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Economic weights of current and new breeding objective traits in Aberdeen Angus

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Abstract: Breeding values estimated for growth, calving performance, and exterior traits are currently combined into simple selection indices for bulls, cows, and heifers of the Aberdeen Angus breed. To establish a comprehensive economic index for this breed, the absolute and relative economic weights (EW) for a complex of 16 production, functional, carcass, and feed efficiency traits were calculated. The absolute EW of a trait expressed the difference in the present values of profit that will be obtained from the descendants of a bull with the average breeding value for this trait, and descendants of a bull with the breeding value one unit higher than the average one. The relative EW of a trait was defined as the standardised EW of a trait (i.e. EW per genetic standard deviation) expressed as percentage of the sum of standardised EWs of all evaluated traits. Sensitivity analysis was conducted to explore the EW of traits under variable production and economic conditions. Variability in the marketing strategy, in product prices and costs, and in trait means was considered in this analysis. Relative EW of the feed efficiency of breeding heifers and of cows reached 4%. The highest relative EW was obtained in three growth traits: weight gains of calves from birth to 120, from 120 to 210, and from 210 to 365 days of age (66% combined). The survival rate of calves until weaning and cow productive lifetime reached 11% and 8% of the total economic importance of traits, respectively. These growth and functional traits accounted for 84% (in marketing strategy involving selling breeding animals) to 90% (in populations with high growth intensity) of the total economic weight of all 16 evaluated traits. Therefore, these traits should be considered as new selection criteria when constructing a comprehensive selection index for the Czech Aberdeen Angus population in future.

Keywords: selection; economic value; feed efficiency; growth traits; functional traits; carcass traits

Breeding objectives and selection criteria for beef cattle have mostly been focused on meat quantity and quality, and on reproductive traits (Albera et al. 2004; Burrow et al. 2019). Recently, feed efficiency traits have become new breeding objectives, especially in dairy cattle, and also in beef cattle (Basarab et al. 2013), because these traits have been shown to be important factors determining the effective utilisation of farm inputs. Moreover, the presumption that selection for high growth rates in beef cattle would increase feed consumption without an adequate increase of revenues from meat increased the breeder's interest in selection for improving feed efficiency traits (Santana et al. 2012). Residual feed intake (RFI) is usually applied as the basic indicator of feed efficiency (Williams et al. 2011; Gonzalez-Recio et al. 2014). The latter authors suggest that through direct selection, including RFI of dairy heifers in a comprehensive selection index, a genetic gain for this trait can be obtained with improved farm profitability by 3%, in spite of the antagonism between RFI and calving interval. In beef

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cattle mostly kept on pasture, feed costs are generally lower than in dairy cattle. Nevertheless, the economic importance of feed efficiency traits in beef breeds could increase due to rising requirements to mitigate the adverse impact of livestock production on the environment in future (Aby et al. 2013).

Aberdeen Angus (AA) is the second most numerous beef breed in the Czech Republic covering 20% of all non-dairy cows (personal communication with the Czech Beef Breeders Association). Many herds of AA are being managed under the certified organic production system and about 50% of the farmland is located in Areas with Natural Constraints (ANC; formerly less favoured areas). The breeding goal is to preserve the pros of the breed such as early maturity, easy calving, excellent fertility and survival of calves, high carcass value, being naturally polled, and to prefer animals with high growth, excellent back muscling, and with high longevity (personal communication with the Czech Beef Breeders Association). Breeding values are routinely estimated for 22 traits (characterising calving performance, growth, exterior, and carcass conformation; e.g. Vostry et al. 2014). Estimation for other traits such as longevity is currently under development (Brzakova et al. 2019).

