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Predicted Feed Efficiency index applied to Italian Holstein Friesian cattle population

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Feed efficiency has a major influence on farm profitability and environmental stewardship in the dairy industry. The aim of this study was to describe a new selection index adopted by the Italian Holstein and Jersey Association (ANAFIJ, Cremona, Italy) to improve feed efficiency using data recorded by the official dairy recording system. Predicted dry matter intake (pDMI) was derived from milk yield, fat content, and estimated cow body weight. Fat-protein corrected milk (FPCM) was derived from milk yield corrected for fat, protein, and a fixed coefficient for lactose content (4.80%). Therefore, the predicted feed efficiency (pFE) was estimated as ratio between FPCM and pDMI. Average pFE was 1.27±0.18 (kg.d^{-1}) with heritability of 0.32. Predicted Feed Efficiency index (pFEi), traditional and genomic, has been implemented in the Italian Holstein Friesian evaluation system. Results suggest that pFEi may be a new breeding objective for Italian Friesians. The official selection index (PFT), in use since 2002, is positively correlated with pFEi. However, the introduction of pFEi will improve the positive feed efficiency trend. This approach will permit the Italian Holstein Friesian breeders to improve feed efficiency, without increasing costs of recording system. However, to avoid the risk of selecting animals with an excessive negative energy balance after calving, it would be useful to include in the pFE a correction for body condition score and reproductive performances. Meanwhile, in order to increase the accuracy of the predicted phenotype, an Italian consortium is creating a consistent phenotypic critical mass of individual data for dry matter intake in cows, heifers and young bulls.

Keywords: feed efficiency, cattle breeding, dry matter intake, breeding value estimation

1 Introduction

Feed costs are half of the total costs of dairy production. One possibility to increase profitability of dairy production is to reduce feed costs by improving feed efficiency. Selection of animals with high feed efficiency can bring benefits in terms of productivity and environmental impact. Benefit of improving feed efficiency is potentially, but not only, the reduction of greenhouse gas emissions even if the debate on this very sensible topic is still hot (Hegarty et al., 2007; Wall et al., 2007; Cassandro et al., 2010; Cassandro et al., 2013; Wallace et al., 2019; Cassandro, 2020). Several factors are indeed involved in this key aspect of livestock sustainability such as microbiome, nutrition and feeding, and animal genetics. However, the recording of a large dataset to estimate genetic parameters for feed efficiency is complicated and expensive. Several countries have set up projects to record dry matter intake (DMI) data (Veerkamp et al., 2000; De Haas et al., 2012; Pryce et al., 2014). One way to produce estimated breeding values (EBV) for traits difficult to collect at population level is to use genomic selection (Meuwissen et al., 2001), where phenotypes such as DMI are measured in a subset of the population, and genomic predictions are calculated for other animals that have genotypes but not phenotypes (Pryce et al., 2014). Although this approach is appealing, allowing industry-wide selection for improved efficiency, the size of the reference population from which the genomic prediction equations are derived is currently too small within each country to achieve satisfactory levels of accuracy of genomic breeding values (Verbyla et al., 2010). Currently, Italy has derived a predicted breeding value for feed efficiency using data from the national routine data recording system. The aim of this paper was to describe a new selection index adopted by the Italian Holstein and Jersey Association (ANAFIJ, Cremona, Italy) to improve feed efficiency exploiting data recorded by the official national recording system.

