Selection indexes for bulls of beef cattle

P. Šafus[1], J. Přibyl[1], Z. Veselá[1], L. Vostrý[1], M. Štípková[1], L. Stádník[2]

[1]Research Institute of Animal Production, Prague-Uhříněves, Czech Republic
[2]Czech University of Agriculture, Prague, Czech Republic

ABSTRACT: Three selection indexes were constructed for bulls of beef cattle: *IM* for terminal crossing (in dairy herds), *IZ* for the selection of foundation sires for beef herd and *IS* for the selection of bulls for beef herd. Each index was constructed in five variants that differed in the number of used traits from the most important ones to all traits with known breeding values. The sources of information were breeding values routinely calculated in performance testing – 10 breeding values for direct and maternal effects for easy calving and growth, breeding value for daily gain of bulls at performance-testing stations and 10 breeding values for the type traits of young animals. The reliability of partial breeding values that enter into the indexes ranged from 11% to 36%. Reliability influences subsequent accuracy of index selection for total genotype that is in the range of 30% to 46%. The discounting of economic values (0% or 10%) did not influence the selection indexes significantly. Index selection was expressed almost exclusively in genetic gain of direct effects while maternal effects were of only small importance in the breeding objective. Direct effects for daily gain until weaning and after weaning are of the highest importance in the breeding objective, accounting for 90% to 96% of the total selection effect. The most important information sources in selection indexes are direct effect of weaning weight (importance of approximately 74% to 95%) and maternal effect of weaning weight (importance of approximately 5% to 7%). The inclusion of daily gain of bulls at performance-testing stations with the importance of about 16% in the index decreased the importance of weaning weight. Selection can be aimed at these main traits – calving ease (direct and maternal effect) and weight at 210 days (direct and maternal effect) only because the importance of the other traits in the index is very low.

Keywords: beef cattle; bulls; genetic parameters; genetic gain; breeding values; breeding objective; selection indexes

Breeding work in a beef cattle herd involves breeding for fertility, growth and carcass traits. Genetic and economic parameters are input data for the construction of selection indexes. Breeding values of many traits that can be combined in a selection index are sources of information. Many authors studied the estimation and choice of input parameters and methods of selection index construction.

MacNeil et al. (1991) determined heritabilities and genetic correlations for post-weaning growth and feed intake. Gutiérrez et al. (2002) calculated genetic correlations between type traits, calving date, calving interval and age at first calving. Arango et al. (2002) determined genetic parameters and genetic correlations for weight, height at sacrum and body condition score (BCS) in crossbred cows of Aberdeen Angus and Hereford breeds. Genetic relationships between pre- and post-weaning traits of calves of the Aberdeen Angus breed (weight, visual evaluation of body conformation, muscle score and size) were investigated by Cardoso et al. (2004). Dodenhoff et al. (1998) determined genetic parameters for birth weight and weaning weight. Eriksson et al. (2004) estimated genetic correlations between calving difficulty and carcass traits for Charolais and Hereford cattle while Johnston and Bunter (1996) estimated genetic correlations for the days to calving and other traits.

Supported by the Ministry of Agriculture of the Czech Republic (Projects No. 0002701401 and No. QD 1234).

Relative economic weights for cow weight, bull and cow reproductive performance, calf survival, direct and maternal effect of weaning weight, average daily gain, feed conversion and dressing percentage were determined by MacNeil et al. (1994). Mwansa et al. (2002) calculated genetic parameters and economic weights for reproductive performance traits in cows of Hereford breed. Phocas and Sapa (2004) estimated genetic correlations between the traits of growth, reproductive performance and calving.

Methodology for the computation of relative importance of traits and for the construction of selection indexes was presented by Cunningham (1969, 1975). Brascamp (1984) reviewed the methods of index construction with different constraints.

Phocas et al. (1998) examined conditions in five basic production systems for beef cattle. The highest economic importance for further improvement was found out for the maternal effect of weaning weight and calving difficulty. Selection index for the population of crossbreds of beef breeds was constructed by Dickerson et al. (1974), who also determined genetic parameters and genetic response for the use of selection index compared to control groups. Herring et al. (1999) described the development of selection indexes for Aberdeen Angus breed.

The use of a bioeconomic model for the estimation of economic weights of traits in selection indexes was investigated by Brumatti et al. (2002). Reproductive performance was found to have the highest economic weight of all used traits.

Newman et al. (1992) constructed a selection index for beef cattle in New Zealand. They included traits used as selection criteria in the selection index – birth weight (direct and maternal effect), weaning weight (direct and maternal effect), and yearling weight, and slaughter weight, number of weaned calves per cow and scrotum circumference. The breeding objective was to increase the number of weaned calves per cow, to increase slaughter weight and to improve feed intake. The authors also studied the influence of leaving out some traits from the selection index on the breeding result. If feed intake was left out, genetic gain for growth and feed intake decreased. Leaving out the number of weaned calves from the index traits resulted in an 11% loss of efficiency; when the scrotum circumference was left out, the loss increased up to 15%, which confirms the importance of this trait for reproductive performance. Koch et al. (1994) compared three variants of selection of Hereford cattle according to yearling weight, weaning weight and according to the index combining yearling weight and muscle score. The highest genetic response in all traits was achieved by the use of selection index.

Xu et al. (1995) compared the economic returns of one-stage and multi-stage selection according to a different number of traits (3–5). Birth weight, gain from birth to 205 days and gain from 205 days to 365 days were included in selection indexes; further traits were thickness of subcutaneous fat or feed conversion. The highest gain was achieved by selection for three traits. The inclusion of feed conversion in total selection index decreased total genetic gain. Maximum genetic gain is achieved if one-stage selection by means of an index with all available data on all traits is used while multi-stage selection leads to a lower genetic gain compared to one-stage selection. Wilton and Goddard (1996) compared selection indexes with different weights of index traits according to management variants. Lin (1996) performed the optimisation of basic selection index expressed as linear combinations of breeding values of traits weighted by their economic values. The influence of adding further traits into the selection index on genetic and economic returns was studied by Sivanadian and Smith (1997), who made model calculations with a limited number of two to four standardised traits. The use of traits with high heritability and high standardised economic weight had the highest influence.

