

*Review article***METHODS FOR CALCULATING ECONOMIC WEIGHTS OF IMPORTANT TRAITS IN SHEEP**

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ABSTRACT

Selection of animals is performed on the basis of a complex of traits, which are characterised by their breeding values and economic weights. The economic weight (EW) of a trait is defined as the change in economic outcome of a production system caused by a change in the genetic value of the trait. The methods used for the calculation of EW can be divided into two - objective and subjective. Using subjective methods, the EW of the traits are set by subjective decisions of the breeders or are calculated according to desired gains in the given traits. The objective methods describe the behaviour of a production system while increasing the genetic level of a trait. Production systems can be modelled by positive or by normative approach. The main disadvantage of the positive approach is the evaluation of historical data (level of the traits and prices achieved in the past) while breeding is oriented towards the future. Normative approaches describe relations between the levels of important traits and the economic result of the production system using profit functions or bio-economic models. These methods are preferred by many authors. The major advantages of profit function are the simplicity and facility for interpretation of results. Bio-economic models consist of a set of equations characterising biological and economic parameters of the system. The main advantages are precision, flexibility, inclusion of many biological details and a more accurate reflection of trait change on overall profitability. These models are difficult to develop but they are most frequently used for the calculation of EW.

Key words: calculation, economic weight, methods, sheep

INTRODUCTION

Selection of animals is an important part of animal breeding. Selection is usually performed on the basis of a complex of traits. Each of these traits is characterised by its breeding value and economic weight. The economic weight (EW) of a trait specifies the change in economic outcome of a defined production system caused by a change in the genetic value of the trait (Hazel, 1943). It is assumed that the change of the trait is implicated by breeding arrangements and that all production factors are optimised in the system. Economic weights (EWs) of production and functional traits were calculated for many species in the past years. For example, economic weights

for pigs were reported by Tess et al. (1983a, b) or Houška et al. (2004), for dairy cattle by Groen et al. (1997), Kahi and Nitter (2004) or Wolfová et al. (2007b), for beef cattle by MacNeil et al. (1994), Amer et al. (1997), Wolfová et al. (2007b), for dual-purpose cattle Wolfová et al. (2007b). EWs for cattle traits under Slovak production conditions have been calculated by Peškovičová et al. (1997), Huba et al. (2004), Krupa et al. (2005a, 2005b) and Huba et al. (2006). EWs for sheep traits were published by Wang and Dickerson (1991a, 1991b), Almahdy et al. (2000), Jones et al. (2004), Fuerst-Waltl and Baumung (2006) and others (Table 1). Economic weights of traits presented in Table 1 have been calculated for various breeds of sheep kept in various productions systems

Table 1: List of papers dealing with calculation of economic weights (EWs) for sheep traits

Author(s)	EWs of traits
Ponzoni (1988)	clean fleece live weight, fibre diameter, number of weaned lambs, live weight, feed intake
Wang and Dickerson (1991b, c)	lambling rate (lambs born at 2 yrs of age), mature weight, wool growth, milk production, fertility, precocity of fertility, body lean production at maturity, viability
Nugent and Jenkins (1993)	fertility, precocity of fertility, litter size, relative salvage value
Amer et al. (1999)	ewe prolificacy (number of lambs born per ewe lambing), lamb survival at birth and during rearing
Almahdy et al. (2000)	conception rate, lambling rate, mortality rate, mature weight, milk production
Gabiña et al. (2000)	mean lambling date, ewe lamb fertility, fertility of ewes, litter size, real lactation yield, fat content, protein content
Kosgey et al. (2003; 2004)	litter size, lambling frequency, pre- and post-weaning lamb survival, ewe survival, lamb weight at age of 12 months, mature ewe live weight, consumable meat, manure sold, residual feed intake
Conington et al. (2004)	mature weight, longevity, number of reared lambs, number of lost lambs, weaning weight, fleece weight, weaning weight, carcass weight, fat class, conformation
Jones et al. (2004)	lean weight and fat weight of female and male lambs
Fuerst-Waltl and Baumung (2006a)	milk carrier, fat yield, protein yield, daily gain, dressing percentage, EUROP grading score, longevity, litter size, still birth, losses in rearing, lambing interval, lambing ease
Fuerst-Waltl and Baumung (2006b)	conformation traits of ewes and rams at auction (type, frame, form, feet and legs, wool, realisation)
Morais and Madalena (2006)	lamb daily gain, live weight, ewe/ram ratio, fertility, prolificacy, lambing interval, lamb survival, carcass yield
Vatankhah et al. (2006)	litter size, mature ewe weight, greasy fleece weight, lamb survival, weaning weight
Legarra et al. (2007a)	fertility, prolificacy, milk yield, longevity
Legarra et al. (2007b)	somatic cell score

and management alternatives, with punctual definition of each trait, character of pricing system and method of evaluating the economic efficiency of the system.