Relative breeding values for growth, calving performance, and exterior traits are currently combined into simple selection indices for bulls, cows, and heifers. The comprehensive economic selection index (synthesizing the breeding values and the economic importance of the appropriate traits) has not been established in practice until now despite the fact that some indices for local beef bulls have been designed (Safus et al. 2006) and economic weights (EW) of the traits have already been calculated (Wolfova et al. 2005b). The bio-economic model of the program package ECOWEIGHT, applied for the calculation of EW of traits in cattle has been updated (Wolf et al. 2013) since the last calculation. The flexibility of the model was increased, taking into account calving seasons during the whole year, including more feeding seasons, muscularity classes, and calving scores and including the calculation of EW for RFI of cows, calves, heifers, and finished animals. Moreover, the production and economic conditions of local beef cattle have changed substantially since the last EW estimates.

Therefore, the main aim of the present study was to calculate the EW for all traits currently included in the AA breeding objectives as well as for new traits such as feed efficiency, and to provide a sensitivity analysis of EW to changes in the breed's production and economic parameters.

MATERIAL AND METHODS

Production system

In accordance with the general principles of organic farming, the production system of the AA breed is based on the maximum utilisation of natural resources (pasture), keeping the external inputs at a minimum level along with the maximum adaptation of animals to local conditions. The pasture (summer) season takes place from 25 April to 6 December, and the mating period during

Table 1. Production parameters in the BASE system of the Aberdeen Angus breed

Parameter (unit)	Base
Maximal number of calving performance classes	4
Percentage of dystocia[1] (%)	0.27
Conception rate at the 1st, 2nd and 3rd mating of:	
heifers	0.80/0.67/0.55
cows	0.73/0.58/0.50
Proportion of calves sold at weaning[2]: female/male	0.45/0.77
Cow losses averaged over all reproductive cycles (%)	2.44
Involuntary culling of cows due to health problems (%)	1.37
Heifers needed for herd replacement (per 100 cow per year)	12
Selected breeding bulls sold after the test (per 100 cow per year)	2.62
Mature weight of bull (kg)	1 050
Productive lifetime of bulls (years)	5.0

[1]Dystocia considers class 3 and 4 of calving performance; [2]Expressed as a proportion of weaned calves

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the spring season. Based on an economic evaluation of AA farms (unpublished data), the average farm size was 540 ha of agricultural land (74% as permanent grasslands) and the density was 0.26 cows per ha, i.e. 140 purebred cows and the appropriate number of other categories per farm. In a commercial pure-breeding system, replacement females are produced, but bulls for natural mating are bought from outside. Surplus calves are sold after weaning (at the age of eight months). On average, 12% of weaned calves are dedicated as heifers for herd replacement and nearly 8% as bulls for test stations. Basic production and economic parameters characterising the actual production system of the breed are given in Table 1 and 2, respectively. In total, about 600 input parameters were used to describe the system in the bio-economic model. The biological and production parameters of the AA breed were taken from the database of the performance testing of the Czech and Moravian Breeders Association provided by the Czech Beef Breeders Association. The economic input parameters were obtained through an investigation of AA farms (unpublished data). In the study, the average annual value of subsidies at €545 per cow (Syrucek et al. 2018) and an exchange rate of 25.64 CZK per € were applied. The cow herd structure in the stationary state is presented in Figure 1.

Table 2. Economic parameters in the BASE system of the Aberdeen Angus breed

Parameter (unit)	Value
Number of classes for fleshiness/for fat covering	6/5
Base market price for class S1[1] (€/kg) of:	
cows	2.90
heifers	3.28
bulls	3.70
Price for a sold breeding bull (€)	3 900
Price for sold weaned calves (€/kg of live weight)	
female	2.03
male	2.34
Price per artificial insemination semen dose (€; including service)	31.2
Price of food (€/100 kg of fresh matter) in summer/winter for:	
cows	1.52/3.16
heifers	1.91/3.35
bulls	2.69/3.31
Straw price (€/100 kg)	0.63
Water price (€/100 lit.)	0.08
Cost for removing and rendering (€):	
per dead cow	260
per young animal	182
Cost for veterinary treatment (€):	
per cow and year with calf until weaning	33.7
per breeding bull per year	31.5
per heifer from weaning to calving	22.9
Veterinary cost connected with calving score 3/4 (€/calving)	66.3/81.1
Stock-man hours connected with calving score 3/4 (hours/calving)	3/5
Cost per stock-man hour (€)	8.19
Fixed cost per day (€)[2]:	
per cow with calf until weaning	1.57
per heifer in rearing	0.82
per breeding bull in the herd	1.42