Hirooka and Sasaki (1998) constructed numerous variants of selection indexes with different economic weights of traits: maximum or minimum values of economic weights for meat marbling, eye-muscle area and depth, and subcutaneous fat thickness in beef cattle in Japan were used in the indexes. Correlations between these selection indexes were high although different traits were included in the indexes. In the course of three years the economic weight of meat marbling increased. Hirooka et al. (1998a) computed economic weights for growth and carcass traits in Japanese beef cattle using a bioeconomic model. Hirooka et al. (1998b) recommended considering husbandry conditions, production system and management variants for the computation of economic values. Hirooka and Groen (1999) determined the genetic response of beef cattle breeding according to a selection index. They also examined the effect of the use of different economic weights for birth, weaning and mature weight of animals, daily gain and meat marbling in the index. Different weights of traits for different husbandry conditions, production systems and management alternatives were used in the indexes. Wolfová et al. (2005a,b) developed a bioeconomic model for the use of beef bulls in various production systems. They also determined economic weights for 16 traits in three production systems and the bioeconomic model was applied in the Charolais breed.

Fürst-Waltl et al. (2002) applied a comprehensive deterministic approach to optimisation of breeding programmes for beef cattle. Different breeding strategies and different intensity of the use of bulls in natural mating and artificial insemination were simulated in a model population of cows composed of beef and dual-purpose cattle designed for crossing. Total selection index comprised meat performance traits (direct and maternal effect for birth weight and weight at 200 days, yearling weight, and average daily gain, dressing percentage and EUROP classification) and functional traits (calving difficulty, number of stillborn calves, reproductive performance and functional longevity).

Selection subindexes for calf quality, growth, calving and reproductive performance for all production types of cattle and a special index for calving ease and pregnancy length according to the production genotype were constructed by Amer et al. (2001), who also computed economic weights for the particular index traits. Dzama et al. (2001) carried out the simulation of selection programmes for beef cattle applying selection indexes.

Herd et al. (2003) examined the use of breeding values for feed intake in combination with growth traits in selection indexes. The combination of breeding values for feed intake after weaning and growth was found optimum. The authors stated that selection indexes were used on a small scale in the beef cattle industry. MacNeil (2003) reported that a positive genetic response was achieved by the selection index with breeding values for yearling weight and birth weight. Avedaño et al. (2003) constructed two selection indexes for the Angus breed. One index comprised slaughter weight, carcass conformation and fatness whereas meat and fat weight in carcass was substituted into the other index.

MATERIAL AND METHOD

Basic input data for the index construction are economic values and population genetic parameters of traits.

Table 1 summarises economic values according to the profit function (Wolf et al., 2004). All computations were made with adjusted inputs so that no part of production (e.g. fattening of heifers) would be loss-making after the inclusion of support. The computation was made for an interest rate of 10%.

The breeds of beef cattle differ in their frame, earliness, carcass composition and other traits. To simplify the solution to the problem we will use only single economic values for the mean of the

Table 1. Economic values according to the profit function

Trait	Economic value		Comparison with gain until weaning (%)	
	direct effect	maternal effect	direct effect	maternal effect
Calving ease	–98.70	–62.80	–12.10	–7.70
Calf losses at calving	–282.40	–282.40	–34.70	–34.70
Losses until weaning	–89.00	–118.60	–10.90	–14.60
Conception rate of heifers	14.00	15.60	1.70	1.90
Conception rate of cows	9.80	11.70	1.20	1.40
Cow longevity	697.80		85.80	
Birth weight	29.90	22.00	3.70	2.70
Gain until weaning	812.90	541.90	**100.00**	66.70
Post-weaning daily gain	2 123.30		261.20	
Cow weight at maturity	–29.80		–3.70	
Dressing percentage	441.50		54.30	
Meatiness	–233.10		–28.70	
Fatness	–13.40		–1.70	

breeds. As the traits show different variability, the comparison is based on the economic value for the genetic standard deviation of direct effect of daily gain until weaning corresponding to 100%.

Breeding values routinely calculated in performance testing were the source of information: 10 breeding values for direct and maternal effects for calving ease and growth (Přibyl et al., 2003), breeding value for daily gain of bulls at performance-testing stations (Přibylová et al., 2004) and 10 breeding values for the type of young animals (Veselá et al., 2005).

Economics and breeding aim are significantly influenced by the production system. Three basic production systems or their combinations are used in beef cattle: grazing system of purebred beef breeds or their crossbreds, commercial crossing in dairy herds and grazing system of crossbred heifers after bulls of beef breeds from dairy herds.

The selection of parents of the next generation is another factor influencing the breeding process. Producers' requirements may be different, and they can be divided into four groups.

