Economic weights as a tool for sustainable livestock farming

Monika Michaličková1, Zuzana Krupová, Emil Krupa, Ludmila Zavadilová
Institute of Animal Science
Department of Genetics and Breeding of Farm Animals
Přátelství 815, 104 00
Prague 10, Czech Republic
e-mail1: michalickova.monika@vuzv.cz

Abstract
The livestock farming synthesizes many aspects which should be taken into account when economic weights are calculated. The most common approach to calculate the economic weights is a bio-economic modelling of the production system. Economically important traits are defined thought the modelling of herd structure using the Markov processes and iterative procedure, taking the total profit as the criterion of the economic efficiency. Marginal economic weights are expressed as a numerical approximation of the partial derivation of the profit function. These are standardized through genetic standard deviations and then expressed relative to the certain trait or as a proportion on the sum all of traits. Except of the production traits, the functional traits (health, reproduction, survival) and feed efficiency traits are very important for the sustainable and competitive animal production. Next to the economic also the environmental benefit (reduction of emissions through more effective utilisation of feed), ensuring the animal welfare (lower mastitis and claw diseases incidence) and finally the food security and sustainable development of the domestic agriculture should be mentioned. To calculate economic weights, the program package ECOWEIGHT (for cattle and for sheep) can be usefully applied. At present, the module for pigs as a part of the program package is under development.

Key words: animal production, economic weights, efficiency, sustainability

JEL classification: Q01, Q12, Q13

1. Introduction
Economic success of agricultural sector is in generally determined by environmental and climatic conditions, marketing strategy, production variables, human labour participation and effective utilisation of inputs (Daňo et al., 2001, Wolfová et al., 2007, Látečková et al., 2009, Krupová et al., 2012). However, animal production is an important part of the agriculture sector in each country (Wolfová et al., 2007, Krupa et al., 2005, Doucha et al., 2012). Farmers should take into account the complexity of the animal production operation and understand how individual components interact to ultimately affect farm profit (Daňo et al., 2001). To develop strategies that increase economic sustainability for farms, it is important to identify which variables influence the system and how they affect the profit. From the breeding point of view, in economically oriented companies, the aim is to improve the biological potential of animals which is a function of additive genetic values of traits weighted with economic values. A beneficial solution is to use a production function where the weights are obtained by calculating the partial derivative with respect to the trait considered, keeping all other traits constant at the mean value (Wolfová et al., 2005).

Based upon literature review, many articles are devoted to analyse of economic important traits in animal production (e. g. Koots& Gibson, 1998, Krupová et al., 2016, Wolfová et al., 2005). The objective of this short review is to comprehensively define the main principles and the most important biological specifics when calculating the economic weights and to define their impact on the economics of farms. Considering the character of study, the structure of paper is adjusted to this aim.
2. Methods for calculation economic weights

Methods used for calculation of economic weights can be divided into subjective and objective. With the subjective methods, the economic weights of traits are calculated by setting the required genetic gain for each trait – called as desired gain method (Simm et al., 1987) or defined by a subjective decision of the breeders – called „ad hoc approach“ (Groen et al., 1989).

In the objective methods, one or more equation are used to represents the behaviour of a production system. The system is modelled by positive (data evaluation) and normative approach (data simulation). The positive approach includes regression analysis that establishes the relationship between the profit of the system and the breeding values of animals for the evaluated traits. A disadvantage is that the huge amount of data from the evaluated production system is required. In addition, economic weights in this case are calculated on the basis of the level of the traits and prices achieved in the past and breeding should be oriented on the future. For this reason, the normative approach is preferred (e. g. Miesenberger, 1999, Wolfová et al., 2005).

Profit functions and bio-economic models are used in normative methods. A profit function is an equation to represent the relationship between the performance of animals in economically important traits and farm-level profit, or some other measure of economic outcome (Wolf et al., 2013). Economic weights are calculated as the partial derivative of the profit function with respect to each trait considered in the breeding objective. The economic weight represents the change in profit caused by a change in the phenotypic or genetic value of the given trait. Major advantage of the profit function is simplicity and facility of the results interpretation (Dekkers et al., 2004).

Bio-economic models consist of the system of equations that characterize biological and economical parameters and their relationships with the evaluated production system (Dekkers et al., 2004). Bio economic models can be based on linear (Fisher, 2001) and dynamic programming (Veerkamp et al., 1995) and on the deterministic or stochastic simulation. In a deterministic approach, the mean values of the input parameters are applied (Brascamp, 1978). In stochastic models the performance of animals is described by their mean and variability (Jones et al., 2004).

At present, a great number of authors prefer a combination of stochastic and deterministic approaches (e. g. Fuerst-Waltl & Baumung, 2009, Wolf et al., 2013). The bio-economic model of the program package ECOWEIGHT (Wolf et al., 2013) is often used to calculate the economic values of traits. The model includes both deterministic and stochastic components. Performance of most traits is simulated as the population average, but variation in several traits is taken into account as well (Wolfová et al., 2007).

