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Claw Health and Feed Efficiency as New Selection Criteria in the Czech Holstein Cattle

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ABSTRACT

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The objective of this study was to calculate economic weights for ten current breeding objective traits and for four new traits characterising claw health and feed efficiency in Czech Holstein cattle and to investigate the impact of different selection indices on the genetic responses for these traits. Economic weights were estimated using a bio-economic model, while applying actual (2017) and predicted (2025) production and economic circumstances. For the actual situation, the economic weights of claw disease incidence were –100.1 € per case, and those of daily residual feed intake in cows, breeding heifers, and fattened animals were –79.37, –37.16, and –6.33 €/kg dry matter intake per day, respectively. In the predicted situation, the marginal economic weights for claw disease and feed efficiency traits increased on average by 38% and 20%, respectively. The new traits, claw disease incidence and daily residual feed intake, were gradually added to the 17 current Holstein selection index traits to improve the new traits. Constructing a comprehensive index with 21 traits and applying the general principles of the selection index theory, a favourable annual genetic selection response was obtained for the new traits (–0.008 cases of claw disease incidence and –0.006 kg of daily residual feed intake across all cattle categories), keeping the annual selection response of the most important current breeding objective traits at a satisfactory level (e.g., 73 kg of milk yield per lactation, 0.016% of milk fat). Claw health and feed efficiency should be defined as new breeding objectives and new selection index traits of local dairy population.

Keywords: dairy cattle; breeding objective; selection index; economic weights; prognosis

In addition to production and reproductive traits, health and feed efficiency have been included in breeding objectives for cattle to enhance the effective utilisation of inputs in the dairy sector, to reach higher safety and quality of products (Gonzalez-Recio et al. 2014; Kargo et al. 2014) and to lower the pollution of the environment (Connor 2015). Genetic parameters of claw health and feed efficiency traits have been estimated for application and selection in dairy cattle (van der Linde et al. 2010; Williams et al. 2011). Feed is the main input in dairy farms; thus, the efficiency of the utilisation of feed for milk production should be increased, which would decrease the overall greenhouse gases pressure on the environment, as reported by Hegarty et al. (2007) and Cassandro et al. (2013).

In the current breeding objective for Czech Holstein cattle, 10 traits characterising complex production and functional traits are included. Routine monitoring of health traits along with claw disease (CLD) have already been ongoing to

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form the basis for the genetic evaluation of these traits in dairy populations in the future (Kasna et al. 2017). In total 17 traits are used as selection criteria in Holstein cattle, which are grouped into five sub-indices for milk production, udder health, reproduction, exterior, and longevity, accounting for 49%, 7%, 12%, 25%, and 7%, respectively, of the total selection index (Plemdat 2018). The current selection for leg traits (included in the sub-index for exterior) seems to reduce CLD incidence indirectly; however, favourable impacts on the selection response in claw health and on the index reliability were found when the health and type traits were jointly included in the sub-index for legs (Krupova et al. 2017).

The relative economic emphasis on traits in the breeding objective for the specific breed, i.e., relative trait economic weights (EWs), should be regularly reassessed according to the actual and the expected situation in cattle production systems to reach the long-term sustainability of the breeding programme for given breed. Since the last estimation of EW traits was realised ten years ago by Wolfova et al. (2007), the production and economic conditions for the most important dairy cattle breed in the Czech Republic (Holstein) have changed considerably (e.g., the milk yield per cow increased by 33%, longevity by 8%, and costs for feeding by 40% (own investigation)). Economic weights of traits in the Holstein population have also been updated in Hungary and Italy as reported by Komlosi et al. (2010) and Cassandro et al. (2016), respectively.

Therefore, the objective of this study was to calculate EWs for new health and feed efficiency traits and for current breeding objective traits under the actual and predicted production and economic conditions and to investigate the genetic and economic selection response in the breeding objective using a new, more comprehensive selection index for the Czech Holstein cattle.

MATERIAL AND METHODS

Production system and economic weights. A closed purebred dairy production system of Czech Holstein cattle with integrated fattening of bulls was assumed when applying the bioeconomic model (developed by Wolfova et al. 2005) for the calculation of the trait EWs. Two sets of input parameters, for the actual and for predicted production and economic situations, were used for this calculation. The production and economic parameters of the Holstein breed in 2017 in the Czech Republic were considered for the actual situation (described by Krupova et al. 2017). The means of the traits predicted for the year 2025 were based on the expected trait annual genetic gains calculated by the Czech Holstein Cattle Breeders Association (pers. comm.). The predicted economic inputs for the model were based on the outlook for the agricultural markets and the incomes for the year 2025 (EU 2015). The main information related to the production parameters and economic inputs (both for actual and predicted conditions) of the breed are given in Tables 1 and 2.