1. Selection of the best dam – the producer requires excellent meat performance of their offspring that is influenced by the own growth abilities fifty percent of which the calf inherited after mother (1/2 of the breeding value for direct genetic effect of the dam BV_D) and by the dam's maternal abilities, both genetic (breeding value for maternal genetic effect of the dam BV_M) and non-genetic (effect of permanent maternal environment – *PE* effect) ones. The combination of values for direct and maternal effects and effect of environment expressed as an index is used for the selection of dams:
   Dam = $1/2BV_D + BV_M + PE$
2. Selection of the sire with the best meat performance of their offspring (e.g. for commercial crossing in dairy herds) – as we can consider only what the offspring will inherit after father (breeding value for direct genetic effect of the sire BV_D), the index for selection will be simple:
   Sire = $1/2BV_D$
3. Selection of the best parents of cows in beef herds – we select the parents that will produce daughters with good maternal traits and whose offspring will have excellent growth abilities. Direct and maternal effects are combined like in item (1) but without permanent maternal environment that is not inherited by the offspring.
   Parent of cows = $1/2BV_D + BV_M$
4. Selection of the sire for a herd of beef cattle (for the production of daughters for herd replacement and also for the production of slaughter calves) – a compromise satisfying items (2) and (3). The importance of direct and maternal effects is identical in this case.
   Sire in beef herd = $1/2BV_D + 1/2BV_M$

Obviously, the selection of animals for breeding may differ significantly according to the objective

Table 2. Marginal values of traits in Czech crowns (calculated per cow/year) and genetic standard deviations of traits

Trait	Unit	Marginal value (10%)	S_G direct	S_G maternal
Calving ease	class	–897.00	0.11	0.07
Calf losses at calving	%	–141.18	2.00	2.00
Losses until weaning		–148.26	0.60	0.80
Conception rate of heifers		3.11	4.50	5.00
Conception rate of cows		1.95	5.00	6.00
Cow longevity	year	1 395.51	0.50	
Birth weight	kg	17.57	1.70	1.25
Gain until weaning	10 g/day	67.74	12.00	8.00
Post-weaning daily gain		141.55	15.00	
Cow weight at maturity	kg	–0.93	32.00	
Dressing percentage	%	401.34	1.10	
Meatiness	0.01 of class	–15.54	15.00	
Fatness		–0.96	14.00	

S_G – genetic standard deviation

of herd improvement. The above-mentioned examples illustrate that also the breeds may differ from each other in the breeding objective according to the purpose they will be used for. The computation of the above indexes can be more accurate if economic instruments such as economic weights of traits, interest rate and inflation are considered.

Method of index construction

To construct a selection index weight coefficients (b) for breeding values of traits (BV) should be determined. Weight coefficients must be determined so that they will ensure as exact as possible prediction of total genotype. Selection index (I) is expressed as the combination of the breeding values of traits multiplied by the respective weight coefficients:

$$I = b_1 \times BV_1 + b_2 \times BV_2 + ... + b_n + BV_n$$

Total genotype is expressed by the sum

$$H = a_1 \times G_1 + a_2 \times G_2 + ... + a_m \times G_m$$

where: a = the economic values of traits in the breeding objective

G = the unknown genetic values of traits in the breeding objective

For the construction of indexes programmes in the IML/SAS environment were used that were based on programmes and methodical procedures applied in dairy cattle (Přibyl et al., 2004; Šafus et al., 2005, 2006). The adjustments of input data for the construction of selection indexes for beef cattle consisted in the exchange of traits and covariance matrices.

Table 2 shows marginal values for traits in the breeding objective and genetic standard deviations for direct and maternal effects.

In the present paper indexes for sires were constructed for the above-mentioned examples in items 2, 3 and 4.

IM = index for selection of sires for production of slaughter calves (index for terminal crossing in dairy herds)

Table 3. Traits in performance testing, standard deviations of breeding values (S_{BV}), genetic standard deviations (S_G) and their average coefficients of reliability (r^2)

Trait	Unit	S_{BV}	S_G	r^2	
				sires	animals with production
Calving ease, direct effect	scores	0.10	0.20	0.25	0.23
Birth weight, direct effect	kg	1.64	3.28	0.25	0.23
Weight at 120 days, direct effect		11.49	23.45	0.24	0.22
Weight at 210 days, direct effect		17.83	37.18	0.23	0.21
Weight at 365 days, direct effect		29.48	62.85	0.22	0.20
Calving ease, maternal effect	scores	0.05	0.14	0.13	0.09
Birth weight, maternal effect	kg	0.66	1.83	0.13	0.09
Weight at 120 days, maternal effect		5.26	15.18	0.12	0.08
Weight at 210 days, maternal effect		7.46	22.49	0.11	0.07
Weight at 365 days, maternal effect		6.51	19.63	0.11	0.07
Gain at testing stations	g/day	90.00	190.00	0.23	0.21
Height at sacrum	scores	0.72	1.23	0.34	0.32
Body length		0.19	0.39	0.24	0.22
Live weight		0.85	1.53	0.31	0.29
Front chest width		0.23	0.42	0.30	0.28
Chest depth		0.24	0.46	0.27	0.25
Rump length and width		0.27	0.45	0.36	0.34
Shoulder muscling		0.25	0.44	0.32	0.30
Back muscling		0.23	0.39	0.34	0.32
Rump muscling		0.30	0.51	0.35	0.33
Production type		0.29	0.51	0.32	0.30

IZ = index for selection of sires – foundation bulls of beef herd
IS = index for selection of sires for beef herds

Several variants were considered for each index according to the amount of data gradually coming from performance testing. In the groups of mutually correlated traits (in the framework of one computation of breeding value) only the most important ones were selected. These effects were substituted into selection indexes according to data sources:

m1 = direct and maternal effects for calving ease and weaning weight
m2 = direct and maternal effects for calving ease, birth weight and weaning weight
m3 = direct and maternal effects for calving ease, birth weight and weaning weight. From the group of type traits production type that is highly correlated with muscling traits was included
m4 = direct and maternal effects for calving ease, birth weight and weaning weight, production type and daily gain of bulls at performance-testing stations
m5 = all traits with known breeding values

Breeding values were calculated jointly by a multi-trait animal model for separated groups of traits. It means that within the group of traits mutual (genetic and environmental) correlations were already used to determine the breeding value of each trait. Applying the above-mentioned breeding values it is possible to construct subindexes for breeding for calving ease, growth abilities and in a part of the animals, especially in sires that underwent progeny testing, for muscling. Reproductive performance and animal losses have not been considered in selection index yet because suitable sources of data from domestic performance testing are missing and correlations are known from literary sources only.

