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Value of traits in beef cattle breeding*

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Abstract

An index has been devised for the selection of bulls in beef breeds. The overall breeding objective was to improve direct and maternal effects on the ease of calving, growth and carcass value. Correlated indirect responses of selection were also examined in calf losses, fertility and cow longevity. The sources of information used were breeding values that are currently calculated in a routine way in the Czech Republic – direct and maternal effects for calving ease and growth (10 breeding values), breeding value for daily gain of bulls at performance-test stations (1 breeding value) and breeding values for the type traits of young animals (10 breeding values). Five indexes were constructed according to the number of information traits included. Economic values of traits in the breeding objective were calculated using discounting rates of 10% and 0%. The accuracy of selection according to indexes for aggregate genotype ranges from 30 to 46%. The discounts of economic values used did not influence selection indexes. Selection according to indexes was almost exclusively reflected in genetic gain of direct effects. In the breeding objective direct effects on the daily gains until weaning and after weaning are of the greatest importance, together accounting for 90 – 96% of the total effect of selection. The most important information sources in selection indexes were direct effect of weight at weaning (importance about 74 – 95%) and maternal effect of weight at weaning (importance about 5 – 7%). The importance of weight at weaning was decreased by including daily gains of bulls at performance-test stations. The importance of the other traits comprising the indexes is very low.

Keywords: selection index, beef cattle, bulls, genetic gain, importance of traits, breeding values, breeding objective, correlations

Introduction

The optimal breeding of beef cattle is a complex problem involving questions of fertility, animal growth and carcass value. Genetic and economic parameters are input data for breeding. Sources of information, the breeding values of different traits, are combined into a summary criterion, known as the selection index. A number of authors have analysed input parameters for index construction and the ways, they are used in practice.

MacNeil et al. (1991) calculated heritability and genetic correlations for growth after weaning and food intake for beef cattle. Gutierrez et al. (2002) determined genetic correlations between type traits and calving date, calving interval and age at first calving. Phocas et al. (1998) found the factors of highest economic importance to be the maternal effect of weight at weaning and calving difficulty.

Amer et al. (2001) calculated economic values for selection subindexes for calf quality, growth, calving and fertility in dairy and beef cattle. Brumatti et al. (2002) used a bioeconomic model for the estimation of economic weights of traits used in selection indexes for beef cattle. These authors pointed out the higher importance of fertility traits compared to growth traits in selection index. Thus, we see that selection criteria, including indexes, are constantly undergoing development in response to changing conditions of production and economic conditions.

Xu et al. (1995) investigated possibilities of updating selection indexes for beef cattle. Sivanadian and Smith (1997) studied the effect of including further traits in the selection

indexes for beef cattle. Herring et al. (1999) described the development of a selection index for the Aberdeen Angus breed. Hirooka and Groen (1999) devised a selection index for beef cattle in Japan. They tested the effect of using various economic values of traits included in the index – weight at birth, weaning and maturity; daily gain and meat marbling – in different husbandry conditions and alternatives of management. The simulation of selection programme using selection index for growth in beef cattle was carried out by Dzama et al. (2001). Possibilities of improvement of meat performance production by the application of a selection index for weight at birth and at one year of age were examined by MacNeil (2003).

Objective of the study

Because many traits are monitored and evaluated, it is necessary to determine their importance both in aggregate genotype (breeding objective) and in performance testing. The relative importance of each trait can be assigned using the selection indices procedure.

Traits with breeding value

Currently, in the Czech Republic, breeding values are determined for three groups of traits.

A. Field test – calving ease, weight at birth, at 120, 210 and 365 days of age. A multi-trait animal model involving maternal effects is used (Přibyl et al., 2003).

B. Performance-test stations of bulls – daily gain in test. A single-trait animal model is used (Vostrý et al., 2004).

C. Type of young animals – ten traits describing the stature, conformation and muscling of young animals aged from 200 to 350 days. A multi-trait animal model is used (Veselá et al., 2005).

Input data

Table 1 shows marginal economic values of traits in the breeding objective computed using the ECOWEIGHT programme (Wolfová et al., 2005), using discounting rates for revenues and costs of 0 and 10%. Taking into account the interest rate, the economic values of all maternal traits were adjusted by the coefficient 0.58 for subsequent computations. This value indicates the ratio of "cumulative expressions" of maternal and direct effects on traits over a 25-year period at a discount rate of 10%. Table 1 also shows genetic standard deviations of direct and maternal effects.