The objective of this short review is to describe the methods used for the calculation of EWs of important traits for sheep. Some papers aimed at calculation of EW for cattle are used to cover this wide issue.

METHODS FOR CALCULATION OF ECONOMIC WEIGHT

Methods used for calculation of economic weights (EWs) may be divided into objective and subjective methods. A detailed classification is presented in Figure 1 (Böbner, 1994). Using subjective methods, the EWs of traits are calculated by setting the required genetic gain for each trait - desired gain method (Simm et al., 1987; Elsen et al., 1986; Groen, 1989) or they are set by "ad-hoc approach". In this case the EWs of the traits are defined by a subjective decision of the breeders. The EWs are then multiplied by the standard deviation of progeny differences for each trait to produce a selection index. Such an index does not qualify as a true selection index,

but it may have educational value for breeders unfamiliar with indices as a selection tool. On the other hand, ad-hoc indices could be misleading because often they are economically and genetically naive (Bourdon, 1998).

The objective methods use one or more equations that represent the behaviour of a production system. The system is modelled by positive (data evaluation) or 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. This method was used, for example, by Gabiña et al. (2000) for calculation of relative economic importance of traits in sheep. He stated that milk production and fertility were the most important traits for gross margin in milk production systems. The positive approach has two main disadvantages. For the regression analysis, huge amount of data from the evaluated production system are required. The economic weights are calculated on the basis of the level of the traits and prices achieved in the past whereas breeding should be oriented to the future. For this reason, the normative approach (data simulation) is preferred by many authors.

Normative methods make use of profit functions or bio-economic models. A profit function is a single equation designed to represent the relationship between the performance of animals in economically important traits and farm-level profit, or some other measure of economic outcome (Bourdon, 1998). The EWs are then calculated as the partial derivatives of the profit function with respect to each trait considered in the breeding objective. The use of partial derivations enable to avoid double counting, e.g. increasing milk production is not accompanied with increasing or decreasing milk fat or milk protein (Dekkers et al., 2004). The EWs represent the change in profit induced by a change in the phenotypic or genetic value of a trait. The major advantage of profit functions is simplicity and facility of the results interpretation. Profit functions were used for calculating EW of traits for Australian Merino sheep (Ponzoni, 1988) and for Laxta and Manchega dairy sheep (Legarra et al., 2007a, 2007b).

Single-equation methods for determining EWs may not be precise and flexible enough for describing different production systems and economic conditions. An alternative to the single-equation method for the calculation of EWs is the use of bio-economic simulation. Bio-economic models consist of a collection of equations that characterize biological relationships, simulate management and economic situations and determine profitability or some other measures of economic efficiency of the evaluated production system. Economic weights are determined from these models by simulating changes in the genetic level of a trait and noting the associated changes in overall economic outcome. The EW of trait i can therefore be usually derived in the following steps (Dekkers et al., 2004):

1. Running the model for current population means for all traits, including the current mean for trait i , μ_i , and recording the average profit per animal: $P\mu_i$
2. Increasing the mean of trait i by Δ ($\mu_i + \Delta_i$), while keeping the means of other traits at their current values; running the model again and recording the new average profit per animal: $P(\mu_i + \Delta_i)$
3. Deriving the economic weight for trait i , v_i as:

$$v_i = \frac{P(\mu_i + \Delta_i) - P\mu_i}{\Delta}$$

Bio-economic models can be deterministic or stochastic. In a deterministic approach, the mean values of the input parameters are applied. This approach was used, for example, by Nugent and Jenkins (1993), Wang and Dickerson (1991a, 1991b, 1991c) and Kosgey et al. (2003) in the calculation of EWs of traits for sheep. In stochastic models, the performance of animals is described by their mean and variability. This method was used, for example, by Jones et al. (2004) for calculation of EWs of carcass traits for terminal sire breeds of sheep

or by Nielsen et al. (2004) for dairy cattle. However, some authors (MacNeil, 1996; Wolfová et al., 2005) question the appropriateness of these models for calculating EWs because a simulated change in the genetic component for one trait invariably causes change in the performance of other traits in the breeding objective. In this case, the EWs do not represent the effects of independent changes in each trait. A great number of authors prefer a combination of stochastic and deterministic approaches, e.g. Amer et al. (1999), Conington et al. (2004), Fuerst-Waltl and Baumung (2006), Wolfová et al. (2007a, 2007b).