Table 3 shows standard deviations of breeding values, genetic standard deviations and average reliabilities of breeding values for sires and individuals with own performance. Reliabilities were derived by simulation calculations (Veselá et al., 2004, 2005) while the amounts of data for individual animals were taken into account. Reliabilities are relatively low, which is connected with the number of performances per individual, number of descendants as well as with the number of unrelated contemporaries in herds. To facilitate the construction of indexes genetic standard deviations are adjusted so as to correspond to standard deviations of breeding values and reliabilities of the estimation of breeding values of sires ($r^2 = s^2_{BV}/s^2_G$).

RESULTS AND DISCUSSION

Discounting resulted in a decrease in the values of those traits that would be expressed on the animals later after some time. Discounting is very im-

Table 4. Accuracy of indexes (*r*), proportion of genetic gains in monetary terms for direct and maternal effects and genetic gain for gain until weaning

Index	*r* (%)	Proportion Δ_G direct:maternal	Δ_G direct effect (g/day)	Δ_G maternal effect (g/day)
IS m1	30	99.07:0.93	56.0	0.9
IS m2	30	99.19:0.81	55.2	0.7
IS m3	30	99.19:0.81	55.0	0.7
IS m4	32	101.15:–1.15	51.3	–1.6
IS m5	46	99.71:0.71	34.3	1.0
IZ m1	30	8 8.71:11.23	51.8	6.6
IZ m2	30	89.10:10.90	51.1	6.4
IZ m3	30	89.18:10.82	50.8	6.4
IZ m4	32	93.18:6.82	48.4	4.2
IZ m5	45	94.07:5.93	32.1	5.2
IM m1	30		57.5	–5.0
IM m2	31		56.8	–5.2
IM m3	31	100:0	56.5	–5.1
IM m4	33		51.8	–7.3
IM m5	46		35.8	–3.2

portant for the comparison of direct and maternal effects because direct effects are mostly expressed on animals sooner than maternal effects. The total discounting factor for direct and maternal effects is at a ratio of 1:0.58 for the chosen interest rate. Economic values shown in Table 2 can be multiplied by these coefficients.

As the traits have different variability, the economic value for genetic standard deviation of direct effect of daily gain until weaning is used as the comparison base representing 100%.

According to such a comparison the most important trait is daily gain after weaning (261%), followed by daily gain until weaning (100%). The values are connected with the length of the period in which the daily gain is expressed on the animal – from birth to weaning and daily gain after weaning by the end of fattening or by the end of rearing (longer period). Earliness is also "hidden" in this trait, which is expressed by a higher proportion of heifers that can calve at the age of two years. Longevity of cows (85.8%) is another important trait among direct effects, followed by dressing percentage (54.3%). The other traits are less important with respect to the given units. It is to note that a higher class for fleshiness and calving ease implies the worsening of the trait; therefore these economic values have negative signs. Maternal effects are given only in those traits where their more significant influence is expected. In general, the effect of maternal effects is lower than in direct effects.

In total, 15 variants of selection indexes were developed. Summarised data on the exactness of indexes and breeding impacts on direct and maternal effects is given in Table 4. The table also shows genetic gains for direct and maternal effect of daily gain until weaning.

With a reduction in the number of information traits included in indexes the exactness of indexes decreases from 46% in the variants of m5 indexes to 30% in m1 variants. There are no larger differences between *IS*, *IZ* and *IM* indexes. In all indexes direct effects are dominant in the total effect of selection while the effect of selection for maternal effects is several times lower regardless of the type of index and amount of the index information. Maternal effects in *IZ* index account for approximately 1/9 of the value of direct effects. In *IM* index the ratio of the effect of selection for direct and maternal effects is 100:0 because in this case the breeding aim

Table 5. Expected genetic gain for unit selection intensity (all *IS* variants)

Trait	Unit	m1	m2	m3	m4	m5
Calving ease, direct effect	class	0.01	0.01	0.01	0.01	0.01
Calving ease, maternal effect		–0.04	–0.00	–0.00	–0.00	–0.00
Calf losses at calving, direct effect	%	–0.01	0.03	0.03	–0.00	–0.07
Calf losses at calving, maternal effect		–0.14	–0.10	–0.10	–0.11	–0.15
Losses until weaning, direct effect		–0.01	–0.02	–0.02	–0.03	–0.00
Losses until weaning, maternal effect		–0.01	–0.01	–0.01	–0.00	–0.02
Heifer conception rate, direct effect		0.08	0.07	0.08	0.10	0.10
Heifer conception rate, maternal effect		–0.08	–0.09	–0.08	–0.11	–0.02
Cow conception rate, direct effect		0.09	0.08	0.09	0.16	0.11
Cow conception rate, maternal effect		–0.10	–0.10	–0.09	–0.13	–0.03
Cow longevity	year	–0.01	–0.01	–0.01	–0.01	0.01
Birth weight, direct effect	kg	0.36	0.43	0.43	0.40	0.27
Birth weight, maternal effect		–0.09	–0.08	–0.08	–0.10	–0.04
Gain until weaning, direct effect	10 g/day	5.60	5.52	5.50	5.13	3.43
Gain until weaning, maternal effect		0.09	0.07	0.07	–0.16	0.10
Post-weaning daily gain		2.75	2.87	2.85	3.49	6.43
Cow weight at maturity	kg	1.34	2.02	2.35	2.93	–1.35
Dressing percentage	%	0.05	0.04	0.05	0.06	0.13
Meatiness	0.01 of class	–0.72	–0.07	–0.99	–1.09	–2.26
Fatness		–0.32	–0.28	–0.32	–0.51	–0.63

applies to direct effects only. In *IS* index a slight deterioration of the influence of some maternal effects was observed.

Genetic gains for the important trait direct effect of daily gain until weaning are almost identical in all indexes, regardless of the type of index and amount of the index information. In maternal effects this trait is maintained at the present level if *IS* index is used; *IZ* index brings about an improvement of maternal effects but genetic gain is 1/10 of the genetic gain for direct effect. *IM* index indicates deterioration, approximately to –10% compared to direct effect.