Tab. 1 Marginal values of traits in Czech crown (calculated per cow/year) and genetic standard deviations of traits (* Traits included in aggregate genotype of indexes)

	Trait	Unit	Marginal value		S_G	
			0 %	10 %	Direct	Maternal
1 *	Calving ease	Class	-1117.00	-897.00	0.11	0.07
2	Calf losses at calving	%	-173.40	-141.18	2.00	2.00
3	Losses until weaning		-180.54	-148.26	0.60	0.80
4	Conception rate of heifers		3.29	3.11	4.50	5.00
5	Conception rate of cows		10.21	1.95	5.00	6.00
6	Cow longevity	Year	1727.41	1395.51	0.50	
7 *	Birth weight	kg	15.14	17.57	1.70	1.25
8 *	Gain until weaning	10g/day	64.04	67.74	12.00	8.00
9 *	Postweaning daily gain		133.67	141.55	15.00	
10 *	Cow weight at maturity	kg	-0.85	-0.93	32.00	
11 *	Dressing percentage	%	461.93	401.34	1.10	
12 *	Meatiness	0.01 of class	-17.71	-15.54	15.00	
13 *	Fatness		-1.05	-0.96	14.00	

Table 2 documents the standard deviations in breeding values, genetic standard deviations and average reliabilities of breeding values for sires with progeny and individual animals with their own record of performance without progeny. Reliabilities were derived on the basis of simulation computations (Veselá et al., 2004) when an amount of information on individual animals was considered. The reliabilities were relatively small, which is clearly connected with the low numbers of productions per animal, of offspring, and of unrelated contemporaries in herds.

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

	Units	S_{BV}	S_G	r^2	
				Sires	Animals with own production
1. Calving ease, DE	Scores	0.10	0.20	0.25	0.23
2. Birth weight, DE	kg	1.64	3.28	0.25	0.23
3. Weight at 120 days, DE		11.49	23.45	0.24	0.22
4. Weight at 210 days, DE		17.83	37.18	0.23	0.21
5. Weight at 365 days, DE		29.48	62.85	0.22	0.20
6. Calving ease, ME	Scores	0.05	0.14	0.13	0.09
7. Birth weight, ME	kg	0.66	1.83	0.13	0.09
8. Weight at 120 days, ME		5.26	15.18	0.12	0.08
9. Weight at 210 days, ME		7.46	22.49	0.11	0.07
10. Weight at 365 days, ME		6.51	19.63	0.11	0.07
11. Gain at testing stations	g/day	90.00	190.00	0.23	0.21
12. Height at sacrum	Scores	0.72	1.23	0.34	0.32
13. Body length		0.19	0.39	0.24	0.22
14. Live weight		0.85	1.53	0.31	0.29
15. Front chest width		0.23	0.42	0.30	0.28
16. Chest depth		0.24	0.46	0.27	0.25
17. Rump length and width		0.27	0.45	0.36	0.34
18. Shoulder muscling		0.25	0.44	0.32	0.30
19. Back muscling		0.23	0.39	0.34	0.32
20. Rump muscling		0.30	0.51	0.35	0.33
21. Production type		0.29	0.51	0.32	0.30

DE - direct genetic effect ME - maternal genetic effect

Method of index construction

Based on methods applied in dairy cattle research (Přibyl et al., 2004; Šafus et al., 2005) and following the work of Cunningham (1969, 1975) IML/SAS programmes were used for index construction.

Breeding values are calculated by multi-trait animal model for separate groups of traits. It means that the correlations (genetic ones and environmental) within a group of traits were already applied when breeding value of each trait was calculated.

The above-mentioned breeding values were used to construct total index for parallel selection for calving ease, growth abilities and muscling. No suitable sources of data from domestic performance testing were available for fertility, animal losses and cow longevity; therefore these traits were not considered in aggregate genotype, and only an indirect selection response was calculated on the basis of correlations.