The structure of the dairy herds for the steady state in the actual and predicted systems was generated using the Markov chain approach (for details see Wolfova et al. 2005). The economic efficiency of the production system was expressed as the present value of the total profit (TP) per cow and per year as follows:

$$\mathrm{TP} = \boldsymbol{rev'} \times \boldsymbol{NDE}^{(\mathrm{rev})} - \boldsymbol{cost'} \times \boldsymbol{NDE}^{(\mathrm{cost})} \quad (1)$$

where:

rev', *cost'* = row vectors of revenues and costs, respectively, per animal of the individual cattle categories (i.e., cows, calves, heifers, and fattened animals)

$NDE^{(\mathrm{rev})}$, $NDE^{(\mathrm{cost})}$ = column vectors of the number of discounted expressions connected with the revenues and costs, respectively (for details to the calculation of NDEs see Wolfova et al. 2005). An annual discount rate of 2.0% (2017) and 1.0% (2025) was applied to account for the delay between the animal birth and the time a trait influences revenues and costs in the life of individual cattle categories.

Revenues were from milk, fattened bulls, culled cows and heifers, sold calves, breeding heifers, and manure. The costs for feeding, housing, veterinary care, and breeding, as well as fixed costs (labour, energy, repairs, insurance, fuel, and overhead costs), were calculated for each category of animal considered in the model. Comparing the actual and predicted systems, the price per kg of sold animals remained almost the same, the milk price increased slightly by 10%, and the costs for

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veterinary treatments, drugs, and disposing of culled animals increased by 10–20%. Subsidies were not considered in both alternatives due to the decoupling of supports from animal performance (thus having no impact on trait economic weights) and due to the uncertainty about its payment for the predicted system.

Marginal EWs for the 10 production and functional traits, which are currently included in the breeding objective for the Czech Holstein cattle, and for the new evaluated traits, including claw disease incidence (CLD) and residual feed intake (RFI), for the cows, heifers, and fattened animals, were calculated using the program EWDC (Wolf et al. 2013). The lists of traits, for which the EWs were calculated, are given in Table 1. The EW of each trait was defined as the partial derivative of the profit function from Eq. 1 with respect to that trait. The value of EW was expressed as a change in the present value of the profit/cow/year when increasing the trait mean by one unit. For the definition of the 10 traits presently included in the breeding objective and for the detailed description of the EW calculation, see Wolfova et al. (2007).

The new trait, CLD incidence, was defined as the number of CLD cases/cow/year that were at risk. The details of the calculation of EW for the CLD incidence are given by Krupova et al. (2017). The trait RFI was defined as the difference between the actual daily dry matter intake (DMI) of an animal and the daily DMI predicted for that animal based on its performance (i.e., on the basis of the animal live weights, weight gains, and milk production). To avoid double counting when calculating the EW traits, the impact of increasing the level of CLD or RFI on the other simultaneously evaluated breeding objective traits (e.g., on longevity, milk yield, mature weight) was not considered. The details about the calculation of EW for RFI can be found in Krupova et al. (2016).

To compare the economic importance of breeding objective traits, which are measured in different units, the relative EWs of the traits (in %) were calculated. The relative EW of a trait expresses the percentage of the standardised EW for this trait (calculated by multiplying the marginal EW with the genetic standard deviation of the trait) from the sum of the standardised EWs of all the traits. The trait genetic standard deviations (Table 1) were estimated from the database of the Czech-Moravian Breeders' Corporation or were based on the literature (van der Linde et al. 2010; Williams et al. 2011) when the relevant data for the local dairy population were not available.

Breeding objective and selection indices. Currently, 10 traits related to milk production, repro-

Table 1. Means and genetic standard deviations (GSD) of 14 traits in the breeding objective[1]

Trait (unit)	Abbreviation	Mean		GSD	
		2017	2025	2017	2025
Milk yield per 305 days of lactation (kg)	MY	9 546	10 500	741.59	830
Milk fat content (%)	%F	3.80	3.80	0.27	0.27
Milk protein content (%)	%P	3.34	3.40	0.145	0.147
Conception rate of cows (%)	CR	91	91	2.54	2.54
Service period (days)	SP	127	127	5.00	5.0
Losses of calves in rearing (%)	CL	5.4	5.0	2.0	2.0
Age at first calving (days)	AFC	765	765	10.0	10.0
Mature weight of cows (kg)	MW	635	650	25.0	25.0
Productive lifetime of cows (years)	PL	2.95	3.12	0.74	0.76
CM incidence (cases/year of risk)	CM	0.98	0.91	0.10	0.10
CLD (cases/year of risk)	CLD	1.00	0.95	0.054	0.052
RFI of cows (kg DM/day)	FRI_c	0	0	0.280	0.300
RFI of breeding heifers (kg DM/day)	RFI_h	0	0	0.120	0.120
RFI of fattened animals (kg DM/day)	RFI_f	0	0	0.100	0.100