Some of the authors prefer to optimize the production system while calculating economic weights. Linear programming or dynamic optimization is mostly applied. Fisher (2001) used linear programming for calculation and comparison of economic efficiency of three sheep production systems – spring, winter and accelerated lambing. Linear programming optimises the production system in a stationary state where as dynamic programming optimises the system in time, during an investment period. The optimal decision at time $t+1$ depends on the system state in time t . Almahdy et al. (2000) applied dynamic programming for the calculation of EWs of production and reproduction traits for meat sheep. New optimizations of the system after changing the level of a trait caused changes not only in the phenotypic and genetic value of the given trait but also in all other traits. This problem is the only disadvantage of bio-economic models that use stochastic simulation or optimization approaches. But according to Bourdon (1998), this might be a problem of the definition of EWs only. If the relative EW of a trait is defined as a change in the economic outcome per independent unit, which enables to express the increase in genetic potential of a trait instead of the performance of the trait, and then if the genetic potential is included in the breeding objective, the requirement of independent change is not violated.

The main advantage of bio-economic models is precision. Simulation models contain large numbers of equations to represent basic biological relationships; they include much more biological details than profit functions, and can therefore more accurately track the effect of a change in a genetic component of animal performance on overall profitability. They may also be more flexible than profit equations. The disadvantages of bio-economic simulation models include the cost, time and money to develop them. A further handicap is the requirement of large amounts of input information that describe physical environment, management, production, and economic factors. Obtaining these data from farmers can be difficult. The models are often designed to simulate specific production environments and are therefore not appropriate for other production systems (Bourdon, 1998). In spite of these disadvantages, bio-

