw trimming, electricity). The average milk yield per lambing cycle was 401 kg with 21.7 kg fat and 19.5 kg protein, which corresponds to 476 kg milk with 25.70 kg fat and 23.13 kg protein per average ewe place and year, respectively. Main revenues resulted from selling milk (€388.86 per lambing cycle) while main costs were costs for labour (€181.29) and concentrates (€114.14). In Table 6, means for all traits across lactations in the reference situation as well as their genetic standard deviations and heritabilities are shown.

**Derivation of economic values**

All presented marginal utilities refer to an improvement in the trait mean by one unit. They are expressed per average ewe place and year. Economic values are calculated by multiplying the marginal utilities with the genetic standard deviations of the traits.

**Dairy traits** - A positive marginal utility of €0.33 per kg milk carrier was achieved (Table 7). Presuming a genetic standard deviation of 65 kg (Table 6, Fuerst-Waltl et al., 2005) resulted in an economic value of €21.45 per average ewe place and year. The marginal utilities for fat and protein yield were €3.17 and €5.08 which corresponds to economic values of €11.73 and €16.87, respectively (Table 7). The dairy traits milk carrier:fat yield:protein yield are thus at a ratio of 2:1:1.5. In Austrian dual purpose Simmental (Fleckvieh) cattle, a slightly negative weight for carrier was derived (Miesenberger, 1997), while economic values for fat and protein yield were at a ratio of 1:1.4, respectively. The remarkably different result for carrier is due to the different milk payment system in dairy sheep. The price per carrier is approximately 10 times higher in dairy sheep than in cattle. Attention should also be paid to the fact that contrary to dairy cattle (Miesenberger, 1997) no milk yield dependent veterinary costs could be considered and that milk production is not constrained by a quota system. In a recent work dealing with Latxa and Manchega sheep (Legarra et al., 2007a) derived marginal utilities were between €0.69 and €1.44 per l of milk. The higher values compared to this study may be explained by the different methodology, especially by the fact that milk with given fat and protein content rather than milk carrier was analysed. In addition, the authors did not generally consider labour time related to the amount of milk yield. Thus, the improvement in milk yield did not cause increased working time throughout. Kominakis et al. (1997) report marginal utilities of €0.57 for kg milk yield and €9.50 per kg fat yield and are thus closer to the results in this study. However, the authors did not describe the methodology of deriving these values in the cited publication.

**Fattening traits** - Within fattening and slaughtering traits, daily gain was found to have the highest economic value at €3.62 (Table 7). This economic value was calculated from an average marginal utility of €0.125 per g originating from three changes of the Gompertz parameters (see Appendix). An increase of 1% of the trait dressing percentage caused a marginal utility of €1.72. With the given genetic standard deviation
Table 5. Results for the reference situation (per average ewe place).

| Trait                               | Unit          | Results in reference situation |
|-------------------------------------|---------------|---------------------------------|
| Results per lambing cycle:          |               |                                 |
| Cycle length¹                       | day           | 308                             |
| Milk yield                          | kg            | 401                             |
| Fat yield                           | "             | 21.7                            |
| Protein yield                       | "             | 19.5                            |
| Fat/Protein content                 | %             | 5.40/4.86                       |
| Milk revenue                        | €             | 388.86                          |
| Revenue from ewes sold              | "             | 17.36                           |
| Feed costs                          | "             | 68.35                           |
| Concentrates                        | kg DM         | 114.14                          |
| Replacement costs                   | €             | 55.91                           |
| Barn costs                          | "             | 17.69                           |
| Labour costs²                       | "             | 181.29                          |
| Insemination costs                  | "             | 7.79                            |
| Costs for lambings                  | "             | 1.66                            |
| Proportionate costs (sales):        |               |                                 |
| -Lamb fattened                      | €             | 52.33                           |
| -Ewe                                | "             | 77.91                           |
| -Ram                                | "             | 5.24                            |
| Proportionate revenues (sales):     |               |                                 |
| -Lamb fattened                      | "             | 66.78                           |
| -Ewe                                | "             | 84.72                           |
| -Ram                                | "             | 24.52                           |
| Revenue total:                      | "             | 582.23                          |
| Costs total                         | "             | 468.17                          |
| Profit                              | "             | 114.06                          |
| Results per year:                   |               |                                 |
| Revenue total                       | "             | 690.97                          |
| Costs total                         | "             | 555.61                          |
| Profit                              | "             | 135.36                          |

¹Shorter than lambing interval as culling is considered.
²Labour costs for feeding included in costs for feed stuff.
Table 6. Means per average ewe place (reference situation), genetic standard deviation (s_a) and heritability (h^2) for all breeding objective traits considered.