CM = clinical mastitis, CLD = claw disease incidence, RFI = residual feed intake, DM = dry matter

[1]values relevant for 2017 and 2025 were based on the actual and predicted scenarios, for more details see the Material and Methods section

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duction, survival, growth, cow productive lifetime, and udder health are included in the breeding objective, and 17 traits are included in the sire index (SIH) of the Czech Holstein. In the present study, the CLD trait incidence and RFI for cows, heifers, and fattened animals was successively added to the breeding objective (together 14 traits) and to the selection criteria (totally 21 traits) to improve cow foot health and feed efficiency, respectively. The reliability of the estimated breeding values and the genetic correlations among the 21 selection criteria are given in Table 3. These values were calculated from the database provided by the Czech and Moravian Breeders' Association or were taken from literature resources (Veerkamp 1995; van der Linde et al. 2010; Berry et al 2011; Buch et al. 2011; Williams et al. 2011; Zavadilova and Zink 2013; Hietala and Juga 2016; Novotny et al. 2017).

The impacts of including CLD incidence and RFI traits in the selection criteria on the genetic selection response for these traits and on the to-

Table 2. Base input parameters for the calculations of revenues and costs[1]

Variable	2017	2025
Milk price (cents/kg of milk with average fat and protein content)	27.89	30.88
Price for carcass weight of cows in the quality class S1[2] (€/kg)	1.92	2.56
Price of pregnant breeding heifers (€)	1 296	1 296
Price of male breeding calf sold to the test station (€)	1 481	1 481
Price of dung (€/100 kg)	0.93	1.11
Price of semen for AI (€[2]/insemination dose)	18.52	20.4
Average number of inseminations per cow/heifer	1.91 / 1.58	1.90 / 1.58
Costs for removing dead animal (€/mature animal)	185	222
Costs for veterinary treatment of cows (€/animal per lactation)	87.04	104.4
Cost for dystocia[3] (€/calving)		
Calving score 1	4.07	4.44
Calving score 2	62.96	69.26
Calving score 3	77.00	84.81
Price per kg fresh matter of feed ration for		
cows	0.103	0.113
calves until weaning	0.130	0.143
fattened bulls	0.071	0.078
reared heifers	0.046	0.051
Fixed costs for cows[4] (€/day)	2.70	3.15
Average charge for veterinary service (€/h)	12.96	14.26
Average cost of drugs for CM[5] (€/case)	14.07	15.48
Average cost of drugs for CLD[6] (€/case) treated		
with antibiotics	14.81	16.30
without antibiotics	9.26	10.19
Number of CLD cases/cow/year at risk (min/max)[7]	1.00 / 1.25	0.87 / 1.18
Percentage of CLD treated with antibiotics (min/max)[8]	20 / 30	
Variation in daily CLD incidence with antibiotic treatment (min/max)[6]	0.00 / 0.02	
Annual discount rate	0.02	0.01

[1]data based on the current situation in 2017 and prognoses for 2025 (1 € =100 cents = 27 CZK); [2]according to SEUROP system for carcass classification; [3]four scores are used for calving performance: easy calving without help (1), easy calving with help (2), difficult calving with veterinary assistance (3), and calving with caesarean section (4); [4]include labour, energy, fuels, reparations, insurance, interest of investments, and overhead costs; [5]clinical mastitis; [6]claw disease incidence; [7]minimum and maximum values obtained over all reproductive cycles; [8]number of cows having CLD requiring antibiotic treatment divided by the total number of cows in a herd on the given day

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Table 3. Reliability of estimated breeding values (on diagonal) and genetic correlations (below diagonal) of the selection criteria traits[1]