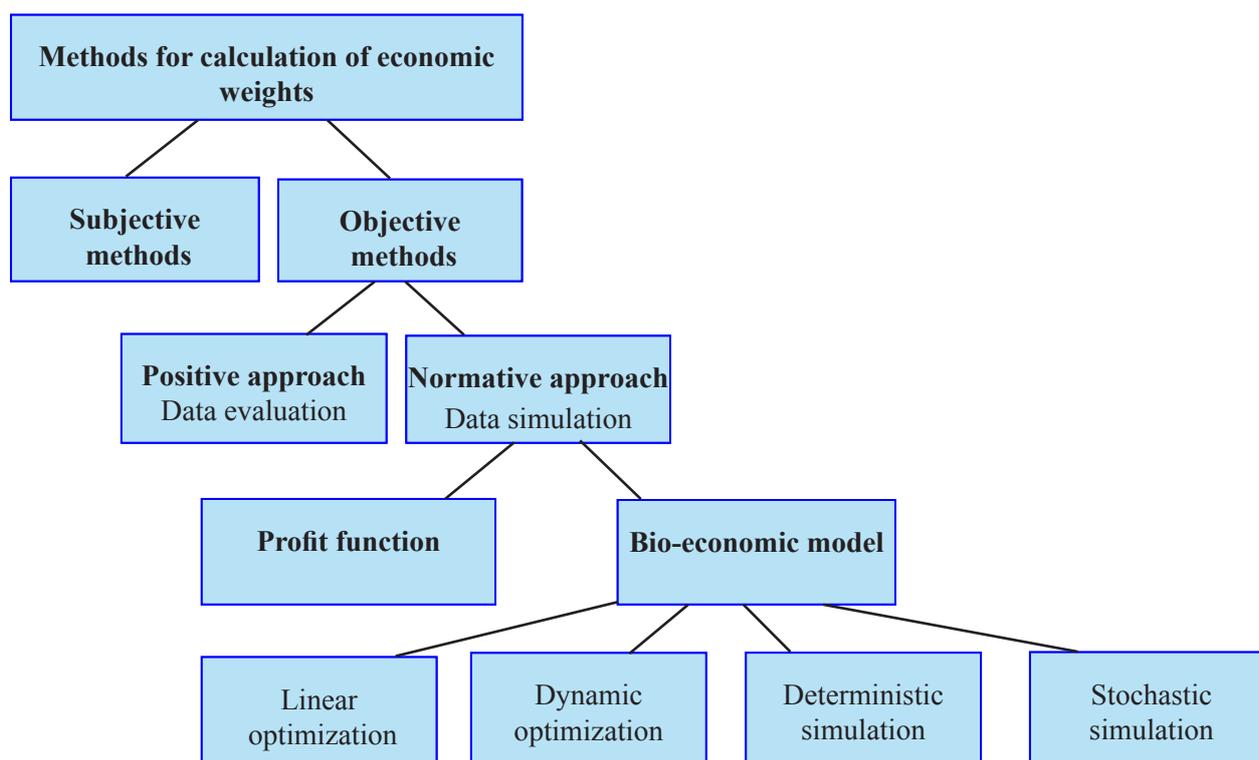


Fig. 1: Methods used for calculation of economic weights

economic modelling is the most widely used method for the calculation of economic weights.

CONCLUSION

As Groen et al. (1997) stated that it is impossible to find the best methodology for deriving EW. The method, which is the best from theoretical point of view, probably will not to be the best for practical implementation. Therefore, when the EW is derived, a fine-tuning of a sound theoretical basis with all important practical demands will be necessary. All of the presented methods used for calculating economic values of important traits have both advantages and disadvantages. The normative approach represented by profit functions and bio-economic simulations seems to be much promised. The bio-economic models are mainly applied for their flexibility and precise simulation of specific production, economic and environmental factors.

REFERENCES

- ALMAHDY, H. – TESS, M. W. – EL-TAWIL, E. – SHEHATA, E. – MANSOUR, H. 2000. Evaluation of Egyptian sheep production systems: II. Breeding objectives for purebred and composite breeds. In: *J. Anim. Sci.*, 2000, vol. 78, no 2, p. 288-295.
- AMER, P.R. – EMMANS, G.C. – SIMM, G. 1997. Economic values for carcass traits in UK commercial beef cattle. In: *Livest. Prod. Sci.*, 1997, vol. 51, p. 267-281.
- AMER, P.R. – MCEWAN, J.C. – DODDS, K.G. – DAVIS, G.H. 1999. Economic values for ewe prolificacy and lamb survival in New Zealand sheep. In: *Liv. Prod. Sci.* 1999, vol. 58, no 1, p. 75-90.
- BÖBNER, C. 1994. Schätzung wirtschaftlicher Gewichte für sekundäre Leistungsmerkmale bei Schweizerischen Zweinutzungsrindern unter Anwendung der dynamischen Optimierung. Dissertation, ETH Zürich, 1994, 127 p.
- BOURDON, R. M. 1998. Shortcomings of current genetic evaluation systems. In: *J. Anim. Sci.*, 1998, vol. 76, no 9, p. 2308-2323.
- CONINGTON, J. – BISHOP, S.C. – WATERHOUSE, A. – SIMM, G. 2004. A bioeconomic approach to derive economic values for pasture-based sheep genetic improvement programs. In: *J. Anim. Sci.* 2004, vol. 82, no 5, p. 1290-1304.
- DEKKERS, J. C. M – GIBSON, J. P. – BIJMA, P. – VAN ARENDONK, J. A. M. 2004. Design and optimisation of animal breeding programmes. Lecture notes for AnS 652 A and B, S05, Ames, USA : Iowa State University, 2004, 300 p.
- ELSEN, J. M. – BIBE, B. – LANDAIS, E. – RICORDEAU, G. 1986. Twenty remarks on economic evaluation of selection goals. In: Proc. 3rd Wld. Cong. Genet. Appl. Livest. Prod.

