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# Comparison of long-term selection responses of breeding policy in dairy herds

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**ABSTRACT**: Genetic and economic responses to genetic gain were evaluated for these breeding arrangements: single use of bulls under testing; single and repeated use of proved bulls for two years and for three years (in combination with selection intensity 1%, 5% or 10% of the best bulls for the use of proved bulls); negative selection of cows in the herd – 10%, 20% or 30% of animals are discarded from reproduction and the animals are left in the herd and used for breeding by beef bulls; negative selection of first-calvers in the herd – 10%, 20% or 25% of animals are discarded for slaughter; discarding of heifers and purchase of animals with higher breeding value, and embryo transfer – a group of selected recipients accounts for 10%, 20% or 30% of the cows with lover breeding value in the dairy herds. Simulations for single use of breeding arrangements and their consequences over a fifty-year period were carried out for the above models using the gene flow method. Only minimum changes will occur since the 25th year of observation. A comparison of the particular models showed the highest gain of proved bulls selected from 1% of the best bulls whose cumulative genetic gain was 41.558 kg of milk proteins on average per cow for the whole observed period. Single use of bulls under testing in the herd resulted in the second highest cumulative genetic gain. Use of proved bulls selected with lower selection intensity (5% or 10%) had worse results. Culling of cows and discarding of first-calvers for slaughter led to lower genetic and economic contribution. The gain of embryo transfer was also lower; moreover, it is not economically advantageous for its very high costs, so it should not be used in production herds generally. High genetic and economic gain was recorded for replacement of all heifers by animals with higher breeding value from other populations.

**Keywords**: dairy cattle; breeding policy; selection; genetic contribution; economic contribution; gene flow method

Simulation calculations are a suitable tool to test the impact of breeding policy in the framework of selection programmes. Based on simulations it is possible to construct a mathematical model of the population included in the process of breeding and to test the influence of breeding arrangements. It is also important to test the estimated breeding effect when conclusions can be drawn from a potential inconsistency of expected values with the actual state achieved in practice during implementation of breeding programmes that will be aimed at higher effectiveness of breeding work.

An important breeding policy is the dimension of the use of tested and proved bulls in a herd. By optimisation calculations Fewson (1987) proved a suitability of wider use of young bulls for breeding. Lohuis et al. (1992) determined the probability of animal survival and expected returns when young bulls were used in progeny testing. Weigel et al. (1995) reported similar results when they determined genetic gain and effectiveness of young bull selection for their use in breeding. Meuwissen and Goddard (1997) constructed an algorithm to determine an optimum volume of information from the offspring under progeny testing of young bulls with available estimations of breeding value on the basis of pedigree information. Selection of young bulls for future use in artificial insemination was also investigated by Dutt and Gaur (1998).

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Ducrocq and Colleau (1989) analysed an optimum culling level for dairy cattle selection from theoretical aspects. Allaire (1981) interpreted economic consequences of replacing cows by heifers with higher genetic level of production traits. Replacement of cow herd in Dutch conditions was studied by van Arendonk (1985). He developed a model to estimate sales and costs on a dairy farm under different production and financial conditions. Others aspects of herd replacement were examined by Furniss et al. (1988), who proved that increased herd turnover improved the breeding value of younger cows that was reflected in the performance of daughters. Meinert et al. (1986) estimated genetic trends in herds with the production of young bulls for A.I. Lehenbauer (1998) reported the annual range of cow discarding between 25% and more than 35%. Lehenbauer and Oltjen (1998) dealt with the economic importance of cow culling and development of optimum strategy. Cardoso et al. (1999) defined an optimum level of culling and insemination for Holstein cattle in a south-eastern area of Brazil. The authors presented two variants: culling of all animals for slaughter, and in the other variant a part of culled animals was used for production by other farmers. Rajala-Schultz et al. (2000) defined the structure of "optimum herd" for Finnish dairy cattle and proposed an optimisation for the level of cow culling and strategy of insemination use. Synergetic effects of the optimum level of culled animal replacement and feeding strategy were investigated by Vargas et al. (2001), who constructed a model for culling and insemination optimisation in the herd. The effectiveness of breeding measures in cow herds was studied by Vacek (1992), who determined the effectiveness of selection in alternative variants of animal selection, different selection intensity and herd turnover in connection with potential use of embryo transfer.