These results are connected with lower variability of breeding values and lower economic importance of maternal effects although the above-mentioned discounting factor for direct and maternal effects was not applied at a 1:0.58 ratio, but at a 1:1 ratio, corresponding to the situation without interests. These results are also influenced by the fact that direct and maternal effects are correlated negatively.

More detailed descriptions of the indexes are given below.

IS index

Table 5 shows expected genetic gains for *IS* indexes in unit selection intensity. Genetic gains are given also for the traits that were not included in the breeding objective (animal losses, conception rate, and longevity). No sources of information for direct selection are known for these traits and selection effect is determined only indirectly, from their correlations with the other traits. These correlations are not known sufficiently; therefore the estimated value zero was substituted, which influenced the results.

Similar results are obtained in all variants of indexes regardless of the amount of index information. As documented by data, given the units of traits genetic gains are more significant in direct effect of daily gain until weaning and daily gain after weaning.

Except for the variants of m5, the mature weight of cows increases in the remaining cases. Genetic gain for direct effect of daily gain until weaning is lower (343 g/day) in comparison with simpler indexes and the genetic gain for daily gain after

Table 6. Importance of traits in total genotype in % of the total value in monetary terms according to all variants for index *IS*

Trait	m1	m2	m3	m4	m5
Calving ease, direct effect	–1.20	–1.20	–1.19	–1.03	–0.49
Calving ease, maternal effect	0.40	0.40	0.39	0.34	0.20
Calf losses at calving, direct effect	0.17	–0.54	–0.47	0.03	0.79
Calf losses at calving, maternal effect	2.50	1.71	1.74	1.81	1.72
Losses until weaning, direct effect	0.27	0.32	0.29	0.59	0.02
Losses until weaning, maternal effect	0.11	0.17	0.21	0.08	0.23
Heifer conception rate, direct effect	0.03	0.03	0.03	0.04	0.03
Heifer conception rate, maternal effect	–0.03	–0.03	–0.03	–0.04	–0.01
Cow conception rate, direct effect	0.02	0.02	0.02	0.03	0.02
Cow conception rate, maternal effect	–0.02	–0.02	–0.02	–0.03	0
Cow longevity	–1.45	–1.49	–1.30	–1.59	0.60
Birth weight, direct effect	0.78	0.94	0.93	0.81	0.39
Birth weight, maternal effect	–0.21	–0.17	–0.16	–0.20	–0.05
Gain until weaning, direct effect	47.18	46.12	45.68	39.93	18.74
Gain until weaning, maternal effect	0.74	0.58	0.58	–1.28	0.56
Post-weaning daily gain	48.37	50.10	49.55	56.85	73.43
Cow weight at maturity	–0.16	–0.23	–0.27	–0.31	0.10
Dressing percentage	2.65	2.16	2.56	2.89	4.24
Meatiness	1.40	1.28	1.90	1.96	2.84
Fatness	0.04	0.03	0.04	0.06	0.05

weaning is higher (643 g/day), which is connected with the weight coefficients in the index.

All index variants show a slight improvement of carcass value (a decrease in the classes of fleshiness and fatness and an increase in dressing percentage).

Table 6 documents % importance of traits in total genotype according to *IS* variants. It illustrates the proportions of traits in total economic profit of selection according to the indexes that are connected with achieved genetic gains. In animal losses, conception rate and longevity the result is influenced by insufficient correlations with the other traits. Of importance is only direct effect of daily gain until weaning (18.74–47.18%), daily gain after weaning (48.37–73.43%) and partly dressing percentage (2.16–4.24%) and fleshiness (1.28–2.84%). The other traits in the breeding objective are not important. An increase in the number of traits included into indexes (from index m1 to index m5) leads to a decrease in the importance of daily gain until weaning but the importance of daily gain after weaning increases. An increase in importance in relation to the increasing number of index traits is evident also in fleshiness. The total importance of carcass value is 3.47–7.13% although its proportion in the variability of total genotype (breeding objective) is approximately 10%.

Preceding Table 4 summarises the proportions of economic profits for direct and maternal effects for all index variants.

Breeding values of traits are combined in indexes. The importance of traits in the index is shown in Table 7. It expresses a change in the total effect of selection as % of the money amount when the given trait is left out from the selection index, i.e. from performance testing.

In indexes m1–m3 only the breeding values for direct effect of weight at 210 days (88.31–94.09%) and maternal effect of this weight (5.64–7.73%) are important in the selection index. In index m4, where in addition the breeding value of gain at performance-testing stations is included, the importance of this trait is 15.71%, and on the contrary, the importance of the breeding value for direct effect of weight at 210 days decreased to 73.98%. The importance of maternal effect for weight at 210 days is 7.34% in this index.

In index m5, which contains all traits in performance testing, the breeding value of direct effect for yearling weight was significantly expressed to the

Table 7. Importance of traits in the index for all *IS* variants (in %)

Trait	m1	m2	m3	m4	m5
Calving ease, direct effect	0.00	0.16	0.19	0.29	0.00
Birth weight, direct effect		1.42	1.46	1.23	0.29
Weight at 120 days, direct effect					0.05
Weight at 210 days, direct effect	94.09	89.42	88.31	73.98	10.14
Weight at 365 days, direct effect					76.31
Calving ease, maternal effect	0.27	0.69	0.71	0.58	0.04
Birth weight, maternal effect		0.55	0.54	0.05	0.11
Weight at 120 days, maternal effect					0.02
Weight at 210 days, maternal effect	5.64	7.77	7.72	7.34	0.03
Weight at 365 days, maternal effect					2.48
Gain at testing stations				15.71	0.77
Height at sacrum					0.10
Body length					0.01
Live weight					–0.77
Front chest width					0.67
Chest depth					0.32
Rump length and width					6.06
Shoulder muscling					0.16
Back muscling					0.00
Rump muscling					3.30
Production type			1.05	0.82	–0.08