Trait[1]	%F	kgF	%P	kgP	SCS	CR	LONG	RLRV	FA	LOC	LEGS	FUA	FTP	TL	UD	RUH	CLI	CLD	RFI_c	RFI_h	RFI_f
%F	0.80																				
kgF	0.431	0.80																			
%P	0.671	0.202	0.80																		
kgP	–0.221	0.770	0.119	0.80																	
SCS	–0.010	0.010	–0.068	–0.024	0.80																
CR	0.055	–0.088	0.064	–0.107	0.168	0.70															
LONG	0.057	0.056	0.129	–0.059	0.287	0.420	0.50														
RLRV	–0.074	–0.019	–0.099	–0.011	–0.003	–0.100	0.023	0.70													
FA	–0.101	–0.009	–0.085	0.045	0.018	–0.155	0.010	0.277	0.70												
LOC	–0.050	0.040	–0.006	0.050	0.030	0.022	0.086	0.392	0.237	0.70											
LEGS	–0.058	0.013	–0.082	0.117	0.041	0.039	0.156	0.641	0.673	0.587	0.70										
FUA	–0.020	0.116	–0.021	0.130	0.209	0.093	0.246	0.157	0.172	0.354	0.337	0.70									
FTP	0.001	0.060	0.001	0.060	0.002	0.088	0.001	0.040	0.092	0.161	0.128	0.291	0.70								
TL	–0.060	0.080	–0.070	0.060	0.070	0.017	–0.029	0.021	0.027	–0.006	0.025	–0.004	–0.189	0.70							
UD	–0.003	0.139	–0.028	0.162	0.197	0.164	0.329	0.078	0.146	0.297	0.300	0.764	0.220	–0.027	0.70						
RUH	–0.100	0.155	–0.120	0.130	0.140	0.027	0.184	0.167	0.074	0.174	0.276	0.490	0.076	0.032	0.533	0.70					
CL	–0.060	0.040	–0.010	0.060	0.120	0.017	0.112	0.125	0.067	0.166	0.235	0.285	0.109	0.147	0.388	0.412	0.70				
CLD	–0.100	0.230	–0.140	0.200	0.191	0.380	0.160	0.230	0.180	0.510	0.440	0	0	0	0	0	0	0.50			
RFI_c	–0.010	0	–0.040	0.100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.30		
RFI_h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.600	0.30	
RFI_f	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.500	0.600	0.30

%F and kgF = percentage and kg of fat, SCS = somatic cells score, CR = conception rate, LONG = longevity, RLRV = rear leg rear view, FA = foot angle, LOC = locomotion, LEGS = legs, FUA = fore udder attachment, FTP = front teat placement, TL = teat length, UD = udder depth, RUH = rear udder height, CLI = central ligament, CLD = claw disease; RFI_c, RFI_h, RFI_f = residual feed intake for cows, heifers and fattened animals, respectively

[1]own calculation from the data provided by the Czech and Moravian Breeders Association or taken from the literature (Veerkamp 1995; van der Linde et al. 2010; Berry et al. 2011; Buch et al. 2011; Williams et al. 2011; Zavadilova and Zink 2013; Hietala and Juga 2016; Novotny et al. 2017)

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tal economic selection response and index reliability were investigated in the four variants of SIH, namely (1) Current index – actual SIH of the breed without the new traits; (2) Health index – SIH, including the CLD incidence; (3) Feed index – SIH, including the RFI for cows, breeding heifers, and fattened animals; (4) Comprehensive SIH index – SIH, with the CLD incidence and the three RFI traits.

Constructing the four selection indices, two sets of EW traits were used for weighting importance in the breeding objective. Indices with EWs were calculated for the actual production circumstances (in 2017) and depicted as A. Those with EWs calculated for the predicted circumstances (in 2025) were designated as P. The relative weight of the traits in the indices was either taken from the current SIH index (index 1), making space for the new traits (in indices 2–4), or were calculated using the general principles of the selection index theory, estimating trait weighting coefficients, which maximise the response in the breeding objective. The optimised selection indices are labelled as “o” in indices 1–4 for production circumstances A and P. For example, index 1A is the current SIH with EW traits calculated for the actual production circumstances and with the currently used weighting coefficients *b* in the index, while index 1Po is the current SIH index constructed with trait EWs for the predicted circumstances in which the weighting coefficients for the index traits were calculated by applying the selection index theory (optimised coefficients). The relative weightings of the new traits in the not optimised indices were 5%, 5%, 1%, and 1% for CLD and for the three traits of RFI, keeping the current relative ratios of the 10 primary traits.

Genetic selection responses in the breeding objective traits were calculated for each of the four selection paths, the sires of the bulls (SB), the sires of the cows (SC), the dam of the bulls (DB), and the dam of the cows (DC), assuming a selection intensity of 5%, 10%, 1%, and 90% and generation intervals of 7, 4, 3, and 4 years for the SB, SC, DB, and DC paths, respectively. The genetic response for a trait per selection path was calculated as a product of the selection intensity, the index accuracy, and the trait genetic standard deviation. The genetic response per year was then estimated by dividing the sum of the responses for the four selection paths by the sum of the four generation intervals. The economic responses in all the breeding objective traits were calculated by multiplying the genetic selection responses by the EW traits.