Modifications with the application of promising findings in reproduction were tested by Váchal et al. (1987). Ferris and Troyer (1987) analysed ET effectiveness in a cow herd. The authors proved economic advantages of ET to dams of bulls for the production of sons for A.I., based on their own calculations. The use of this technique for the production of daughters was not economically advantageous. The influence of the number of descendants after one donor was studied by Ruane (1988), Bovenhuis et al. (1989), Woolliams and Wilmut (1989).

A gene flow method is regularly used to study genetic and economic gain. Applying the gene flow method it is possible to analyse how the genes of individuals of a selection round are conferred to direct descendants in the whole population. This principle is used to simulate gene transfer from generation to generation. Many authors applied this method (Hill, 1974; Brascamp, 1975, 1978). Jalvingh et al. (1993) simulated dairy herd management using the Markov chain method.

The analysis of selection programme usually consists of four paths (selection programmes may be divided into more paths in relation to their structure) through which genes pass from generation to generation. For selection purposes it is advisable to study not only these separate paths but also the age classes within these paths. Transition matrix ($T$) describes reproduction process and aging course in a summary way. The expected proportion of genes from particular animals and its influence on gene flow and genetic gain were investigated by Woolliams et al. (1999).

Bijma and Woolliams (2000) studied the relation between the theory of gene flow method and genetic gain. The authors stated that in the general theory of gene flow the genetic gain is determined from selection differences and asymptotic proportions of genes in the age categories. Previous studies reported that asymptotic gene proportions might differ considerably from actual proportions. Bijma and Woolliams proved that it was possible to determine genetic gain in spite of these differences. Reinsch and Kalm (1995) applied the gene flow method to examine relative importance of maternal, paternal and direct effect in dairy cattle for reproductive traits. Kennedy and Trus (1993) evaluated genetic relations between herds or regions applying the gene flow method to reveal mutual exchange of genes. Hill (1974) demonstrated a possibility of using the gene flow method for modelling a crossing scheme and for the use of reproduction and production herds. The gene flow method can also be applied to the construction of selection indexes; it was reported by Philipsson et al. (1994), who worked out a simulation study of the effectiveness of total selection index. Kadlečík et al. (2004) analysed alternatives of breeding program for Pinzgau cattle.

The objective of the paper is to evaluate genetic and economic responses of different variants of breeding work in a commercial dairy herd without production of sires, particularly the use of mating bulls and cow selection.

## MATERIAL AND METHOD

The long-term selection response during fifty years was examined for single use of breeding arrangements.

These breeding policies were used to compare genetic and economic responses:

Model 1 – single use of young bulls under testing;
Model 2 – single use of proved bulls – submodels A, B, C – selection of 1%, 5% or 10% of the best bulls;
Model 3 – repeated use of proved bulls for two years – submodels A, B, C – selection of 1%, 5% or 10% of the best bulls;
Model 4 – repeated use of proved bulls for three years – submodels A, B, C – selection of 1%, 5% or 10% of the best bulls;
Model 5 – negative selection of cows in the herd – submodels A, B, C – 10%, 20% or 30% of animals are culled from reproduction in the herd (the animals are left in the herd and used for insemination by beef bulls);
Model 6 – negative selection of first-calvers in the herd – submodels A, B, C – 10%, 20% or 25% of animals are culled from the herd for slaughter
Model 7 – purchase of heifers;
Model 8 – embryo transfer – submodels A, B, C – a group of selected recipients accounts for 10%, 20% or 30% of cows with the lowest breeding value.

Simulation calculations for single use of breeding measures and their consequences over a fifty-year period were carried out for the above models using the gene flow method. The breeding measures were used separately – use of bulls for models 1–4 and selection of cows for models 5–8.

This methodical procedure was applied to calculate genetic and economic responses of breeding measures:

### (1) Construction of transition matrix ($T$)

$$T = \begin{bmatrix} T_{SS}\ T_{DS} \\ T_{SD}\ T_{DD} \end{bmatrix} \tag{1}$$

where: $T_{SS}$ = the submatrix of transition of a gene between sires
$T_{DS}$ = the submatrix of transition of a gene from dams to sires
$T_{SD}$ = the submatrix of transition of a gene from sires to dams

$T_{DD}$ = the submatrix of transition of a gene between dams

In the examined breeding arrangements a modified transition matrix ($T$) is used that comprises either submatrices ($T_{SD}$) and ($T_{DD}$) for models 1–4 or only submatrix ($T_{DD}$) for models 5–8. To construct the submatrix of dams-daughters the age structure of cows taken over from Přibyl and Přibylová (2001) was used. The age structure for model 6 – culling of first-calvers for slaughter – was adjusted in relation to the intensity of negative selection of cows. Table 1 shows the age structure for the particular models.