[1]Based on the SEUROP carcass classification system; [2]Including other costs of labour, energy, repairs, insurance, fuel, and overheads. The average exchange rate in 2018 (25.64 CZK per €) was used

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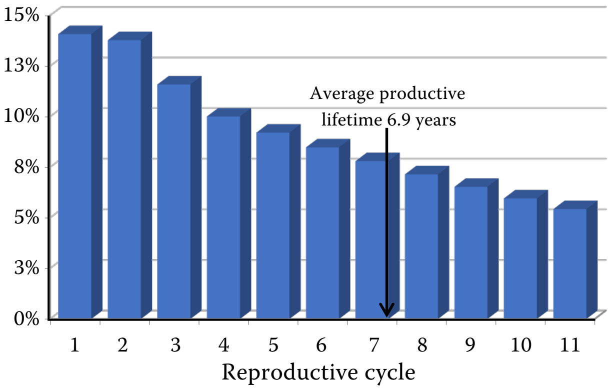

Figure 1. Structure of the cow herd (%)

Economic weights of traits

Mean values for the 16 evaluated traits and genetic standard deviations of the traits are listed in Table 3. The first seven traits represent the current selection criteria for the AA breed, and the remaining traits are new candidates for breeding objectives or selection criteria in beef populations. The RFI trait was defined as the difference between the animal's actual daily dry matter intake (DMI) and the animal's predicted daily DMI. In the BASE calculation, the average RFI of the given categories of animals (cows, bulls, and breeding heifers) was assumed to be zero, i.e. the animal's actual daily DMI was assumed to be equal to the animal's predicted daily DMI; the latter was calculated according to animal weight, growth rate, and cow pregnancy status (Williams et al. 2011). Detailed definition of all traits can be found in Wolfova et al. (2005a).

Each trait was considered to be a direct or maternal trait or to have a direct and a maternal component, in accordance with the estimation of breeding value for that trait. Direct traits were those expressed only once in animal's life (e.g. carcass conformation traits, heifer conception rate, heifer RFI). Maternal traits were those expressed repeatedly in each cow parity (e.g. cow conception rate, cow RFI). Some traits were assumed to have both direct and maternal components (e.g. calving performance, birth weight, growth of calves until weaning).

Economic weight (EW_{ijk}) of trait i belonging to the trait type j (maternal or direct) was calculated as a product of the marginal economic value (EV_i) of the trait and the number of discounted gene expressions (NDE_{jk}) for that trait coming from a selected animal of category k (two-year old bulls in our calculation):

Table 3. Mean values (mean), genetic standard deviation of evaluated traits

	Trait (unit)[1]	Mean	GSD
Current[2]	Birth weight of calves (kg)	37	1.5
	Weight gain of calves from:		
	birth to 120 d (kg)	133	7.2
	120 d to 210 d (kg)	102	10.2
	from 210 d to 365 d (kg)	220	21.5
	Calving performance (class)	1.013	0.03
	Fleshiness (class)	4.206	0.025
	Fat covering (class)	1.951	0.012
New[3]	Productive lifetime of cows (year)	6.89	0.76
	Losses of calves at calving (%)	0.32	0.11
	Losses of calves from calving until weaning (%)	3.2	0.99
	Conception rate of heifers (%)	97	1.2
	Conception rate of cows (%)	94	1.8
	Dressing percentage (%)	65	1.1
	Mature weight of cows (kg)	680	20.5
	RFI of breeding heifers (kg DM/d)	0	0.13
	RFI of adult animals (kg DM/d)	0	0.23

[1]Mean and GSD are given in units of the trait. The values for birth weight, weight gains, meat parameters and dressing percentage refer to male calves; [2]Represents the traits currently used in the selection of Czech Aberdeen Angus; [3]Traits usually considered as breeding objectives and selection candidates in beef cattle

GSD = genetic standard deviation; RFI = residual feed intake

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$$EW_{ijk} = EV_i NDE_{jk} \quad (1)$$

where:

EW_{ijk} = economic weight (EW_{ijk}) of trait i belonging to the trait type j;

EV_i = change in the present value of profit per cow per year caused by an increase in the trait mean by one unit;

NDE_{jk} = number of expressions of bull genes for trait i of type j in all generations of bull descendants in the defined investment period (25 years in our calculation).