3. Methodology

The program package ECOWEIGHT (Wolf et al., 2013), at the current stage (version 6.0.4), enable to calculate the economic values for economically important traits in cattle and in sheep (Table 1) and the module for pigs is nowadays under development.
Table 1: Structure of the program package ECOWEIGHT 6.0.4

<table>
<thead>
<tr>
<th>Program</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWBC</td>
<td>Beef cattle</td>
</tr>
<tr>
<td>EWDC</td>
<td>Dairy cattle</td>
</tr>
<tr>
<td>EWSH1</td>
<td>Sheep, one lambing per year, stand-alone program</td>
</tr>
<tr>
<td>EWSH2</td>
<td>Sheep, one lambing per year, used in combination with GFSH</td>
</tr>
<tr>
<td>GFSH</td>
<td>Sheep, program for gene flow, used in combination with EWSH</td>
</tr>
</tbody>
</table>

Source: Wolf et al. 2013

Considering the current unstable economic situation in animal production (mainly due to the abolition of the quota system in milk production) the program ECOWEIGHT can be very flexible and a useful tool. Variable production systems with and without production limitation can be modelled. Besides this, the program is useful for economic analyses of various production systems (e.g. Krupa et al., 2005, Wolf et al., 2013). Using the bio-economic models, the impact of production, management and economic circumstances on the economic efficiency of the given production system (measured as profit) can be studied (Koots & Gibson, 1998, Krupa et al., 2005).

In the program package ECOWEIGHT, the stationary state of the herd structure is derived using the Markov chain procedure (Reinsch & Dempfle, 1998). The herd dynamics is described in terms of the individual animal categories and probabilities of the transition between them. Profit (i.e. the difference between the present values of revenues and costs per cow and year at the stationary state of herd structure) is the criterion of economic efficiency for the modelled production system (Wolf et al., 2013):

$$ profit = rev \times NDE^{(rev)} - cost \times NDE^{(cost)} $$

where $rev$ and $cost$ are the row vectors of revenues and costs, respectively, per animal, the elements of which are $rev_i$ and $cost_i$, with $i$ being the category of animals. $NDE^{(rev)}$ and $NDE^{(cost)}$ are the column vectors of the number of discounted expressions connected with revenues and costs, respectively, the element of which are $NDE_i^{(rev)}$ and $NDE_i^{(cost)}$. Using this approach, all revenues and costs occurring in the herd during a year and in the life of progeny born in the herd are discounted to the date of birth of progeny. The life of progeny covered the time from birth to slaughter, death and sale or (by cows) the first calving of heifers.

Revenues in all systems are calculated for each category of animal. These revenues came from selling of all categories of animal, from selling of products typical for the given production system (e.g. milk in dairy cattle) and from governmental subsidies (direct and indirect) (Wolfová et al., 2005, Hietala et al., 2014, Krupová et al., 2016).

As stated in Wolf et al. (2013), costs are calculated separately for feeding, housing, breeding and health. All other costs (labour, interest rate for capital, energy, repairs, insurance and overheads) are accounted as fixed cost per animal category per day (e.g. Hietala et al., 2014, Krupová et al., 2016). Feeding costs are calculated on the basis of daily net energy and protein requirements of the animal (cows, breeding heifers, animals in fattening period) and on the price for feed with given dry mater, net energy and protein contents and include cost for water as well (Fox et al., 1990; AFCR, 1993). Housing costs were those for bedding (costs for straw minus revenues for manure). Breeding costs were costs for artificial insemination and included the price for semen, labour and services per conception (Krupová et al., 2016). Health costs included veterinary costs that were expressed per animal, dystocia costs expressed per calving, and cost for removing and rendering dead animals. The dystocia cost depended on proportions of total calving in each calving score class and on veterinary and labour cost specific to those scores (Wolfová et al., 2007, Wolf et al., 2013).
Based on Wolf et al. (2013), the marginal economic value of trait \( l \) (\( ev_l \)) is defined as the partial derivative of the profit function as follow:

\[
ev_l = \frac{\partial \text{profit}}{\partial TV_l} \bigg|_{TV_l=TV_{l0}}
\]

(2)

where: \( \text{profit} \) is the profit per cow and year, \( TV_l \) is the value of the given trait, and \( TV_{l0} \) is the trait mean in the population. In the calculations, the partial derivative is approximated by the difference quotient.

For a better comparison of the relative importance of different traits in the scenario considered, the marginal economic values are standardized by first multiplying them by the genetic standard deviation of each respective trait (Wolf et al., 2013):

\[
ev_{sl} = ev_l \times s_l
\]

(3)

where: \( ev_{sl} \) is a standardized economic weight for trait \( l \), \( ev_l \) is a marginal economic value of trait \( l \) and \( s_l \) is the genetic standard deviation for trait \( l \).