### (2) Construction of vector ($S$) to examine the expression of breeding policy

$$S_i = T \times S_{(i-1)} \tag{2}$$

where: $S_{(i-1)}$ = the vector whose elements ($s_{i-1,j}$) describe the given system at moment ($i$–1)
$S_i$ = the vector whose elements ($s_{i,j}$) describe the system at moment ($i$), $i$ = (1; 50)
$T$ = the transition matrix (equation 1), whose elements ($t_{j,j'}$) are conditioned probabilities of a change in the system state from state $s_j$ to state $s_j$

The elements of vector ($s_{i,j}$) are defined as probabilities that the system at moment ($i$) is in state

Table 1. Age structure of cows (in %)

| Lactation | Model 1–5, 7–8 | Model 6A | Model 6B | Model 6C |
|---|---|---|---|---|
| 1 | 33.80 | 36.20 | 39.00 | 40.50 |
| 2 | 22.20 | 21.40 | 20.50 | 20.00 |
| 3 | 16.00 | 15.40 | 14.70 | 14.40 |
| 4 | 11.40 | 11.00 | 10.50 | 10.20 |
| 5 | 7.60 | 7.30 | 7.00 | 6.80 |
| 6 | 4.80 | 4.60 | 4.40 | 4.30 |
| 7 | 2.80 | 2.70 | 2.60 | 2.50 |
| 8 | 1.40 | 1.40 | 1.30 | 1.30 |

($j$). Vector ($S$) in the first step ($S_0$) contains 1 for the class from which the gene flow is followed and the other elements of the vector are zeros.

### (3) Calculation of average proportion of genes in animals that in the given year exhibit performance coming from the given path of selection

The average proportion of genes ($PG_i$) in the year ($i$) coming from the given path of breeding policy in animals that exhibit performance is:

$$PG_i = h' S_i \tag{3}$$

where: $h'$ = the incidence vector that expresses what categories of animals exhibit the acquired genetic value by increased performance and in what proportions

$S_i$ = the vector to examine gene flow on the basis of formula (2)

With reference to the preceding calculation the cumulative and average proportion of genes will be determined ($PGC_n$) and ($PGA_n$).

$$PGC_n = \sum_{i=1}^{n} PG_i \tag{4}$$

$$PGA_n = \frac{PGC_n}{n} \tag{5}$$

where: $n$ = the length of the period of observation in years

### (4) Determination of the expression of discounted value of breeding policy

Discounted value per cow at moment ($i$) related to the beginning of the period of observation, is calculated from this equation:

$$E_i = PG_i \left(\frac{1}{1+r}\right)^i \tag{6}$$

where: $r$ = interest rate (alternative substitutions $r$ = 0; 0.05 and 0.10)

Cumulative discounted value, coming from one selection cycle by year ($i$), is given by the sum across the whole period of observation.

$$CE_n = \sum_{i=1}^{n} PG_i \left(\frac{1}{1+r}\right)^i \tag{7}$$

Average value per cow for the period of observation is calculated

$$\overline{CE_n} = \frac{CE_n}{n} \tag{8}$$

In further steps discounted values are used to calculate genetic contribution, cumulative genetic contribution and average genetic contribution of the breeding arrangements in question.