| Traits                  | Unit     | Mean  | h^2  | s_a  |
|-------------------------|----------|-------|------|------|
| Milk yield              | kg/year  | 476   | 0.27 | 65.0 |
| Fat yield               | "        | 25.70 | 0.26 | 3.70 |
| Protein yield           | "        | 23.13 | 0.26 | 3.32 |
| Daily gain              | g        | 262   | 0.30 | 29   |
| Dressing percentage     | %        | 46    | 0.40 | 0.94 |
| EUROP grading score     | points    | 3.18  | 0.25 | 0.23 |
| Functional longevity    | d        | 1027  | 0.12 | 189  |
| Litter size             | no. of lambs | 2.13 | 0.04 | 0.11 |
| Stillbirth              | %        | 5     | 0.02 | 3.08 |
| Losses before first mating | "      | 8    | 0.05 | 6.07 |
| Lambing interval        | d        | 354   | 0.05 | 10.7 |

1E=5 to P=1.

Table 7. Marginal utilities (€/unit), economic values (€/genetic standard deviation s_a) and relative economic values (setting the economic value for longevity 0) for all breeding objective traits and trait groups considered.

| Traits (unit)          | Marginal utility in € | Economic value in €/s_a | Relative economic value (%) | Rel. economic value for trait complex (%) |
|------------------------|-----------------------|--------------------------|-----------------------------|------------------------------------------|
| Carrier (kg)           | 0.33                  | 21.45                    | 29.47                       | Milk 68.8                               |
| Fat yield (kg)         | 3.17                  | 11.73                    | 16.12                       |                                           |
| Protein yield (kg)     | 5.08                  | 16.87                    | 23.18                       |                                           |
| Daily gain (g)         | 0.125                 | 3.62                     | 4.97                        | Meat 9.2                                |
| Dressing percentage (%)| 1.72                  | 1.62                     | 2.22                        |                                           |
| EUROP grading score (points) | 4.54              | 1.45                     | 1.99                        |                                           |
| Longevity (d)          | -0.0015               | -0.28                    | 0.00                        | Functional 22.0                          |
| Litter size            | 27.25                 | 3.00                     | 4.12                        |                                           |
| Stillbirth (%)         | 0.57                  | 1.77                     | 2.43                        |                                           |
| Losses before first mating (%) | 0.97              | 5.92                     | 8.13                        |                                           |
| Lambing interval (d)   | 0.50                  | 5.35                     | 7.35                        |                                           |
of 0.94%, an economic value of 1.62 was derived. For the EUROP grading score the lowest economic value among fattening and slaughter traits was derived with €1.45. The fattening traits are at a ratio of daily gain:dressing percentage:EUROP grading score of approximately 2.2:1:0.9. Carta and Ugarte (2003) mention that approximately 25% of the income derives from lambs' meat in dairy sheep. However, in a recent approach to derive economic values in Spanish dairy sheep (Legarra et al., 2007a) the fattening and carcass trait complex was not considered. In an earlier study on Greek dairy sheep (Kominakis et al., 1997), a marginal utility of €0.066 per g daily gain was reported, however, dressing percentage and EUROP grading score were not considered. The authors state that fattening and carcass traits are of minor importance in Greek dairy sheep. Taking the small economic values in this study and especially the current lack of routine performance testing for these traits into account, an inclusion of fattening and carcass traits in a future total merit index in Austrian dairy sheep is rather unlikely. Furthermore, dairy sheep breeding organizations are currently not interested in this trait complex. However, upon other terms the inclusion of the routinely recorded auxiliary traits daily gain and muscling score in breeding rams might be an option. In model calculations in Austrian Mountain sheep (Fürst-Waltl et al., 2006) positive genetic gains for daily gain and EUROP grading score and an increased annual monetary genetic gain could be achieved by this measure.

**Functional traits** - The functional trait with the highest economic value is losses before first mating (€5.92, Table 7). For stillbirth rate, an economic value of only €1.77 was derived. The corresponding marginal utilities are €0.97 and 0.57 per 1% improvement of these traits. To our knowledge, no economic values were published for these traits in earlier studies dealing with dairy sheep. Compared to other breed groups in Austria the derived values are markedly lower (Fürst-Waltl et al., 2006). The reasons for this most likely include lower prices for breeding stock and higher prolificacy in the reference situation. However, even if the economic values are lower than in other sheep breeds, breeding organizations should consider recording losses until the animals are registered in herd books. Currently, only stillbirth rate including losses within the first 48h are routinely recorded for replacement animals.

For lambing interval, the second highest economic value (€5.35; marginal utility €0.50/day; Table 7) within the functional traits was derived. Generally, selection for less seasonal strains of dairy sheep may seem questionable. However, according to Notter and Cockett (2005) development of populations with reduced seasonality is possible through selection and may thus result in a competitive advantage. Legarra et al. (2007a) also derived marginal utilities for fertility. However, their target trait was lambing per year (yes=1 or no=0) while the resulting marginal utility was very high (from approximately €80 – €150). In other Austrian sheep breeds (Fürst-Waltl et al., 2006) similar results for lambing interval were found. The marginal utilities ranged from €0.49 (Tyrol Mountain) to €0.81 (a seasonal mutton sheep) per day.