Secondary, to compare the economic importance of different traits, the relative economic values of traits are calculated as follows (Wolfová et al., 2007; Krupová et al., 2016):

\[
ev_{rl} = 100 \times \frac{|ev_{sl}|}{\sum |ev_{sl}|}
\]

(4)

where: \( ev_{rl} \) is the relative economic weight for trait \( l \) and \( ev_{sl} \) is the absolute value of standardized economic weight for trait \( l \). The same principles are used, when economic values of traits in sheep and in pigs are calculated.

4. Biological specifics

Bio-economic model of the program package ECOWEIGHT (Version 6.0.4, Wolf et al., 2013) allows applying some biologic specifics. To describe this, the module EWDC (Version 2.2.3) will be used as an example in the following text.

In dairy cattle, milk production is the most important source of revenues (Michaličková et al., 2014). Selection for milk production traits has traditionally received most emphasis in national breeding programs for dairy cattle in many countries (e. g. Hietala et al., 2014). Revenues from milk are usually a function of milk amount, fat and protein content and somatic cell count. To calculate them, the pricing system, basic price, milk yield and proportion of cows on the individual reproduction cycles, calving interval, length of the lactation period and the modified Wood function (Fox et al. 1990) are taken into consideration in module EWDC. The somatic cell count, which is defined as the average number of somatic cells per millilitre of milk is expressed as somatic cell score (Wolfová et al., 2007, Wolf et al., 2013). The pricing system for milk usually divided in high extension among the farms and countries, as well. For example, the pricing system in the Slovak Republic is usually based on fat and protein content of milk and on the somatic cell count level of milk (Krupová et al., 2016).In the module EWDC, a great variety of pricing systems can be modelled. Moreover, the milk pricing system is the most important factor affecting the economics of farms and finally the relative weighting of traits (milk volume, fat and protein content, clinical mastitis incidence and somatic cell score) included in the breeding objective (Wolfová et al., 2007, Hietala et al., 2014). At present, due to the abolition of the EU milk quota system from 2015 it
is possible to calculate economic values of traits under the quota-free milk production conditions.

Functional traits (health, reproduction and survival traits) are usually associated with a reduction of production costs (Miglior et al., 2005, Gonzalez-Recio et al., 2014) and therefore, more attention has been recently paid to their genetic improvement. Furthermore, the noneconomic value of health traits should be taken into account, which is connected with a growing interest of consumers and sociotechnical aspects of animal production, such as animal welfare and product quality (Hietala et al., 2014). The most important health traits calculated in the program EWDC are claw diseases and clinical mastitis incidence. Claw disease incidence is defined as the number of claw disease cases per cow and year at risk in the herd averaged over all lactations. Effects of claw disease on the loss of revenue due to discarding of milk during cow illness as well as additional costs for drugs, veterinary service and labour for herdsman or veterinary time are considered when calculating the economic value for the trait (Wolf et al., 2013; Wolfová et al., 2007). Clinical mastitis incidence is defined as the number of clinical mastitis cases per cow and year at risk, i.e. number of cows having mastitis divided by the total number of cows at the given day of each lactation (Wolfová et al., 2007). Effect of the clinical mastitis incidence to the economics of farm is similar like described by claw disease incidence.

Moreover, from an environmental point of view, more efficient feed utilization in dairy cattle has been connected with a reduction in greenhouse emission through lower methane and manure outputs of animals (Hietala et al., 2014). An option for achieving a direct genetic improvement in feed efficiency is selection for residual feed intake (Hietala et al., 2014). Residual feed intake is defined as the difference between the actual daily dry matter intake and the predicted daily dry matter intake of an animal (Williams et al., 2011). When the economic weights for residual feed intake are calculated, the net energy and protein digestible in the intestine requirements for growth maintenance, milk production and pregnancy and the basis of the dry matter, net energy and protein content in the feed ration of the corresponding animal category are taken into consideration (Wolf et al., 2013, Hietala et al., 2014).

5. Conclusions

Profitability of farming has become more dependent on minimizing the cost of production. To maintain the economic sustainability, production level should be improved and inputs should be utilized more efficiently. Improving animals for so-called functional traits is one way to reduce costs. The calculation methodology presented in this review provides, a comprehensive evaluation of biological (production variables) and economical aspects of the animal production system. Moreover, collection of appropriate data and a regular accounting of cost are necessary to identify optimal utilisation of inputs and to evaluate the farm from an economic point of view. Except the production traits, the functional traits (health, reproduction, survival) and traits for effective feed intake utilization are very important for the sustainable and competitive animal production. Effective utilisation of inputs in the production process, i.e. decreasing of the unit costs is significantly determined by these traits. Moreover, next to the economic also the environmental benefit as the reduction of greenhouse gas emissions, ensuring the animal welfare and finally the higher food security and sustainable development of the domestic agriculture should be mentioned.
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