### (5) Determination of breeding value expression – genetic contribution of breeding arrangements in the herd

Kilograms of milk proteins were used as the measure of genetic contribution. Breeding values of selected animals ($BV$) were calculated on the basis of standard deviations acquired from the database of breeding values in the Czech Republic (standard deviation for the breeding value of milk protein amount on average per breed in Holstein cattle was 13.60 kg for cows and 15.61 kg for bulls) and the values of standardised selection difference ($d_s$) in relation to selection intensity. Standardised selection differences were taken over from statistical tables (Stahl et al., 1970).

$$BV = d_s \, \delta_{BV} \tag{9}$$

where: $d_s$ = the standardised selection difference in relation to selection intensity

$\sigma_{BV}$ = the standard deviation of breeding value

In model 1 (single use of bulls under testing) dams of bulls and sires of bulls were selected from 0.5% of the best individuals – standardised value of selection difference was 2.892 and standard deviations were 13.60 kg for dams of bulls and 15.61 kg of milk proteins for sires of bulls. Breeding value of bulls under testing is expressed by the equation:

$$BV_{TB} = \left(\frac{BV_{SB} + BV_{DB}}{2}\right) - (t \times GT) \tag{10}$$

where: $BV_{TB}$ = the breeding value of bulls under testing

$BV_{SB}$ = the breeding value of sires of bulls

$PH_{DB}$ = the breeding value of dams of bulls

$t$ = the time interval until inclusion in breeding

$GT$ = the assumed genetic trend in the population

As the breeding value of tested bulls is estimated from breeding values of parents, the calculated breeding value must be adjusted for genetic trend. Bulls under testing are not included in breeding immediately, but after a certain time interval has elapsed. The assumed genetic trend in the population was 3 kg of milk proteins per year. If pregnancy length is 9.5 months and the length of rearing until inclusion in the test is 18 months, the time from the mating of parents to the inclusion of bulls in breeding is 27.5 months. The breeding value determined on the basis of parents' values should be decreased by the value of genetic trend for the past period of 2.25 years (6.88 kg). After adjustment, the breeding value of bulls tested for protein amount is 35.36 kg.

Model 7 represented the import of heifers for one standard deviation better than the domestic population.

In model 8 – embryo transfer – donors were selected from 1% of the best cows – standardised value of selection difference was 2.665 and standard deviations were 13.60 kg of milk proteins. Recipients were selected from 10%, 20% or 30% of cows with the lowest breeding value.

Average breeding value for a herd was calculated as weighted average of both parts of the herd

$$BV = k_1 d_{s_1} \delta_{BV_1} + k_2 d_{s_2} \delta_{BV_2} \quad (11)$$

where: $k_1$ = the coefficient which described the proportion of donors in the herd
$k_2$ = the coefficient which described the proportion of recipients in the herd
$d_s$ = the standardised selection difference
$\sigma_{BV}$ = the standard deviation

Table 2 shows breeding values used for the particular breeding policies.

Genetic contribution in the given year ($GC_i$) to genetic gain, cumulative genetic contribution for the whole period of observation ($GCC_n$) and average genetic contribution ($GCA_n$) were calculated for each model.

$$GC_i = PG_i \times BV \quad (12)$$

where: $PG_i$ = the proportion of genes coming from a breeding arrangement according to equation (4) and (5)
$BV$ = the breeding value

$$GCC_n = PGC_n \times BV \quad (13)$$

$$GCA_n = PGA_n \times BV \quad (14)$$

where: $GCC_n$ = the cumulative proportion of genes according to formula (4)
$GCA_n$ = the average proportion of genes according to formula (5)

### (6) Calculation of economic contribution

Economic weight ($EW$) for protein amount in kg (Wolfová et al., 2001) 93.62 CZK/kg was used for this calculation. Economic contribution of the applied breeding policy was determined for alternative interest rates – zero interest rate, 5% and 10% interest rates.

Table 2. Breeding values ($BV$) for breeding arrangements

| Model | Category | $BV$ (kg of milk proteins) |
|---|---|---|
| 1 | bulls under testing | 35.36 |
| 2A, 3A, 4A | proved bulls (selection of 1% of the best) | 41.60 |
| 2B, 3B, 4B | proved bulls (selection of 5% of the best) | 32.20 |
| 2C, 3C, 4C | proved bulls (selection of 10% of the best) | 27.40 |
| 5A | cows | 2.65 |
| 5B | cows | 4.76 |
| 5C | cows | 6.76 |
| 6A | first-calvers | 2.65 |
| 6B | first-calvers | 4.76 |
| 6C | first-calvers | 5.76 |
| 7 | heifers | 13.60 |
| 8A | cows | 6.53 |
| 8B | cows | 11.50 |
| 8C | cows | 15.99 |