The NDE_{jk} of each descendant generation were discounted to the year of bull selection with an annual discount rate of 1%.

All calculations were done with the program EWBC which is a part of the software package ECOWEIGHT (Wolf et al. 2013). The methods for the calculation of EV and NDE, and the detailed description of the assumptions made when calculating the marginal EV and the EW of all traits were described in detail by Wolfova et al. (2005a) and in the manual of the cited program.

To make the EW of the trait (expressed in different units) comparable, relative economic weights (REW) of the trait given in per cent were calculated as follows:

$$REW_{ijk} = 100 \times EW_{ijk}GSD_i/\Sigma EW_{ijk}GSD_i \quad (2)$$

where:

REW_{ijk} = relative economic weights;

EW_{ijk} = economic weight (EW_{ijk}) of trait i belonging to the trait type j;

GSD_i = genetic standard deviation of trait i;

$EW_{ijk} \times GSD_i$ = standardised EW of trait i.

The absolute values of the products $EW_{ijk} \times GSD_i$ were taken, because EW can take positive as well as negative values.

Sensitivity analysis of EW of the trait

The sensitivity analysis explored the impact of changes in production and economic parameters (inputs) for the AA breed on REW of the trait. It was based on the variation of the management strategy, of trait means, and of prices and costs. The lowest and the highest level of the input parameters was chosen according to obtained variability among farms. The following variants were investigated in the sensitivity analysis:

0) BASE; all input parameters have the mean values given in Tables 1, 2, and 3.
1) WEAN+, WEAN–; the proportion of calves sold at weaning was increased by 15%, with decreased selling of breeding animals; and calves sold decreased by 15%, with increased selling of breeding animals, respectively.
2) ADG+, ADG–; the average daily gain of female calves until weaning and heifers in rearing was increased and decreased by 20%, respectively.
3) COST+, COST–; feeding costs of all categories were increased and decreased by 20%, respectively.
4) REV+, REV–; market prices of weaned calves and breeding animals were increased and decreased by 20%, respectively.

For presentation of the sensitivity analysis results, the REW of traits characterising similar animal performance were summarised to one value. For example, the REW for growth summarised REW for weight gains of calves from birth to 120 d, from 120 d to 210 d, and from 210 d to 365 d of age. The REW for calf losses included REW for losses of calves at calving and from calving until weaning; REW for RFI comprised RFI of breeding heifers and of adult animals (cows and bulls).

RESULTS

The absolute EW calculated for the maternal and direct traits or trait components for the AA breed are given in Table 4. The differences in EW for the direct and maternal components of the same trait were caused by the differences in NDE for both trait components. The NDE for direct traits (or direct trait components) originating from one mating with selected two-year old bull was 2.10 whereas the NDE for maternal traits (or maternal trait components) was 1.54.

The economic importance of RFI was €–22.6 and €–46.0 per kg of dry matter intake per day for breeding heifers and adult animals, respectively. This means that the progeny of the selected bulls with breeding value +1 kg DM intake per day per heifer increased feeding costs and thus reduced

Table 4. Absolute and relative economic weights for direct and maternal traits or trait components