The marginal utility for litter size was €27.25 per lamb born. Consequently, assuming a genetic standard deviation of 0.11, the economic value is €3.00. In comparison with Austrian non-dairy sheep breeds, the economic value is markedly lower. For example, in Tyrol Mountain and Merinoland sheep, the marginal utilities are beyond €100 (Fürst-Waltl et al., 2006). Similar to losses until first mating, the reasons for this
may be found in the lower price of breeding stock and higher prolificacy in the reference situation as well as the high milk revenue in general. It should be noted that economic values were derived for litter size independently from other traits to avoid double counting. Thus, a possible correlated increase in milk yield due to a higher litter size (e.g. Othmane et al., 2002) is not included in the economic value.

The result for length of productive life, a slightly negative marginal utility of € -0.0015 per day (Table 7) and hence an economic value of € -0.28, was rather amazing. Evidence suggests that the decreasing milk yield in higher lactations and the selling of breeding rams play a major role in this context. Legarra et al. (2007a) reported positive, albeit very low, marginal utilities for longevity and consider this trait to be of little importance. Unlike sheep, functional longevity was found to be the most important functional trait in Austrian dairy cattle (Miesenberger, 1997), a result which is mainly caused by obviously higher replacement costs.

**Relative economic values**

In Table 7 not only the absolute economic values but also relative economic values are shown. These were in %: dairy:meat: functional traits = 68.8:9.2:22.0, respectively, when setting length of productive life to zero. In dual purpose Simmental cattle, where economic values were derived by the same methodology (Miesenberger, 1997), economic values were recently recalculated and are weighted in %: dairy:beef: functional:milkability = 37.8:16.5:43.7:2.0, respectively, with the weight of functional longevity accounting for 13.4% (ZuchtData, 2007). The comparison with other dairy sheep populations is impossible as to our knowledge no economic values for the given trait complexes were published.

**Sensitivity analysis**

As selling a proportion of breeding rams for comparably high prices seemed to have an important effect on the economic values, a sensitivity analysis for the reference situation without selling breeding rams was conducted. At present, no artificial insemination is practiced in Austrian sheep breeding. In the future, however, this technique could also be applied to the quite intensively working dairy sheep farms. As a consequence, the number of breeding rams sold will obviously decrease. The profit for this alternative scenario was noticeably lower with €113.58 per average herd book ewe and year. The economic values for the dairy trait complex remained more or less stable, while the economic values for all fattening traits increased. The lack of selling rams lead to different absolute and relative economic values in functional traits. Most importantly, the economic value for length of productive life became positive, even though the value was low (marginal utility €0.002/day, economic value €0.61/day). At the same time the economic values for stillbirth rate, losses until first mating and litter size were about halved. That means as lambs become less valuable, it is less important to have more of them and at the same time more important to keep ewes producing. The relative economic values for the trait complexes were dairy:meat:functional traits = 68.3:20.6:11.1.

**Conclusions**

The set up of a modern breeding programme implies the thorough definition of breeding objectives and, for the construction of a total merit index, the knowledge of the economic importance of the traits considered. Thus, economic values were derived for essential traits in the Austrian dairy sheep population for the first time. Milk, fat and protein yield
have by far the highest economic importance. However, to meet the demands of sustainability, not only production but also functional traits have to be considered, even if their heritabilities are rather low. Functional longevity, for which a negative economic value was found, should especially either be included with a zero or slightly positive value to avoid the risk of deterioration as observed in cattle (Fuerst-Waltl, 2006, unpublished results; Fürst and Fürst-Waltl, 2006). Traits, which could not be included in this analysis due to lack of data, are type traits, somatic cell count and milkability. The latter trait, milkability, is currently not recorded in dairy sheep. Due to budget constraints in performance recording, it is not likely that this trait will be considered in the future routine performance recording scheme. Somatic cell count, an indicator of mastitis, is, however, recorded routinely. Further work on the estimation of economic values of this trait is suggested as soon as the relevant data are available. According to dairy cattle (ZuchtData, 2007) type traits, e.g. udder depth, could be considered as auxiliary traits for longevity.

The breeding organisations now have a tool to select for a total merit index which should result in higher economic efficiency. However, next steps must include model calculations to evaluate genetic but also economic gains with different breeding schemes. Special emphasis will have to be placed on the long-term development of functional traits. Another point worth mentioning is that economic values need to be re-evaluated at regular intervals as they are affected by selection response or changed economics, for example.

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