Economic contribution ($EC_i$) is:

$$EC_i = iE_n \times BV \times EW \qquad (15)$$

where: $E_i$ = the discounted value per cow in the year ($i$)
$BV$ = the breeding value
$EW$ = the economic weight of trait

Cumulative and average economic contribution $ECC_n$ and $ECA_n$, respectively, were calculated in a similar way:

$$ECC_n = CE_n \times BV \times EW \qquad (16)$$

$$ECA_n = \overline{CE}_n \times BV \times EW \qquad (17)$$

## RESULTS

Figure 1 illustrates the proportion of genes, cumulative and average proportions of genes coming from the given path of selection. Single use of bulls under testing was described as an example of the pattern of gene proportions. The proportion of conferred genes ($PG$) peaks in the third year of the period of observation, then a continuous decrease follows as a result of the use of other bulls whose genes displace the genes of "herd founders". In the given case the genes of single-use bulls will disappear approximately in the 36th year of the period of observation. The influence of breeding policies was examined during fifty years; the graph shows that only minimum changes will occur since the 25th year of observation. The cumulative proportion of genes ($PGC$) conferred in the particular years will increase gradually. The increase will slow down and stop completely as indicated above approximately in the 36th year when the genes completely disappear from the herd. $PGA$ expresses the average proportion of conferred genes from the beginning of the period of observation.

Figure 2 shows a comparison of cumulative economic contribution in some variants of breeding policy in dependence on time – single use of bulls under testing, single use of proved bulls selected from 5% of the best bulls, culling of 20% of the worst cows from breeding, culling of 20% of the worst cows for slaughter and use of 20% of cows as embryo recipients. Cumulative economic contribution was examined at interest rate 5%. Maximum values in this figure were obtained for single use of bulls under testing. The graphs differ in relation to the type of breeding policy – for single and repeated use of bulls, cow discarding from breeding and embryo transfer the cumulative economic contribution was zero in the first two years of the period of observation. In relation to the gene proportion (Figure 1) it is also evident in this case that only minimum changes will occur since the 25th year of observation. Genetic and economic contribution of breeding policy is influenced by the above-mentioned proportions of conferred genes, breeding values of selected animals, interest rate and economic weight.

Table 3 shows the values of cumulative and average genetic and economic contribution of all variants of breeding policies. The highest genetic and economic contribution was achieved by single use of proved bulls selected from 1% of the best bulls. The second highest contribution was achieved by use of young bulls under testing. Culling of heifers and their replacement by the purchase of animals with higher breeding value (model 7) leads to similar results like the use of proved bulls for three years at lower selection intensity 10% (submod-

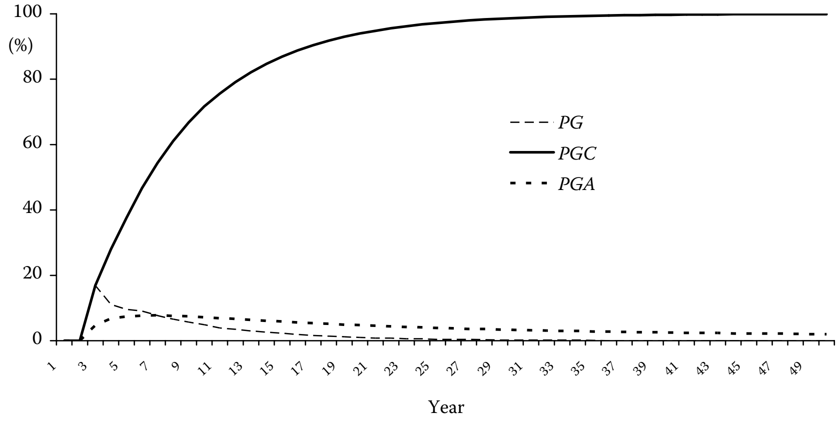
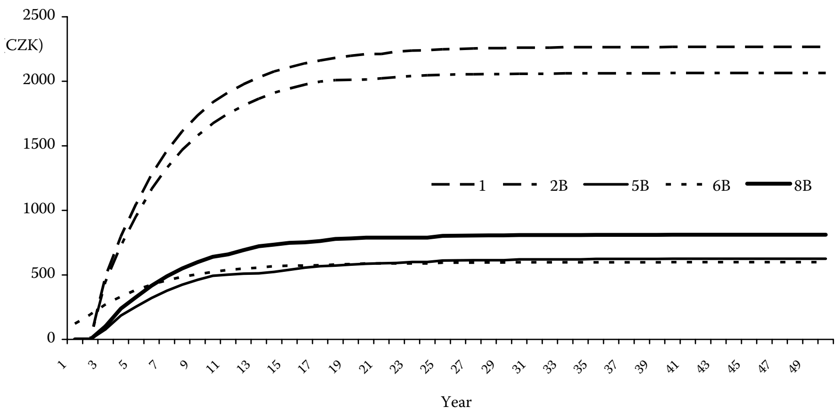