Indexes

The same aggregate genotype is defined for all indexes as shown above (denoted traits in Table 1). Five indexes were constructed that involve various sources of information:

m1) Direct and maternal effects for calving ease and weight at weaning.
m2) As (m1) and direct and maternal effects birth weight.
m3) As (m2) and production type.
m4) As (m3) and daily gain of bulls at performance-test stations.
m5) All traits with known breeding values according to Table 2.

Results

Table 3 summarizes the correlations of indexes with aggregate genotype and of the effects of selection for direct and maternal effects. The table also indicates genetic gains for direct and maternal effects of daily gain until weaning.

Tab. 3 Correlations of indexes with aggregate genotype in %, ratio of genetic gains in monetary units for direct and maternal effects and genetic gains for daily gain until weaning

	r %	Ratio Δ_G of direct : maternal	Δ_G direct g/day	Δ_G maternal g/day
Interest rate 0%				
m1	30	99.24 : 0.76	56.2	0.5
m2	30	99.36 : 0.64	55.5	0.3
m3	30	99.35 : 0.65	55.1	0.4
m4	32	101.20 : -1.20	51.3	-2.0
m5	46	99.45 : 0.55	34.1	0.7
Interest rate 10%				
m1	30	100.69 : -0.69	57.0	-1.6
m2	30	100.75 : -0.75	56.2	-1.8
m3	30	100.73 : -0.73	56.0	-1.8
m4	33	101.77 : -1.77	51.8	-4.1
m5	46	100.17 : -0.17	35.0	-0.8

With a decreasing number of traits included in indexes their correlation with aggregate genotype decreases from 46 to 30%. In all indexes the ratio of monetary genetic gain of maternal effects in total effect was many times lower than the ratio of direct effects. Genetic gains for the important trait – direct effect of daily gain until weaning – were similar, regardless of the type of index and quantity of information included in the index. The present level of this trait was practically maintained in maternal effects. The changes in the index correlations with aggregate genotype (decrease from 46 to 30%) were reflected mainly in other traits, depending on the type of index.

These results are connected with the lower variability of breeding values in maternal effects and with the lower economic weights of maternal effects. They also reflect the fact that direct and maternal effects are correlated negatively.

The inclusion of discounts in calculation of economic values of traits hardly influences the result of selection. It leads only to a small shift of maternal effects towards negative values (maternal effects are expressed later, so their economic values decrease). Therefore we will deal with indexes with economic value without discounting in the next part of this paper.

Genetic gains at unit intensity of selection expressed in % of genetic standard deviations of the traits are shown in Table 4. Similar results were obtained in all these indexes regardless of the quantity of information included in the index. The highest genetic gains were achieved for the direct effect of daily gain until weaning and daily gain after weaning. An increase was also obtained in the birth weight of calves. All indexes indicate a moderate

improvement in carcass value – a decrease in the classes for meatiness and fatness and an increase in dressing percentage. Genetic gains in the other traits were very low. If the indexes are compared, index m5 has a somewhat higher effect on carcass value.

Tab 4. Genetic gains at unit selection intensity (in percentage of S_G)

	m1	m2	m3	m4	m5
1. Calving ease, DE	9.15	9.30	9.26	8.46	5.74
2. Calving ease, ME	-5.39	-5.40	-5.35	-4.89	-3.98
3. Calf losses at calving, DE	-1.07	0.86	0.62	-0.81	-4.21
4. Calf losses at calving, ME	-7.11	-5.24	-5.38	-5.91	-8.00
5. Losses until weaning, DE	-2.49	-2.90	-2.66	-5.75	-0.14
6. Losses until weaning, ME	-0.74	-1.13	-1.45	-0.56	-2.63
7. Heifer conception rate, DE	1.88	1.73	1.86	2.37	2.49
8. Heifer conception rate, ME	-1.75	-1.77	-1.54	-2.11	-0.28
9. Cow conception rate, DE	1.88	1.73	1.86	3.22	2.33
10. Cow conception rate, ME	-1.75	-1.77	-1.54	-2.11	-0.28
11. Cow longevity	-1.62	-1.67	-1.41	-1.89	1.55
12. Birth weight, DE	20.85	24.86	24.71	22.82	15.54
13. Birth weight, ME	-7.63	-6.19	-6.09	-8.13	-3.03
14. Gain until weaning, DE	46.81	46.26	45.95	42.73	28.39
15. Gain until weaning, ME	0.66	0.43	0.45	-2.51	0.85
16. Postweaning daily gain	18.36	19.11	18.94	23.26	42.46
17. Cow weight at maturity	4.17	6.06	7.31	9.14	-5.29
18. Dressing percentage	4.78	4.01	4.92	5.90	13.45
19. Meatiness	-4.81	-4.48	-7.12	-7.76	-17.04
20. Fatness	-2.26	-2.00	-2.36	-3.70	-5.02