	Trait (unit)[1]	EW		REW[2]	
		direct	maternal	direct	maternal
Current[3]	Birth weight of calves (kg)	2.45	1.82	1.0%	0.7%
	Weight gain of calves from:				
	birth to 120 d (kg)	3.72	2.76	7.0%	5.2%
	from 120 d to 210 d (kg)	3.87	2.89	10.4%	7.7%
	from 210 d to 365 d (kg)	3.67	2.72	20.7%	15.4%
	Calving performance (class)	−111.4	−82.7	0.9%	0.7%
	Fleshiness (class)	−39.1	–	0.3%	–
	Fat covering (class)	−2.65	–	0.0%	–
New[4]	Productive lifetime of cows (year)	–	38.3	–	7.6%
	Losses of calves at calving (%)	−21.1	−15.7	0.6%	0.5%
	Losses of calves from calving until weaning (%)	−22.2	−16.5	5.8%	4.3%
	Conception rate of heifers (%)	0.86	–	0.3%	–
	Conception rate of cows (%)	–	6.72	–	3.2%
	Dressing percentage (%)	1.14	–	0.3%	–
	Mature weight of cows (kg)	–	−0.76	–	4.1%
	RFI of breeding heifers (kg DM/d)	−22.6	–	0.8%	–
	RFI of adult animals (kg DM/d)	–	−46.0	–	2.8%
Sum		–	–	48%	52%

[1]Absolute EW are given in € per unit of the trait. The values for birth weight, weight gains, meat parameters, and dressing percentage refer to male calves; [2]The REW of a trait was defined as the standardised EW a trait (i.e. absolute EW*genetic standard deviation) expressed as percentage of the sum of standardised EWs of all evaluated traits; [3]Represents the traits currently used in the selection of Czech Aberdeen Angus; [4]Traits usually considered as breeding objectives and selection candidates in beef cattle

EW = absolute economic weights; REW = relative economic weights; RFI = residual feed intake

the present value of profit over the investment period of 25 years by €22.6. If these bulls also have the breeding value for RFI of adult animals +1 kg DM intake per day per animal, the present value of profit over this investment period will be further reduced by €46.0. Of course, selection would be focused on animals with a negative breeding value for RFI, i.e. with the predisposition to reduce feed consumption while keeping meat production at the same level. Therefore, the means of simultaneously evaluated traits (daily weight gain and carcass quality traits) were held constant when calculating the marginal EV of RFI to avoid double counting.

The EWs of the remaining direct and maternal traits (or trait components) were both positive and negative depending on the character of the given trait and on its impact on the farm economics. Higher breeding values for the current selection criteria, namely for the birth weight, weight gains of calves in the three periods of life, and for calving performance had a positive impact on the present value of profit (the EW being from €2.45 to €3.87 for the direct components and from €1.82 to €2.89 for the maternal components of these traits per trait unit (Table 4). For the trait related to muscularity (dressing percentage), the EW was low (€1.14 per %) due to the low number of slaughtered animals. Even negative EW were calculated for increasing the mean classes for fleshiness and fat covering, namely €−39.1 and €−2.65 per class, respectively. These values emphasise that under the current payment system the fleshiness and fat covering of AA carcasses are optimal and no changes in these traits should be sought. The EW for the improvement of cow productive lifetime was €38.3 per year. This value results mainly from reduced costs for replacement heifers.

The REW for maternal and direct traits or trait components are presented in Table 4. The ratio

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of the sums of REW for direct and maternal traits (or trait components) was 48 : 52. In both types of traits, the highest economic importance was in growth traits (taken together, calf weight gains in different time periods accounted for 66% of the trait total economic importance). The next economically most important traits were calf losses at birth and until weaning (together 11%), and cow productive lifetime (8%).

Cow conception rate reached 3%, RFI (for adult animals and breeding heifers) and mature cow weight had the relative importance of 4% each. The relative economic importance of all other traits was less than 3%.

The results of the sensitivity analysis are presented in Figure 2. The REW of traits are relatively insensitive to the investigated range of input parameters. Only the growth intensity of calves had a major impact on the relative economic importance of investigated traits.