Figure 1. Proportion of genes – single use of bulls under testing

PG – proportion of genes
PGC – cumulative proportion of genes
PGA – average proportion of genes



1 – single use of bulls under testing
2B – single use of proved bulls selected from 5% of the best bulls
5B – culling of 20% of cows from breeding
6B – culling of 20% of first-calvers for slaughter
8B – use of 20% of cows as embryo recipients

Figure 2. Cumulative economic contribution (*ECC*) in some variants of breeding arrangements – interest rate 5%

el 4C). Compared to the use of tested and proved bulls, negative selection of cows and their culling for slaughter bring to breeders lower genetic and economic contribution. The contribution of ET is also lower; moreover, it is economically disadvantageous for very high costs, and therefore it should be used only for the production of top-performance animals, not generally in production herds.

Table 3. Cumulative and average genetic and economic contribution of all variants of breeding policy – interest rate 5%

| Model | *GCC* (kg) | *GCA* (kg) | *ECC* (CZK) | *ECA* (CZK) |
|---|---|---|---|---|
| 1 | 35.33 | 0.71 | 2 267.63 | 45.35 |
| 2A | 41.56 | 0.83 | 2 667.80 | 53.36 |
| 2B | 32.17 | 0.64 | 2 064.98 | 41.30 |
| 2C | 27.37 | 0.55 | 1 519.34 | 30.39 |
| 3A | 41.56 | 0.83 | 2 754.33 | 51.49 |
| 3B | 32.17 | 0.64 | 1 992.63 | 39.85 |
| 3C | 27.37 | 0.55 | 1 419.86 | 28.40 |
| 4A | 41.56 | 0.83 | 2 512.01 | 50.24 |
| 4B | 32.17 | 0.64 | 1 994.39 | 38.89 |
| 4C | 27.37 | 0.55 | 1 353.54 | 27.07 |
| 5A | 5.30 | 0.11 | 348.34 | 6.97 |
| 5B | 9.51 | 0.19 | 625.22 | 12.50 |
| 5C | 13.50 | 0.27 | 887.26 | 17.75 |
| 6A | 4.76 | 0.10 | 335.15 | 6.70 |
| 6B | 8.47 | 0.17 | 598.48 | 11.97 |
| 6C | 10.20 | 0.20 | 722.31 | 14.45 |
| 7 | 27.19 | 0.54 | 1 992.58 | 38.45 |
| 8A | 6.69 | 0.14 | 435.97 | 8.72 |
| 8B | 12.96 | 0.26 | 811.60 | 16.23 |
| 8C | 18.47 | 0.37 | 1 156.45 | 23.13 |

*GCC* – cumulative genetic contribution; *GCA* – average genetic contribution; *ECC* – cumulative economic contribution; *ECA* – average economic contribution

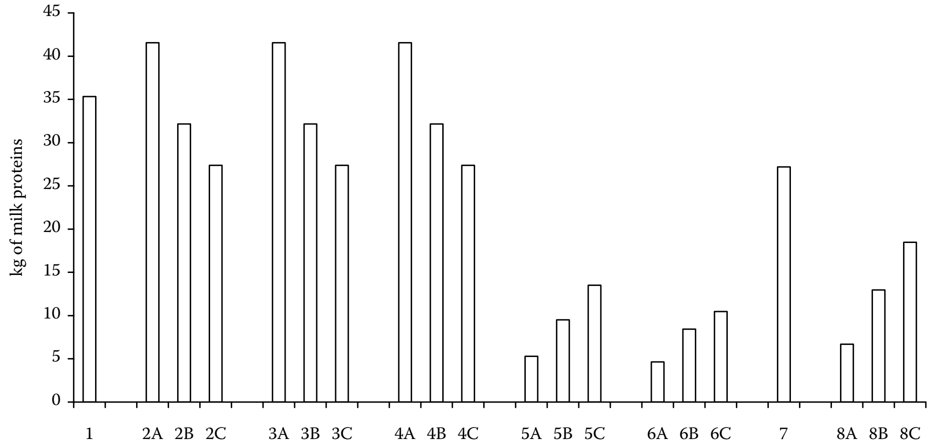


Figure 3. Cumulative genetic contribution for all variants of breeding arrangements