Table 8. Weight coefficients of breeding values in all *IS* variants converted into standard deviation of breeding value

Trait	m1	m2	m3	m4	m5
Calving ease, direct effect	–0.03	–3.33	–3.42	–3.55	0.36
Birth weight, direct effect		11.20	10.53	8.14	–4.73
Weight at 120 days, direct effect					2.81
Weight at 210 days, direct effect	81.00	70.96	66.28	53.59	–50.44
Weight at 365 days, direct effect					132.46
Calving ease, maternal effect	–5.24	–6.57	–6.20	–4.72	–1.50
Birth weight, maternal effect		6.24	5.77	1.58	2.72
Weight at 120 days, maternal effect					2.04
Weight at 210 days, maternal effect	24.27	21.50	19.89	16.38	2.80
Weight at 365 days, maternal effect					17.35
Gain at testing stations				23.26	–6.98
Height at sacrum					3.30
Body length					1.39
Live weight					–3.93
Front chest width					16.74
Chest depth					–7.92
Rump length and width					–61.74
Shoulder muscling					9.59
Back muscling					–0.23
Rump muscling					49.64
Production type			7.16	5.34	–3.75

detriment of the other traits (76.31%). Except for weaning weight, rump length and width and rump muscling the index importance of the other traits (information sources) is very low.

Table 8 shows the weight coefficients of breeding values in indexes. The values in the table are percentages weights converted into standard deviation of breeding value of the given trait in relation to the total sum of all index traits. These weights are connected with the importance of traits in a preceding table. The improbable opposite values for direct effect of weight at 210 days (–50.44) and yearling weight (137.46) in index m5 result from different correlations. Similarly, back muscling has a negative, even though low value (–0.23) contrary to positive values for shoulder muscling (9.59) and rump muscling (49.64). For these reasons simpler variants of indexes containing only basic traits were used.

IZ and *IM* indexes

As differences between the variants of the three basic selection indexes are small, only variants m1 will be described in greater detail for the other indexes *IZ* and *IM*.

Table 9 shows expected genetic gains at unit selection intensity. Compared to index *IS* the changes were negligible. The change of economic values for maternal effects in *IZ* to the double of *IS* index influenced the selection result to a small extent. Indexes *IM* and *IS* were very similar, but losses of maternal effects were incurred. Genetic gains in direct effects are similar to those in *IS* index.

Table 10 illustrates the importance of traits in total genotype in % for the particular indexes. Like in genetic gains the value of the traits in breeding objective is similar like in *IS* index, with a very slight increase in maternal effects of daily gain until weaning to the value 10.76% for *IZ* index. As selection was aimed only at direct effects in *IM* index, the importance of all maternal effects at selection was zero. The other traits behaved like in preceding indexes.

Table 11 documents the importance of the traits in indexes. Index *IZ* is different from *IM* index in the importance of direct effect of weight at 210 days. The importance of maternal effect of weight at

Table 9. Expected genetic gain for unit selection intensity for selection indexes (variant ml)

Trait	Unit	*IS*	*IZ*	*IM*
Calving ease, direct effect	class	0.01	0.01	0.01
Calving ease, maternal effect		–0.04	–0.00	–0.00
Calf losses at calving, direct effect	%	–0.01	–0.01	–0.01
Calf losses at calving, maternal effect		–0.14	–0.15	–0.12
Losses until weaning, direct effect		–0.01	–0.01	–0.01
Losses until weaning, maternal effect		–0.01	–0.01	–0.00
Heifer conception rate, direct effect		0.08	0.00	0.08
Heifer conception rate, maternal effect		–0.08	–0.08	–0.09
Cow conception rate, direct effect		0.09	0.09	0.09
Cow conception rate, maternal effect		–0.10	–0.09	–0.11
Cow longevity	year	–0.01	–0.01	–0.01
Birth weight, direct effect	kg	0.36	0.32	0.38
Birth weight, maternal effect		–0.09	–0.07	–0.11
Gain until weaning, direct effect	10 g/day	5.60	5.18	5.76
Gain until weaning, maternal effect		0.09	0.66	–0.50
Post-weaning daily gain		2.75	2.55	2.82
Cow weight at maturity	kg	1.34	1.19	1.43
Dressing percentage	%	0.05	0.05	0.05
Meatiness	0.01of class	–0.72	–0.69	–0.72
Fatness		–0.32	–0.30	–0.33

Table 10. Importance of traits in total genotype (in %) for particular indexes (variant ml)

Trait	*IS*	*IZ*	*IM*
Calving ease, direct effect	–1.20	–0.99	–1.29
Calving ease, maternal effect	0.40	0.77	0.00
Calf losses at calving, direct effect	0.17	0.10	0.23
Calf losses at calving, maternal effect	2.50	5.25	0.00
Losses until weaning, direct effect	0.27	0.25	0.26
Losses until weaning, maternal effect	0.11	0.33	0.00
Heifer conception rate, direct effect	0.03	0.03	0.03
Heifer conception rate, maternal effect	–0.03	–0.06	0.00
Cow conception rate, direct effect	0.02	0.02	0.02
Cow conception rate, maternal effect	–0.02	–0.04	0.00
Cow longevity	–1.45	–1.22	–1.54
Birth weight, direct effect	0.78	0.68	0.81
Birth weight, maternal effect	–0.21	–0.30	0.00
Gain until weaning, direct effect	47.18	42.14	47.76
Gain until weaning, maternal effect	0.74	10.76	0.00
Post-weaning daily gain	48.37	43.33	48.84
Cow weight at maturity	–0.16	–0.13	–0.16
Dressing percentage	2.65	2.42	2.62
Meatiness	1.40	1.28	1.38
Fatness	0.04	0.03	0.04

Table 11. The importance of traits in selection index (%) and relative weights of traits in indexes for standard deviation of breeding values (m1 variant)

Trait	*IS*		*IZ*		*IM*	
	IT	*WC*	*IT*	*WC*	*IT*	*WC*
Calving ease, direct effect	0.00	–0.03	0.00	–0.43	0.00	0.49
Weight at 210 days, direct effect	94.09	81.00	81.75	70.04	99.52	95.47
Calving ease, maternal effect	0.27	–5.24	0.55	–6.65	0.08	–3.37
Weight at 210 days, maternal effect	5.64	24.27	17.70	37.05	0.39	7.41

IT – importance of the traits in index
WC – weight coefficients of breeding values in index converted to standard deviation

210 days increased approximately three times in *IZ* compared to *IS* index, nevertheless its importance is small in comparison with direct effects. The other values are similar in all indexes.