Table 5 documents the importance of all traits in the breeding objective in % (in aggregate genotype of indexes and the other correlated traits) according to the particular indexes. It documents the percentages of traits in total economic benefit of selection according to the indexes that are connected with the achieved genetic gains. In animal losses, conception rate and longevity the result was influenced by insufficient relationships with the other traits. Of importance was only the direct effect of daily gain until weaning (18.35% – 47.08%), daily gain after weaning (48.18 – 71.62%), and the much lower dressing percentage (2.65 – 5.75%) and meatiness (1.55 – 3.81%). The other traits were not important in the selection objective within the present structure of breeding programme.

With an increase in the number of information traits included in indexes (from index m1 to index m5) the importance of daily gain until weaning decreases, and, in contrast, the importance of daily gain after weaning increases. The increase in importance in relation to a higher number of information traits in the index is also evident in meatiness. The total importance of carcass traits was 4.24 – 9.62%.

Breeding values of the particular traits are combined in indexes. The importance of traits in selection indexes is shown in Table 6. It indicates a change in the total effect of selection in monetary units in % when a given trait (source of information) is left out of the selection index, i.e. from performance testing.

Tab 5 Importance of traits in breeding objective in % of the total value in monetary units according to indexes (* Traits included in aggregate genotype of indexes)

		m1	m2	m3	m4	m5
1. Calving ease,	DE *	-1.47	-1.48	-1.47	-1.25	-0.59
2. Calving ease,	ME *	0.52	0.52	.51.00	0.43	0.25
3. Calf losses at calving,	DE	0.48	-0.39	-0.28	0.34	1.23
4. Calf losses at calving,	ME	3.03	2.22	2.26	2.32	2.20
5. Losses until weaning,	DE	0.35	0.41	0.37	0.75	0.01
6. Losses until weaning,	ME	0.13	0.20	0.25	0.09	0.30
7. Heifer conception rate,	DE	0.04	0.03	0.04	0.04	0.03
8. Heifer conception rate,	ME	-0.04	-0.04	-0.03	-0.04	0.00
9. Cow conception rate,	DE	0.13	0.12	0.12	0.20	0.10
10. Cow conception rate,	ME	-0.13	-0.13	-0.11	-0.15	-0.01
11. Cow longevity		-1.83	-1.88	-1.57	-1.97	1.13
12. Birth weight,	DE *	0.70	0.83	0.84	0.71	0.34
13. Birth weight,	ME *	-0.18	-0.14	-0.14	-0.17	-0.05
14. Gain until weaning,	DE *	47.08	46.19	45.55	39.61	18.35
15. Gain until weaning,	ME *	0.42	0.27	0.28	-1.46	0.35
16. Postweaning daily gain	*	48.18	49.79	49.00	56.26	71.62
17. Cow weight at maturity	*	-0.15	-0.21	-0.25	-0.30	0.12
18. Dressing percentage	*	3.18	2.65	3.23	3.62	5.75
19. Meatiness	*	1.67	1.55	2.44	2.49	3.81
20. Fatness	*	0.04	0.04	0.05	0.07	0.06

Tab. 6 The importance of traits in selection index in %

	m1	m2	m3	m4	m5
1. Calving ease, DE	0.01	0.21	0.26	0.38	0.00
2. Birth weight, DE		1.12	1.15	0.93	0.37
3. Weight at 120 days, DE					0.05
4. Weight at 210 days, DE	94.59	90.46	88.89	74.06	9.45
5. Weight at 365 days, DE					72.97
6. Calving ease, ME		0.76	0.80	0.65	0.06
7. Birth weight, ME	0.31	0.52	0.51	0.04	0.10
8. Weight at 120 days, ME					0.01
9. Weight at 210 days, ME	5.08	6.94	6.84	6.46	0.01
10. Weight at 365 days, ME					2.38
11. Gain at testing stations				16.21	0.57
12. Height at sacrum					0.12
13. Body length					0.04
14. Weight					-0.75
15. Front chest width					0.87
16. Chest depth					0.39
17. Rump length and width					8.40
18. Shoulder muscling					0.32
19. Back muscling					0.02
20. Rump muscling					4.73
21. Production type			1.54	1.28	-0.12