RESULTS

Trait economic weights. The marginal EWs of the breeding objective traits for Czech Holstein cattle under the actual (2017) and predicted scenarios (2025) are presented in Table 4. The actual marginal EWs for the new traits were –100.1 € per case of CLD and –79.37, –37.05, and –6.33 € per kg daily DMI for the cows, breeding heifers, and fattened animals, respectively. The marginal EWs of these traits increased on average by 38% and by 20%, respectively, when the parameters predicted for the year 2025 were applied. The relative EWs of the traits (presented in Figure 1) remained almost the same (e.g., 2% and 7% for CLD incidence and for RFI across all cattle categories, respectively), except for the relative EW of the cow productive lifetime, which slightly decreased by 3 percentage points under the predicted conditions. Milk yield, milk components, conception rate, and productive lifetime remained the most important traits, covering from 80% (in 2017) to 81% (in 2025) of the total economic importance of all the evaluated traits.

Selection response. Genetic and economic selection responses calculated for the new traits and for the current breeding objective traits to the selection criteria specified in the evaluated selection indices are summarised in Table 4. Because very similar genetic responses for all the traits were obtained in index variants 2–4 for the actual (A) and predicted (P) situations, only values for situation A are presented in Table 4.

The genetic selection response of the new traits was favourable, varying from –0.005 to –0.009 in cases of CLD and from –0.001 to –0.006 kg of RFI per year, using the indices that included these new traits. As expected, the total economic selection response was always higher when applying optimised indices (with label “o” in Table 4) than when applying indices with the predefined actual weighting of traits. However, for the CLD incidence, a slightly higher response was calculated using the index with trait weightings equal to the actual ratios of the 10 original selection criteria and with 5% relative weight on the CLD inci-

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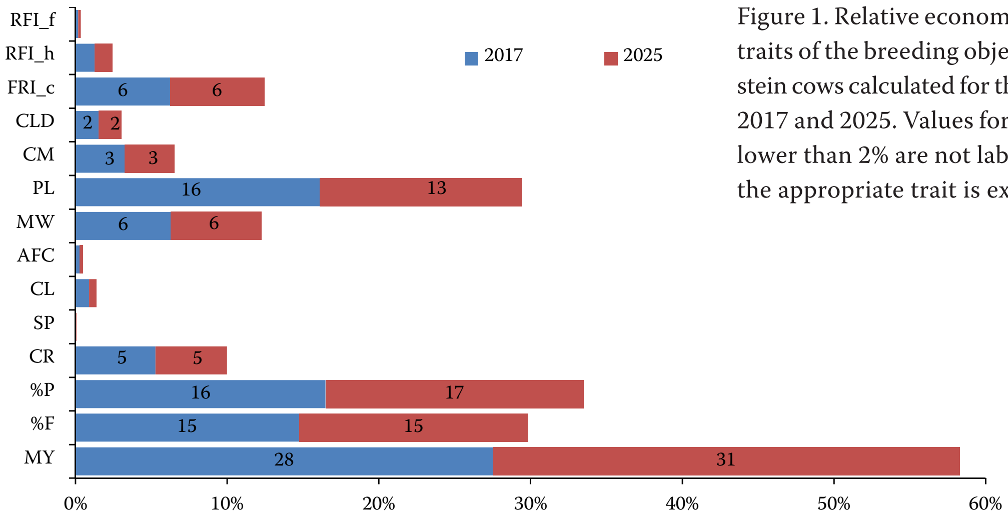

Figure 1. Relative economic weights (EWs) of the traits of the breeding objective (%) of Czech Holstein cows calculated for the production system in 2017 and 2025. Values for EWs with proportions lower than 2% are not labelled. Abbreviation for the appropriate trait is explained in Table 1

dence (index 2A) than using the optimised index (index 2Ao). On the other hand, the use of the 3 and 4 optimised selection indices yielded higher selection responses for RFI traits than the use of indices with actual trait weighting and with 7% relative weight on all three RFI traits. Favourable genetic responses were also found for the current breeding objective traits, applying any variants of

Table 4. Marginal economic weights (EWs)[1], genetic selection response for the breeding objective traits (GR)[2], overall economic response (ER)[3], and the index reliability (r_{IH})