Table 11 also shows the weight coefficients of breeding values in indexes converted to standard deviations. The results are similar like in *IS* index. In *IM* index weights for direct effects for weaning weight increased to some extent while weights for maternal effects decreased. But the index is very similar to preceding indexes *IS* and *IZ*.

CONCLUSION

The result of selection according to selection indexes was almost exclusively genetic gain in direct effects regardless of the type of index and the amount of index information. Discounting had a minimum influence on selection indexes.

The highest importance in the breeding objective was found in direct effect of daily gain until weaning and after weaning (45% and 50%, respectively). Dressing percentage and fleshiness were of lower importance. In connection with the existing organisation of performance testing, estimated breeding values and calculated economic values of traits the importance of the other traits appears very low in beef cattle breeding. The economics of herds designed for export may be distorted due to temporarily favourable prices and we need not be interested in traits that are connected with carcass quality in produced animals. However, in future it may lead to the deterioration of carcass traits, subsequently to lower demand and finally to non-merchantability of animals. This is the reason why the whole system including animal fattening should be considered in the breeding process.

Breeding values are determined by a multi-trait animal model where correlations between traits are applied. Each trait improves the accuracy of all other traits. As the number of evaluated animals decreases with increasing age, only the index with live weight at weaning can be recommended as a selection criterion. Response will be also for correlated traits. Direct and maternal effects are in negative correlations, so maternal effect should also be used or economic values should be adjusted for their use in indexes by the coefficient 0.58.

Based on our results we recommend to use simpler indexes combining only basic traits.

REFERENCES

Amer P.R., Simm G., Keane M.G., Diskin M.G., Wickham B.W. (2001): Breeding objectives for beef cattle in Ireland. Livest. Prod. Sci., *67*, 223–239.

Arango J.A., Cundiff L.V., Van Vleck L.D. (2002): Genetic parameters for weight, weight adjusted for body condition score, height, and body condition score in beef cows. J. Anim. Sci., *80*, 3112–3122.

Avendaño S., Villanueva B., Woolliams J.A. (2003): Expected increases in genetic merit from using optimized contributions in two livestock populations of beef cattle and sheep. J. Anim. Sci., *81*, 2964–2975.

Brascamp E.W. (1984): Selection indices with constraints. Anim. Breed., *52* (Abstr.), 645–654.

Brumatti R.C., Ferraz J.B.S., Formigoni I.B., Eler J.P. (2002): Application of a bio-economical model to estimate economical weights for traits used in selection index in beef cattle. In: Proc. 7th World Congress on Genetics Applied to Livestock Production, August 19.–23. 2002, Montpellier, France.

Cardoso F.F., Cardellino R.A., Campos L.T. (2004): (Co)variance components and genetic parameters of post-weaning traits in Angus cattle. Rev. Bras. Zootechnol., *33*, 313–319.

Cunningham E.P. (1969): The relative efficiency of selection indexes. Acta Agric. Scand., *19*, 45–48.

Cunningham E.P. (1975): Multistage index selection. Theor. Appl. Genet., *46*, 55–61.

Dickerson G.E., Künzi N., Cundiff L.V., Koch R.M., Arthaud V.H., Gregory K.E. (1974): Selection criteria for efficient beef production. J. Anim. Sci., *39*, 659–673.

Dodenhoff J., Van Vleck L.D., Kachman S.D., Koch R.M. (1998): Parameter estimates for direct, maternal and grandmaternal genetic effects for birth weight and weaning weight in Hereford cattle. J. Anim. Sci., *76*, 2521–2527.

Dzama K., Walter J.P., Ruvuna F., Sanders J.O., Chimonyo M. (2001): Index selection of beef cattle for growth and milk production using computer simulation modelling. S. Afr. J. Anim. Sci., *31*, 65–75.

Eriksson S., Nasholm A., Johansson K., Philipsson J. (2004): Genetic relationship between calving and carcass traits for Charolais and Hereford cattle in Sweden. J. Anim. Sci., *82*, 2269–2276.

Fürst-Waltl B., Willam A., Sölkner J. (2002): Optimization of a specialized beef breeding program with a crossbreeding component. Arch. Tierz., *45*, 433–441.

Gutiérrez J.P., Alvarez I., Fernández I., Royo L.J., Diez J., Goyache F. (2002): Genetic relationships between calving date, calving interval, age at first calving and type traits in beef cattle. Livest. Prod. Sci., *78*, 215–222.

Herd R.M., Archer J.A., Arthur P.F. (2003): Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci., *81*, E9–E17.

Herring W.O., Pierce V., MacNeil M.D., Kaiser C.J., Benyshek L.L. (1999): Development of a generalized selection index for profit in Angus sires. UMC Animal Sciences Departmental Report, 30–34.

Hirooka H., Sasaki Y. (1998): Derivation of economic weights for carcass traits in Japanese Black cattle from field records. J. Anim. Breed. Genet., *115*, 27–37.