DISCUSSION

A comparison of the EW for the AA breed in our calculation and in the former estimation of Wolfova et al. (2005b) is impossible because of different production and market payment systems assumed in both studies. In Wolfova et al. (2005b), all surplus calves were fattened and supported by 1 000 CZK (€39) per animal with favourable bonuses for higher meat quality. These facts were reflected in the high relative economic importance of fattening and carcass traits (taken together, REW for dressing percentage, fleshiness and fat covering classes, and for daily gain in fattening accounted for 23%). In our study, the majority of surplus calves were sold after weaning without adequate bonuses for carcass quality, which caused the low importance of carcass traits (less than 1%) and the high relative importance of calf growth (66%). This situation was also reflected in the sensitivity analysis where nei-

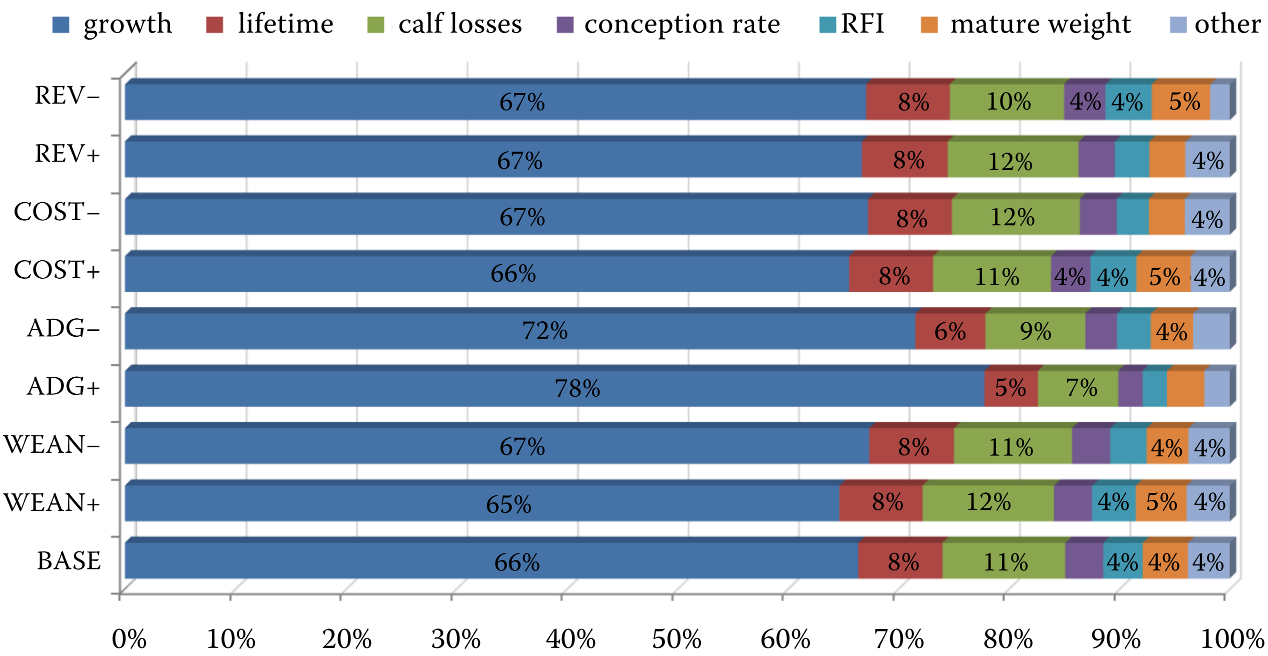

Figure 2. Relative economic weight of the trait groups[1] under the sensitivity analysis[2]

[1]Groups of traits: growth (weight gain of calves from birth to 120 d, from 120 d to 210 d, and from 210 d to 365 d of age), calf losses (losses at calving and from calving until weaning), RFI (RFI of breeding heifers and of adult animals), conception rate (conception rate of cows and heifers) and other traits (calving performance, birth weight, fleshiness, and fat covering). Further traits are single (see Table 3). Traits are sorted from the highest to the lowest economic weight. Traits with relative values equal or less than 3% are not labelled; [2]In the actual production system the input parameters were based on the mean values of the breed (BASE) and in the sensitivity analysis the variability of inputs was considered: WEAN+ (system intended to sell weaned calves), WEAN– (system producing breeding animals), ADG± (growth intensity until weaning and in the rearing changed ± 20%), variation of feeding costs (COST±) and market prices of weaned calves and breeding animals (REV±) by ± 20%

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ther changes in market price nor in management strategy led to a substantial variation in the relative economic importance of the evaluated traits.