Trait[4]	EWs		GR for the index variant[5]									
	2017 (A)	2025 (P)	1A	1Ao	1P	1Po	2A	2Ao	3A	3Ao	4A	4Ao
MY	0.132	0.177	85.91	71.72	87.29	98.59	81.40	92.63	79.11	65.02	73.06	86.07
%F	195.6	267.0	0.019	0.026	0.017	0.023	0.018	0.027	0.017	0.024	0.016	0.025
%P	406	552.6	0.017	0.020	0.015	0.019	0.016	0.020	0.015	0.018	0.014	0.019
CR	7.402	8.859	0.204	0.225	0.185	0.181	0.220	0.215	0.186	0.202	0.197	0.198
SP	–0.024	–0.028	–0.393	–0.455	–0.356	–0.366	–0.396	–0.525	–0.358	–0.409	–0.353	–0.485
CL	–1.606	–1.17	–0.014	–0.010	–0.011	–0.009	–0.014	–0.019	–0.013	–0.009	–0.013	–0.017
AFC	–0.098	–0.108	0.230	0.265	0.209	0.263	0.227	0.303	0.213	0.244	0.204	0.286
MW	–0.894	–1.144	0.258	–0.824	0.235	–0.724	0.254	–0.674	0.280	–0.661	0.273	–0.543
PL	77.53	83.56	0.079	0.111	0.074	0.102	0.080	0.109	0.072	0.100	0.071	0.101
CM	–115.4	–156.7	–0.012	–0.013	–0.008	–0.010	–0.012	–0.012	–0.011	–0.011	–0.011	–0.011
CLD	–100.1	–138.5	–	–	–	–	–0.009	–0.005	–	–	–0.008	–0.005
RFI_c	–79.37	–98.77	–	–	–	–	–	–	–0.004	–0.006	–0.004	–0.006
RFI_h	–37.05	–47.01	–	–	–	–	–	–	–0.001	–0.002	–0.001	–0.002
RFI_f	–6.334	–8.112	–	–	–	–	–	–	–0.001	–0.002	–0.001	–0.002
ER[3]	–	–	30.45	35.43	37.20	46.61	30.52	38.34	28.21	32.45	27.53	36.00
r_{IH}	–	–	0.633	0.665	0.521	0.653	0.645	0.704	0.533	0.548	0.518	0.610

[1]marginal trait EWs for actual (A) and predicted (P) scenarios are expressed in € per unit of the trait/cow/year; [2]expressed in units of traits/year; [3]expressed in €/year; [4]abbreviation and unit for the appropriate trait are given in Table 1; [5]index variants: in indices 1–4, the new traits (RFI and CLD) were gradually added to breeding objective and to selection criteria, indices designated with A and P were calculated considering actual and predicted genetic parameters and trait EWs, respectively; because very similar GR for all traits were obtained in index variants 2–4 for A and P situation, only values for A situation are presented here; weighting of traits in the index variants labelled "o" were optimised to reach maximal economic selection response and index reliability. In index variants without "o", the trait weighting was set according to the trait ratio in the actual selection indices

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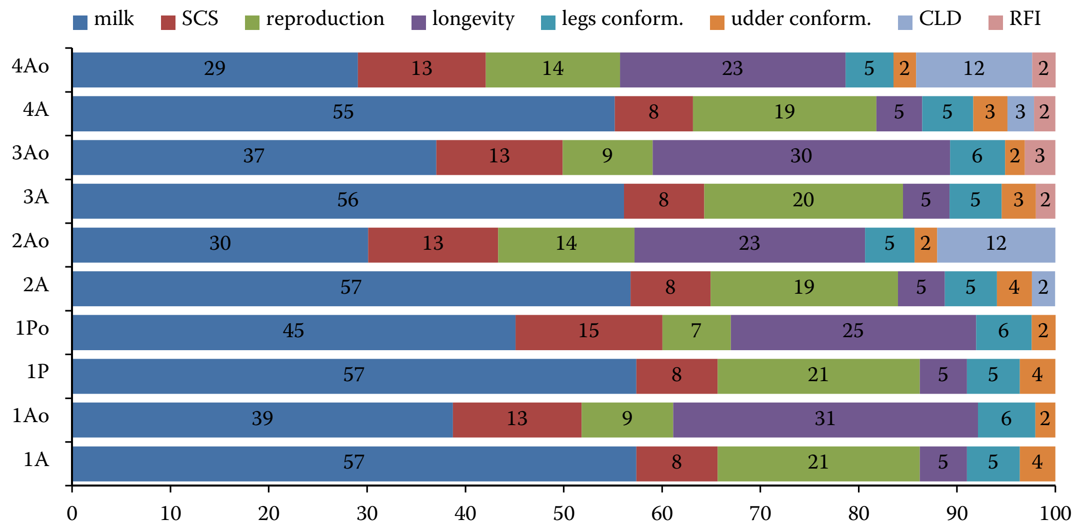

Figure 2. Contribution (%) of the groups of the selection criteria to the overall selection response in the breeding objective using specific indices 1A to 4Ao

SCS = somatic cell score; for other explanations see legend under Table 4

the evaluated selection indices. For example, using the comprehensive selection index and the current trait weighting ratios (index 4A), the milk yield per lactation can be increased by 73 kg, the milk fat content by 0.016%, and the milk protein content by 0.014% per year, retaining a favourable annual response in functional traits, such as 0.197% for the cow conception rate, –0.013% for calf losses, and 0.071 years for the cows productive lifetime. When optimising the trait weighting coefficients in the comprehensive index (index 4Ao), a reduction of the mature weight was reached (–0.543 kg per year), maintaining the positive selection response in milk yield (86 kg/year).