Hirooka H., Groen A.B. (1999): Effect of production circumstances on expected responses for growth and carcass traits to selection of bulls in Japan. J. Anim. Sci., *77*, 1135–1143.

Hirooka H., Groen A.B., Hillers J. (1998a): Developing breeding objectives for beef cattle production, I. Bioeconomic model. Anim. Sci., *66*, 607–621.

Hirooka H., Groen A.B., Hillers J. (1998b): Developing breeding objectives for beef cattle production, II. Biological and economic values of growth and carcass traits in Japan. Anim. Sci., *66*, 623-633.

Johnston D.J., Bunter K.L. (1996): Days to calving in Angus cattle: Genetic and environmental effects, and covariances with other traits. Livest. Prod. Sci., *45*, 13–22.

Koch, R.M., Cundiff L.V., Gregory K.E. (1994): Cumulative selection and genetic change for weaning or yearling weight or for yearling weight plus muscle score in Hereford cattle. J. Anim. Sci., *72*, 864–885.

Lin C.Y. (1996): Technical note: Optimization of breed composition to maximize net merit of synthetic populations. J. Anim. Sci., *74*, 1477–1480.

MacNeil M.D. (2003): Genetic evaluation of an index of birth weight and yearling weight to improve efficiency of beef production. J. Anim. Sci., *81*, 2425–2433.

MacNeil M.D., Bailey D.R.C., Urick J.J., Gilbert R.P., Reynolds W.L. (1991): Heritabilities and genetic correlations for postweaning growth and feed intake of beef bulls and steers. J. Anim. Sci., *69*, 3183–3189.

MacNeil M.D., Newman S., Enns R.M., Stewartsmith J. (1994): Relative economic values for Canadian beef production using specialized sire and dam lines. Can. J. Anim. Sci., *74*, 411–417.

Mwansa P.B., Crews D.H., Wilton J.W. (2002): Multiple trait selection for maternal productivity in beef cattle. J. Anim. Breed. Genet., *119*, 391–399.

Newman S., Morris C.A., Baker R.L., Nicoll G.B. (1992): Genetic improvement of beef cattle in New Zealand – Breeding objectives. Livest. Prod. Sci., *32*, 111–130.

Phocas F., Sapa J. (2004): Genetic parameters for growth, reproductive performance, calving ease and suckling performance. Anim. Sci., *79*, 41–48.

Phocas F., Bloch C., Chapelle P., Becherel F., Renand G., Menissier F. (1998): Developing a breeding objective for a French purebred beef cattle selection programme. Livest. Prod. Sci., *57*, 49–65.

Přibyl J., Misztal I., Přibylová J., Šeba K. (2003): Multiple-breed, multiple-traits evaluation of beef cattle in the Czech Republic. Czech J. Anim. Sci., *48*, 519–532.

Přibyl J., Šafus P., Štípková M., Stádník L., Čermák V. (2004): Selection index for bulls of Holstein cattle in the Czech Republic. Czech J. Anim. Sci., *49*, 244–256.

Přibylová J., Vostrý L., Veselá Z., Přibyl J., Bohmanová J. (2004): Breeding value for own growth of beef bulls in performance-test station. XXI. Genetic Days. In: Proc. Int. Scientific Conference, 1.–3. September, Wroclaw, Poland. Anim. Sci. Pap. Rep., *22*, 97–103.

Sivanadian B., Smith C. (1997): The effect of adding further traits in index selection. J. Anim. Sci., *75*, 2016–2023.

Šafus P., Štípková M., Stádník L., Přibyl J., Čermák V. (2005): Sub-indexes for bulls of Holstein breed in the Czech Republic. Czech J. Anim. Sci., *50*, 254–265.

Šafus P., Štípková M., Stádník L., Přibyl J., Kučera J. (2006): Selection index for bulls of Czech Fleckvieh cattle in the Czech Republic. Czech J. Anim. Sci., (in press).

Veselá Z., Přibyl J., Vostrý L., Štolc L. (2004): Effect of sire referencing scheme on reliability of the breeding value estimation in beef cattle. XXI. Genetic Days. In: Proc. Int. Scientific Conference, 1.–3. September, Wroclaw, Poland. Anim. Sci. Pap. Rep., *22*, 151–157.

Veselá Z., Přibyl J., Šafus P., Vostrý L., Šeba K., Štolc L. (2005): Breeding value for type traits in beef cattle in the Czech Republic. Czech J. Anim. Sci., *50*, 385–393.

Wilton J.W., Goddard M.E. (1996): Selection for carcass and feedlot traits considering alternative slaughter end points and optimized management. J. Anim. Sci., *74*, 37–45.

Wolf J., Wolfová M., Krupa E., Peškovičová D. (2004): Ecoweight– a C program for modelling the economic efficiency of cattle production systems. In: Proc. 55th Annual Meeting of the EAAP, Bled, Slovenia, September 5.–9., Book of Abstract No. 10. Wageningen Acad. Publ., 64.

Wolfová M., Wolf J., Přibyl J., Zahrádková R., Kica J. (2005a): Breeding objectives for beef cattle used in different production systems. 1. Model development. Livest. Prod. Sci., *95*, 201–215.

Wolfová M., Wolf J., Zahrádková R., Přibyl J., Daňo J., Krupa E., Kica J. (2005b): Breeding objectives for beef cattle used in different production systems. 2. Model application to production systems with the Charolais breed. Livest. Prod. Sci., *95*, 217–230.

Xu S., Martin T.G., Muir W.M. (1995): Multistage selection for maximum economic return with an application to beef cattle breeding. J. Anim. Sci., *73*, 699–710.

Received: 2005–12–07
Accepted after correction: 2006–02–09

Corresponding Author

Ing. Petr Šafus, Ph.D., Research Institute of Animal Production, Přátelství 815, P.O. Box 1, 104 01 Prague-Uhříněves, Czech Republic
Tel. +420 267 009 664, e-mail: safus.petr@vuzv.cz