In indexes m1 – m4 only the breeding values for direct effect of weight at weaning (74.06 – 94.59%) and for maternal effects of this weight (5.08 – 6.94%) were basically of

importance in selection indexes. In index m4, where in addition, the breeding value of daily gain at performance-test stations was included, the importance of this trait was 16.21%, and on the contrary, the importance of breeding value for direct effect of weight at weaning decreased to 74.06% compared to the preceding indexes. In this index the importance of maternal effect for weight at weaning was 6.46%.

In index m5, which comprises all traits in performance testing, breeding value of direct effect for weight at 365 days was the most important to the detriment of the other traits (72.97%). In connection with Table 7 however, it is evident that it is not a credible value.

The importance of the other traits (sources of information) in all indexes was very low except the linear description of rump. As documented by the subsequent table of weight coefficients in indexes, the rump measures and muscling have opposite coefficients, which may lead to the compensation of opposite deviations and lower resultant effect.

Table 7 shows weight coefficients of breeding values in indexes. The values in the table are weights for the standard deviation of breeding value of a given trait in % in relation to the total sum of absolute values of all traits in the index. The weights are connected to the importance of traits in the preceding table. In index m5 the opposite values for the direct effect of weight at weaning (-11.89) and weight at 365 days (+31.70), which are results of various correlations, are not credible. Similarly, the coefficients of traits of muscling and production type had opposite values although their correlations are high. Therefore simpler indexes are to be preferred.

Tab. 7 Relative weights of traits in indexes for standard deviation of breeding values. (Weights in the percentage of the sum of absolute values of weights of all traits)

	m1	m2	m3	m4	m5
1. Calving ease, DE	-1.02	-3.29	-3.36	-3.48	-0.07
2. Birth weight, DE		8.41	7.84	6.08	-1.31
3. Weight at 120 days, DE					0.69
4. Weight at 210 days, DE	73.02	60.15	55.64	45.91	-11.89
5. Weight at 365 days, DE					31.70
6. Calving ease, ME	-5.13	-5.86	-5.5	-4.29	-0.44
7. Birth weight, ME		5.05	4.69	1.17	0.63
8. Weight at 120 days, ME					0.44
9. Weight at 210 days, ME	20.83	17.24	15.72	13.18	0.51
10. Weight at 365 days, ME					4.15
11. Gain at testing stations				20.23	-1.47
12. Height at sacrum					0.87
13. Body length					0.58
14. Weight					-0.95
15. Front chest width					4.66
16. Chest depth					-2.14
17. Rump length and width					-17.71
18. Shoulder muscling					3.32
19. Back muscling					-0.91
20. Rump muscling					14.49
21. Production type			7.26	5.67	-1.08

Conclusion

1) Selection according to the applied indexes results in genetic gain almost exclusively in direct genetic effects, regardless of the type of index and quantity of information used.
2) Discounting of economic values hardly influenced the indexes.

3) For the breeding objective the importance of the direct effect for daily gain until weaning against the daily gain after weaning were approximately equal at a ratio of 45% to 50%. With the current structure of performance testing, existing breeding and economic values the other traits are scarcely relevant in beef cattle breeding.
4) In performance testing the direct effect of weight at weaning (or yearling weight) was of the greatest importance. This is followed by daily gain of bulls at performance-test stations and maternal effect for weights at weaning (or yearling weight) while the importance is connected with the type of index. The other traits in performance testing are of little importance for breeding at least for current schemes.
5) On the basis of existing results we recommend the use of simpler indices based only on the *main* traits. Noting that i) breeding values are determined by a multi-trait animal model employing correlations *between* traits (each trait influences the estimation of the breeding value of the other traits) and, ii) the number of evaluated individuals decreases with age, we recommend two alternatives as the main selection criterion:

- an index with weight at weaning only,

or

- an index with weight at weaning together with the daily gain of bulls at performance-test stations

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