The contribution of the main groups of selection criteria to the overall economic selection response in the breeding objective by applying specific selection indices is shown in Figure 2. Among all 21 selection criteria in all indices, the milk yield, protein content, SCS, conception rate, and cow longevity were found to be the most important traits contributing to the overall economic selection response, from 77% (using the comprehensive index with optimised trait weighting ratios) to 90% (using the actual index with the current trait ratios). Both new traits in the indices, CLD incidence and RFI, contributed to the overall economic response, mostly from 2 to 3%, but the contribution of CLD to the overall selection response reached 12% when using the indices with the optimised trait weighting ratios (2Ao and 4Ao).

When constructing the optimised selection indices, the total economic response was higher in the comprehensive 14-trait SIH than in the actual 10-trait SIH (36.00 € using index 4Ao vs 35.43 € using index 1Ao). Similar tendencies were found when evaluating the index reliabilities.

DISCUSSION

Profit and marginal trait economic weights. Generally, higher marginal EWs of all the evaluated traits were in the scenario predicted for the year 2025 than in the current scenario (2017), which was caused mainly by the higher total profit (185 € vs 11 € per cow per year). The positive profit without subsidies in both scenarios was reached due to the fact that most of the surplus calves (85%) were exported at 40 days of age with profit of +69 € per calf. Fattening of the bulls was unprofitable in the Czech Republic (losses of –250 € per bull were identified). This negative profit in fattening for the 6% of the calves in both scenarios caused a slight underestimation of the EW for calf losses. As stated by Wolfova et al. (2005) and Krupova et al. (2009), for the correct economic evaluation of traits expressed in different cattle categories, the profit in all these categories should be positive. Economic results for further cattle groups were actually positive (e.g. 377 €/cow/year), which assured that the EWs of the key traits of the Holstein breed

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were connected with cow performances (e.g., milk yield, milk components, and especially functional traits as productive lifetime, conception rate, and calving interval) and were correctly estimated. By comparing the EWs of Czech Holstein cattle traits that were estimated in the former study by Wolfova et al. (2007) and those calculated here for the actual and predicted production circumstances, it can be stated that the economic importance of the breeding objective traits is stable and sustainable long-term.

Regarding the new traits, the negative economic values for CLD incidence and RFI indicate that increase in the mean value for these traits is economically unfavourable. The negative value of EW for CLD resulted from economic losses due to discarded milk and from the additional costs related to treatment and medication. Similarly, increase in the mean RFI led to increased feeding costs of milk and meat productions, remaining at the same level. Marginal EW of CLD incidence calculated here was generally lower compared to the literature estimates. Higher EWs (ranging from −155 to −188 € per case) than in our study (−100 to −138 € per case) were calculated for Holstein and Red dairy cattle farmed in Nordic countries (Kargo et al. 2014). The higher veterinary costs (75 to 90 € per case) and longer veterinarian time (1.43 to 1.87 h) spent per case in these countries in comparison with those variables in the Czech Republic are the main reason for this difference. In contrast, the EW for the feed efficiency in Czech Holstein cows (−79.4 € per kg DM intake/day) was slightly higher than that found for Slovak Pinzgau (−55.2 €) (Krupova et al. 2016) or for Finnish dairy cattle (−55.8 €) (Hietala et al. 2014). The reason for this difference could be the higher prices of feed, which were 0.103 €/kg in the Czech Republic vs 0.055 and 0.060 €/kg in the Slovak Republic and in Finland, respectively. The large difference in the marginal EW of RFI for the fattened animals (−6.33 € in our study vs −29.5 € by Hietala et al. (2014)) was caused by differences in the number of fattened animals per year in these studies (6 animals in our study vs 55 animals by Hietala et al. 2014 per 100 cows).

The marginal EWs for the 10 actual breeding objective traits were ranked from −115.4 € (per case of clinical mastitis, CM) to 406.0 € (per % of milk protein). Compared with the previously calculated EWs of these traits (Wolfova et al. 2007), the EW of the CM incidence increased on average by 53 €/case/cow/year. The higher actual EW of mastitis reflects the increase in costs for drugs and veterinary care (e.g., cost for veterinary treatment per cow per lactation increased from 43 € in 2005 to 87 € in 2017) and the higher milk losses per mastitis case due to the higher milk yield per cow in the past several years in the Czech Republic (7200 kg in 2005 vs 9500 kg in 2017). Slightly higher economic impact of CM incidence (205 $/one case/lactation) found for Spanish dairy population (Perez-Cabal et al. 2009) was based on the higher milk yield (10 441 kg per lactation).