Cumulative genetic contribution of breeding policies is documented in Figure 3. Cumulative genetic contribution of single and repeated use of proved bulls selected from 1% of the best ones and of single use of bulls under testing was highest again. The values of cumulative economic contribution for all variants of breeding policies at interest rate 5% are compared in Figure 4. The size of columns in the graph corresponds to the values of cumulative genetic gains for the whole period, that means according to Figure 2 at the moment when the curves have already stabilised and no changes occur any longer. Hence the column height represents the highest value of the curve in Figure 2. The highest economic contribution was achieved by single and repeated use of proved bulls selected from 1% of the best ones. Single use of bulls under testing and purchase of heifers with higher breeding values also resulted in high cumulative economic contribution. The lowest values of cumulative economic contribution were recorded for the culling of cows from breeding and culling of first-calvers for slaughter.

## DISCUSSION

Genetic and economic contribution had the highest values of all evaluated breeding policies for either single or repeated use of tested and proved bulls in the herd (models 1–4). In model 1 (single use of bulls under testing in the herd) cumulative genetic contribution is 35.325 kg of milk proteins; it is the second highest cumulative genetic contribution after single and repeated use of proved bulls selected from 1% of the best animals. In farming conditions the selection of proved bulls is less strict, therefore their effect does not equal the gain of bulls under testing, and it may be considerably lower. From this aspect, single use of tested bulls seems an economically advantageous breeding policy in the cow herd. Fewson (1987) derived similar results by optimisation calculations and proved the advantages of a more frequent use of young bulls for breeding in the herd. Economic advantages of the use of bulls under testing were also demonstrated by Lohuis et al. (1992) and Weigel et al.

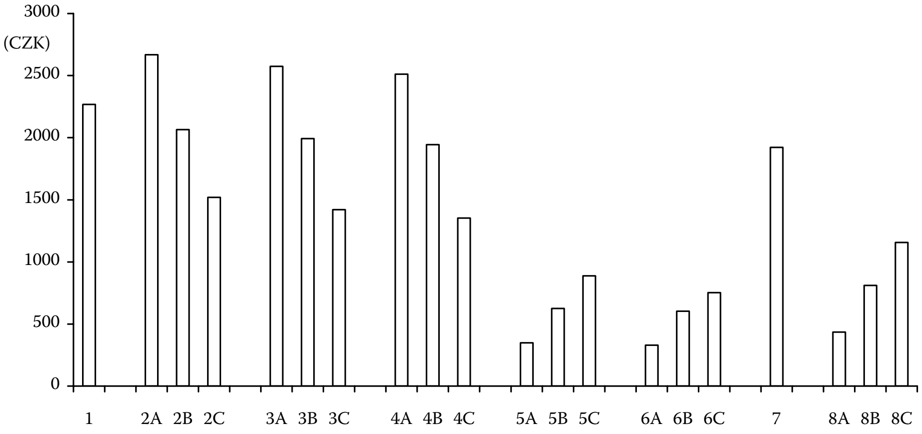


Figure 4. Cumulative economic contribution for all variants of breeding arrangements – interest rate 5%

(1995). A comparison of the particular models using proved bulls shows that it is best to use bulls selected from 1% of the best bulls whose cumulative genetic contribution is 41.558 kg of milk proteins in all cows in the herd. Cumulative genetic contribution decreases to 32.168 kg and 27.368 kg of milk proteins, respectively, at lower intensity of selection of proved bulls.

The influence of different intensity of cow selection was evaluated as another breeding policy in the cow herd. Ten, 20 and 30% of cows were discarded from breeding within three variants of model 5, and discarded cows were mated by beef bulls. In model 6, which also had three variants according to selection intensity, 10, 20 or 25% first-calvers were discarded for slaughter.