- Lincoln. 1986, no 12, p. 321-327.
- FERNÁNDEZ-PEREA, M.T. - JIMÉNEZ, R.A. 2004. Economic weights for a selection index in Avileña purebred beef cattle. In: *Livest. Prod. Sci.*, 2004, vol. 89, p. 223-233.
- FISHER, J. W. 2001. An economic comparison of production systems for sheep. In: *Canadian Journal of Agricultural Economics*, 1991, vol. 49, no 3, p. 327-336.
- FUERST-WATTL, B. – BAUMUNG, R. 2006a. Economic weights for performance and functional traits in dairy sheep. In: 8th World Congress on Genetics applied to Livestock Production, 13.-18. August, Belo Horizonte, MG, Brazil, 2006, vol. 34, 4 p.
- FUERST-WATTL, B. – BAUMUNG, R. 2006b. Economic weights for conformation traits in Mountain sheep. In: *Arch. Tierz.* 2006, vol. 49, no. 6, p. 575-582.
- GABIÑA, D. – UGARTE, E. – SANTAMARIA, P. 2000. The definition of breeding objectives in the Lacha dairy sheep breed. In: Analysis and definition of the objectives in genetic improvement programmes in sheep and goats. An economic approach to increase their profitability. Proceedings of the meeting of the Sub-Network on Genetic Resources of the FAO-CIHEAM. Mediterranean Seminars Series A/43, Zaragoza, Spain, 18-20 November 1999. D. Gabiña - Zaragoza: CIHEAM/FAO, 2000, s. 19-25, ISBN 2-85352-218-0.
- GROEN, A. 1989. Cattle breeding goals and production circumstances. Dissertation, Wageningen Agricultural University, the Netherlands. 1989, 167 p.
- GROEN, A.F. – STEINE, T. – COLLEAU, J.J. – PEDERSEN, J. – PŘIBYL, J. – REINSCH, N. 1997. Economic values in dairy cattle breeding, with special reference to functional traits. Report of an EAAP-working group. In: *Liv. Prod. Sci.*, 1997, vol. 49, no 1, p. 1-21.
- HAZEL, L. N. 1943. The genetic basis for constructing selection indexes. In: *Genetics*, vol. 28, 1943, p. 476-490.
- HOUŠKA, L. – WOLFOVÁ, M. – FIEDLER, J. 2004. Economic weights for production and reproduction traits of pigs in the Czech Republic. In: *Liv. Prod. Sci.* 2004, vol. 85, p. 209-221.
- HUBA, J. – DAŇO, J. – KICA, J. – PEŠKOVIČOVÁ, D. – KRUPA, E. – POLÁK, P. 2004. Economic weights of milk efficiency traits in production system of the year 2003. In: *J. of Farm Anim. Sci.*, 2004, vol. 37, p. 119 – 124
- HUBA, J. – KICA, J. – DAŇO, J. – KRUPA, E. – ORAVCOVÁ, M. – HETÉNYI, L. 2006. Economic weights for milk yield traits under the quota restriction in Slovakia. In: Farm Management and extension needs in Central and Eastern European countries under the EU milk quota. Wageningen: Academic Publishers, 2006, (EAAP Techn. Ser. 8). ISBN 10:90-76998-92-2, p. 263-269.
- JONES, H.E. – AMER, P.R. – LEWIS, R.M. – EMMANS, G.C. 2004. Economic values for changes in carcass lean and fat weights at a fixed age for terminal sire breeds of sheep in the UK. In: *Liv. Prod. Sci.*, 2004, vol. 89, no 1, p. 1-17.
- KAHI, A.K. – NITTER, G. 2004. Developing breeding schemes for pasture based dairy production systems in Kenya. I. Derivation of economic values using profit functions. In: *Liv. Prod. Sci.* 2004, vol. 88, p. 161-177.
- KOSGEY, I. S. – VAN ARENDONK, J. A. M. – BAKER, R. L. 2003. Economic values for traits of meat sheep in medium to high production potential areas of the tropics. In: *Small Rum. Res.* 2003, vol. 50, no 1-2, p. 187-202.
- KRUPA, E. – WOLFOVÁ, M. – PEŠKOVIČOVÁ, D. – HUBA, J. – KRUPOVÁ, Z. 2005a. Economic value of traits for Slovakian Pied cattle under different marketing strategies. In: *Cz. J. Anim. Sci.*, 2005, vol. 50, issue 10, p. 483-492.