The relative EWs of evaluated traits calculated for actual and for predicted scenario were similar due to comparable changes in the marginal EWs of evaluated traits (+23% on average) between studied scenarios. When comparing the relative EWs of traits estimated for the predicted situation in 2015 (Wolfova et al. 2007) and the current estimates for 2017, a different number of traits in both studies should be considered. Nevertheless, the four most important traits remained the same in both years, namely, the milk yield, milk fat, protein contents, and cow productive lifetime. The relative importance of these four traits estimated by Wolfova et al. (2007) was 51%, 14%, 20%, 15%, and in our study 37%, 20%, 22%, 22% for milk yield, milk fat, protein content, and cow longevity, respectively.

The relative EW of CLD seems to be low (1%), but due to the genetic correlation of CLD with milk and other traits, the contribution of the CLD incidence as a selection criterion in the comprehensive optimised index to the total economic selection response could reach 12% (see Figure 2). Some authors, e.g., van der Linde et al. (2010) or Krupova et al. (2017), recommended including this trait in breeding objectives and selection criteria to improve claw health. Summing the relative EWs of the RFI across all the animal categories, the relative importance of RFI reached 7%, which is similar to the relative weights of RFI, from 6 to 8% estimated by Hietala et al. (2014) for Finnish dairy cattle.

Selection response for CLD and RFI traits. Comparing the annual selection response for the CLD incidence calculated in our study with estimates published in the literature, the selection criteria used to improve the CLD by different authors had to be considered. Koenig et al. (2005) calculated the selection response for the CLD of −0.041 and −0.124 cases per generation using selection indices for the Holstein breed in Germany, which were based on the foot angle and on the foot angle and

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sole ulcer as information sources, respectively. Supposing an average generation interval of 5 years, the corresponding annual selection response would be –0.008 and –0.025 cases/cow/year, which is close to our results (average annual response –0.006 cases). According to van der Linde et al. (2010), the prevalence of various claw disease traits was reduced by –0.0% to –0.5% when applying the selection on a Dutch claw index without CLD traits, but by –0.1% to –0.7% when the CLD traits were included in the index. Transferring the percentage expression to the number of cases of the appropriate CLD, their calculated genetic gain was also close to our findings. When comparing our results with the former pilot study oriented to CLD just as a part of sub-index "Legs" (Krupova et al. 2016) the selection response was reduced to 20% on average due to the more comprehensive approach (inclusion of all traits in breeding objective and selection index). Nevertheless, this response is still favourable with keeping the appropriate selection response in other traits included into the consideration.

The CLD incidence, defined in our study as the incidence of different claw illnesses, can be replaced by the individual claw health traits in the future. Evaluation of these traits is now ongoing to investigate the actual status and to design the most appropriate solution for genetic evaluation in the dairy cattle breeds in the Czech Republic (Kasna et al. 2017). The prevalence of individual health disorders changes during the cow's life (van der Linde et al. 2010; Kasna et al. 2017); therefore, a reference to specific traits seems to be favourable for genetic improvement and economic consequences of selection process. As stated by van der Linde et al. (2010), the CLD incidence as a composite trait cannot replace specific claw health traits in the index without losing a substantial amount of information.

The estimated annual genetic selection response in RFI traits calculated in our study (on average –0.008 kg of DM in cows, heifers, and bulls per cow per year) promises the possibility of improving the feed efficiency with maintaining favourable genetic gain in the current breeding objective traits in the Czech Holstein breed. This genetic response complies on average with the economic response of 0.49 € per year. As noted by Connor (2015), it should, however, be considered that including the RFI traits in the selection criteria will result in higher costs for performance testing and that individual data of such traits will be of limited availability. Regardless of this fact, some authors, e.g., Gonzalez-Recio et al. (2014) and Hietala and Juga (2016), recommended comprehensive selection indices which would include RFI traits simultaneously with other production and functional traits. Using these indices, the mentioned authors published favourable selection responses for RFI traits. We suppose that the economic benefit of the inclusion of feed efficiency traits into current breeding objectives and selection criteria for Holstein cattle could still overcome the challenge of additional testing costs. However, the economic evaluation of the appropriate breeding programme, which would include RFI traits, should first be proven.

CONCLUSION

The economic weights of traits in the current breeding objective and of the four new traits, characterising claw health and feed efficiency, reflect the actual economic situation but are also representative of the long-time breeding goals of Czech Holstein cattle. Claw health and feed efficiency should be defined as new breeding objectives and new selection index traits of local dairy population. Further improvement of the health status of cow herds and effective utilisation of feeds meets the trends in the reduction of greenhouse emissions. The general construction of the bio-economic model predisposes it to be widely applied when calculating the economic weights for various traits and populations. Further studies should be oriented to optimise and evaluate a breeding programme that would consider the direct traits characterising claw health and feed efficiency.

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