Cardoso et al. (1999) described two variants of negative selection – culling for slaughter or the mating of discarded cows by bulls of beef cattle. The highest cumulative genetic and economic contribution (+13.496 kg of milk proteins) was achieved in model 5C, where the intensity of negative selection was 30% of cows. In model 6C, where 25% of first-calvers were discarded for slaughter, cumulative genetic contribution was +10.199 kg of proteins in all cows. Many authors have agreed on this level of negative selection. Golda and Suchánek (1990) reported 30% of cows as optimum selection intensity in the first lactation and 26–28% of cows in subsequent lactations. Lehenbauer (1998) gave 25–35% of cows as optimum negative selection. Similarly, 25–30% was mentioned as optimum negative selection intensity by Ducrocq and Colleau (1989), Furniss et al. (1988). The increase in herd turnover would be reflected in an increase in the breeding value of young cows (Furniss et al., 1988). The quality of cow herd should be taken into account when different selection intensity is to be used. Calving interval and fruitfulness rearing of young animals until the first calving are limiting factors from the aspect of selection intensity. If e.g. 10% of cows are discarded, the calving interval should be 365 days and fruitfulness rearing of animals 75% to ensure the relevant number of animals for herd replacement. In case the calving interval is longer, the improvement of the herd quality – a possibility of cow culling – requires to increase the fruitfulness rearing of animals. Therefore a conclusion can be drawn that in the present state (calving interval longer than 400 days) higher selection intensity may endanger the herd replacement. Another possibility of coping with the given state is to increase longevity and survivability, which would lead to changes in the age structure of the population.

The replacement of heifers by animals with higher breeding value (+standard deviation 13.6 kg of milk proteins) resulted in a high genetic and economic contribution. Cumulative genetic contribution of this breeding policy was +27.186 kg of proteins in all cows of the herd, but it did not match the genetic contribution resulting from the use of bulls except the economic contribution of repeated use of proved bulls (prolongation of generation interval) in combination with low intensity of bull selection (Table 3). Cumulative economic contribution of heifer replacement was higher than that of single or repeated use of proved bulls selected at low intensity; it was due to a different pattern of breeding arrangements (for the use of bulls economic gain is zero in the first two years of observations, for heifer replacement the contribution of arrangements is materialised since the first year).

Maximum cumulative genetic contribution of embryo transfer was 18.469 kg of proteins when 30% of the worst cows were used as embryo recipients. Cumulative economic contribution was relatively high, +1 156.45 CZK at interest rate 5% in model 8C (30% of recipients). Embryo transfer can be used as a breeding arrangement to a limited extent only because its use on a larger scale is connected with high costs. Identical results were reported by Ferris and Troyer (1987), who considered embryo transfer as an advantageous policy for dams of bulls and production of sons for insemination. Production of daughters is not economically advantageous, which agrees with the results of Poděbradský et al. (1988) and Přibyl (1989).

Model calculations were performed only for the main selection criterion – amount of milk proteins in kg. If we used combined selection indices for a complex of traits, selection intensity, transition of genes and the other calculations would be the same. Results would only be expressed by different values.

## CONCLUSION

Based on the results of this study, we can recommend the use of bulls that provide the highest genetic and economic contribution in the herd in relation to their breeding value as the best breeding policy. As for the use of bulls, the highest genetic contribution was achieved by the use of proved bulls at high selection intensity 1% of the best ones (1:100). Genetic contribution for the use of young bulls under testing ranked as the second highest, and it was followed by contribution for the use of bulls selected at lower intensity 5% or 10% (1:20 or 1:10). Repeated use of bulls in subsequent years decreases total genetic contribution as a result of prolongation of the generation interval, but the decrease is not important compared to single use.

Culling of cows from breeding or discarding of heifers for slaughter are less economically advantageous measures. The replacement of heifers by purchased heifers with higher breeding value provided relatively high genetic and economic gain but this breeding measure is rather costly due to high purchasing costs of these animals. In embryo transfer the model confirmed a previously well-known finding that the general use of embryo transfer was not economically advantageous and it can be recommended only for dams of bulls and production of sons for insemination.

Applying the gene flow method it is possible to describe the influence of breeding policy within subsequent generations and to acquire information for decisions on the choice of appropriate strategy of breeding work in the herd.

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