- KRUPA, E. – POLÁK, P. – ORAVCOVÁ, M. – KRUPOVÁ, Z. – HANUSOVÁ, E. 2005b. Ekonomické váhy mäsového dobytku v prognózovanom produkčnom systéme. (Economic weight of beef cattle in predicted production system). In: *J.Farm Anim.Sci.*, 2005, vol. 38, p.265-272
- LEGARRA, A. – RAMÓN, M. – UGARTE, E. – PÉREZ-GUZMÁN, M. D. 2007a. Economic weights of fertility, prolificacy, milk yield and longevity in dairy sheep. In: *Animal*, 2007, vol. 1, no 1, p. 193-203.
- LEGARRA, A. - RAMON, M. - UGARTE, E. - PÉREZ-GUZMÁN, M.D. 2007b. Economic weights of somatic cell score in dairy sheep. In: *Animal*, 2007, vol. 1, no 2, p. 205-212.
- MACNEIL, M.D. – NEWMAN, S. – ENNS, R.M. – STEWART-SMITH, J. 1994. Relative economic values for Canadian beef production using specialized sire and dam lines. In: *Can. J. Anim. Sci.*, 1994, vol. 74, p. 411-417.
- NIELSEN, H. M. 2004. Economic values for production and functional traits in dairy cattle breeding goals derived by stochastic simulation. Dissertation, Royal Veterinary and Agricultural University, Frederiksberg. 156 p.
- NUGENT, R. A. – JENKINS, T. G. 1993. Simulated effects of culling ewes for age and failure conceive on biological efficiency of an annual lambing production system. In: *J. Anim. Sci.*, 1993, vol. 71, no 2, p. 310-320.
- PEŠKOVIČOVÁ, D. – HUBA, J., –CHRENEK, J. – KICA, J. 1997. Economic weights of milk efficiency parameters in production system in 1996. In: *J. of Farm Anim. Sci.*, 1997, vol.37, p. 134-137.
- PONZONI, R. W. 1988. The derivation of economic values combining income and expense in different way: An example with Australian Merino sheep. In: *J. Anim. Breed. Genet.*, 1988, vol. 105, no 2, p. 143-153, ISSN 0044-3581.
- SIMM, G. – YOUNG, M. J. – BEATSON, P. R. 1987. An economic selection index for lean meat production in New Zealand sheep. In: *Anim. Prod.*, 1987, vol. 45, p. 465-475.
- TESS, M. V. – BENNETT, G. L. – DICKERSON, G. E. 1983a. Simulation of genetic changes in life cycle efficiency of pork production. I. A bioeconomic model. In: *J. Anim. Sci.*, 1983, vol. 56, p. 336-353.
- TESS, M. V. – BENNETT, G. L. – DICKERSON, G. E. 1983b. Simulation of genetic changes in life cycle efficiency of pork production. II. Effects of components on efficiency. In: *J. Anim. Sci.*, 1983, vol. 56, p. 354-368.
- WANG, C. T. – DICKERSON, G.E. 1991a. A deterministic computer simulation model of life-cycle lamb and wool production. In: *J. Anim. Sci.*, 1991, vol. 69, no 11, p. 4312-23.
- WANG, C. T. – DICKERSON, G. E. 1991b. Simulated effects of reproductive performance of life-cycle of lamb and wool production at three lambing intervals. In: *J. Anim. Sci.*, 1991, vol. 69, no 11, p. 4338-4347.

- WANG, C.T. - DICKERSON, G.E. 1991c. **Simulation of life-cycle efficiency of lamb and wool production for genetic levels of component traits and alternative management options.** In: *J. Anim. Sci.*, 1991, vol. 69, no 11, p. 4324-4337.
- WOLFOVÁ, M. – WOLF, J. – KVAPILÍK, J. – KICA, J. 2007a. **Selection for profit in cattle: I. Economic weights for purebred dairy cattle in the Czech Republic.** In: *J. Dairy Sci.* 2007, vol. 90, p. 2442-2455.
- WOLFOVÁ, M. – WOLF, J. – KVAPILÍK, J. – KICA, J. 2007b. **Selection for profit in cattle: II. Economic weights for dairy and beef sires in crossing systems.** In: *J. Dairy Sci.* 2007, vol. 90, p. 2456-2467.
- WOLFOVÁ, M. – WOLF, J. – PŘIBYL, J. – ZAHŘÁDKOVÁ, R. – KICA, J. 2005. **Breeding objectives for beef cattle used in different production systems. 1. Model development.** In: *Liv. Prod. Sci.*, vol. 95, p. 201-215.

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