In relation to the carcass traits, it should be mentioned that the recent excellent carcass quality of the AA breed makes the selection for carcass traits unnecessary (negative EW for increasing the fleshiness and fat covering classes). The improvement of calving performance during the last 13 years (a decrease of the average calving score from 2.6% to 1.0%) caused a decrease of the REW for calving performance from 10% (Wolfova et al. 2005b) to less than 2% (in the present study). Similarly, an improvement of the productive lifetime of cows, which has decreased the number of replacement heifers from 15.6 to 14.1 per 100 AA cows, lowered the REW of cow productive life from 16% to 8%. However, the REW of calf losses and cow conception rate were similar in both studies, at 11% and 3%, respectively.

Looking at the estimates of the economic importance of traits in other beef cattle populations, the traits daily gain, calving performance, and reproductive characteristics (represented mainly by calving interval) had the main economic priority [e.g. Albera et al. (2004)]. Keller et al. (2009) found cow conception rate to be the most important trait in Hungarian beef cattle herds, followed by weight gain of calves, cow weight, and cow productive lifetime. However, the excellent reproductive characteristics and the high productive life of cows in the Czech AA breed make these traits less important for selection, making growth traits the priority.

The low feeding costs due to an extensive pasture system in the Czech AA breed resulted in the relatively low economic importance of feed efficiency traits. In dairy cattle with intensive production systems and high feeding costs, the REW of RFI were estimated to be twice as high as for AA in the present study [comparing the REW of RFI estimated by Hietala et al. (2014) at 6%, or Krupova et al. (2018) at 8% with our study's results]. Of course, in countries where greenhouse and methane emissions result in higher costs for farmers, the improvement of RFI would also have higher economic importance for beef cattle (Arthur et al. 2004).

The current production and economic conditions of the AA breed were applied when calculating EW of traits in the present study. One may argue that breeding is done for the future and therefore predicted economic circumstances should be considered. Nevertheless, when applying the predicted production and economic conditions in dairy cattle (Krupova et al. 2018), the REW of traits remained almost the same, though the absolute EW of traits increased on average by 23%. Similarly, in our study variations in marketing strategies and in the production and economic parameters were mostly of negligible impact on the REW of traits. This implies the long-term stability of the REW of breeding and its validity for the future. Likewise, Albera et al. (2004) found the relative economic importance of traits in beef cattle quite insensitive to changes in product prices and costs. Wolfova et al. (2005b) stated that the highest impact on the REW of traits came from including or excluding governmental subsidies in the profit function. In spite of the substantial effect on the efficiency of the beef cattle production system, there are still uncertainties and discussions concerning the future existence and form of subsidies. In our study, high subsidies (€545 per cow per year) were included in the calculation of EW of traits. However, the program EWBC, which is part of the software package ECOWEIGHT (Wolf et al. 2013), allows an easy recalculation of the beef cattle EW of traits if the production, economic, or biological parameters change substantially in the populations of evaluated breeds in future.

CONCLUSION

Weight gain of calves was confirmed as the most important trait, accounting for about 66% of the overall economic importance of all evaluated traits in Czech AA breed. The productive lifetime of cows, with relative economic weight of 11%, is currently undergoing genetic evaluation and this trait is a potential selection criterion for the future. The survival of calves from birth until weaning, with relative economic weight of about 11%, is the next candidate trait for selection. The carcass traits had no economic importance in our calculation, which justifies the current exclusion of these traits from the selection criteria for the AA breed. The RFI, as a trait representing feed efficiency, has the low economic importance at present in extensive beef cattle production systems. Taking into account the high costs of RFI testing, the inclusion of RFI in selection criteria cannot yet be recommended for beef cattle. In future research, the EW of traits of the breeding objective calculated in this study, with the appropriate genetic parameters, will be further developed into a comprehensive economic selection index to reach the optimised selection response for AA traits.

Conflict of interest

The authors declare no conflict od interest.

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