2 Material and methods

2.1 Data analysis and parameter estimation

Body weight (BW) was estimated for cows undergoing test-day milk recording as reported by Finocchiaro et al. (2017). Briefly, measured BW was collected over a 3-year period (2013-2015) using an automatic weighting system in a modern precision farm. Data were merged with routine linear type traits dataset. Only first-parity records with a maximum distance of 30 days between weighting and linear scoring dates were retained, leading to a final dataset of 890 first-parity cows belonging to 30 herds. A predictive algorithm was set up using type traits. Specifically, a linear model using SAS software (SAS Institute Inc., Cary, NC, USA) was adopted considering the measured BW after milking as dependent variable and herd-year-month of weighting, month of calving, stage of lactation, age of cows at scoring, stature, chest width, body depth, and rump as predictor variables. The developed algorithm was then applied to the national linear score dataset. However, it predicts the BW of the cow at a given time of lactation. In order to estimate the BW during lactation and parity, 10 coefficients for the correction with respect to lactation stage and parity were estimated. This work was carried out thanks to the dataset of individual measured BW and the whole national milk production national dataset. We studied the measured BW trend during lactation from 5 to 305 days. The days of lactation were divided into 10 classes, the first from 5 to 30 days and the others with a range of 30 days each, up to 305 days of lactation. An ANOVA was then performed where predicted BW was investigated based on class of stage of lactation by parity. Least square means were estimated and correction coefficients were derived. Predicted DMI (pDMI) was derived from milk yield, fat content, and cow estimated BW corrected for coefficients based on parity and lactation stage as follows (National Research Council, 2001):

$$\text{pDMI (kg.d}^{-1}\text{)} = (0.372 \times \text{FCM} + 0.0968 \times \text{BW}^{0.75}),$$

where FCM is 4 percent fat corrected milk (kg.d^{-1}). Fat-protein corrected milk (FPCM) was derived from milk yield corrected for fat, protein, and a fix coefficient for lactose content (Sjaunja et al., 1990):

$$\text{FPCM (kg.d}^{-1}\text{)} = (\text{milk}*(0.383*\text{FP})+(0.242*\text{PP})+0.7832)/3.140),$$

where milk is daily milk production (kg.d^{-1}), FP is fat content (%), and PP is protein content (%). Predicted feed efficiency (pFE) was estimated as ratio between FPCM and pDMI. A test-day repeatability animal model was applied. Fixed effects were herd-test-date and the interaction between parity and stage of lactation, and random effects were cow permanent environmental across lactation, additive genetic animal and the residual. Genetic parameter estimation was conducted using a subset of data extracted randomly in the Italian Holstein population (300 herds), and this procedure was repeated 5 times. Editing resulted in cows with lactation stage between 5 and 305 days in milk, with at least 2 test-day records and belonging to HTD classes with a minimum of 3 contemporary animals. Sires were required to have at least 5 daughters in 3 herds. The final dataset included 632,840 records of 39,574 cows and 1,434 sires. Pedigree (76,268 animals) consisted of individuals with records and their ancestors up to 6 generations back. Genetic parameters were applied to the entire test-day dataset to obtain estimated breeding values (EBV) for Predicted Feed Efficiency index (pFEi) on a score scale of 100±5 in order to make possible the comparison of pFEi with all other functional traits published by ANAFIJ. Pearson correlations between bull's EBV were estimated. Once EBV_for pFE was estimated we performed a genomic analysis to produce also genomic breeding values (gEBV) for this trait. In order to understand the definition of an efficient cow for a farmer, we run an analysis taking into consideration bulls with at least 800 daughters. We divided those bulls in 3 groups: 1) bulls with EBV for pFE >105, 2) bulls with EBV for pFE between 95 and 105, and 3) bulls with EBV for pFE <95. Within these groups phenotypic pFE was 1.32, 1.27 and 1.21 kg.d^{-1}, respectively. We considered 2 fixed parameters: milk price of 0.40 € per kg of milk and feed cost of 0.26 € per kg dry matter. Considering DMI = average daily FPCM production (30 kg) * average pFE (1.27), we compared 2 cows with the same DMI (23.62 kg.d^{-1}).

3 Results and discussion

Phenotypically, pFE, FPCM and pDMI averaged 1.27±0.18, 30.22±7.75 kg.d^{-1} and 23.30±3.14 kg.d^{-1}, respectively. All traits showed the same pattern through lactation for the 3 parity classes. Figure 1 depicts pFE trend through lactation for the 3 parities. First- and third-parity cows showed an increase in the first 60 days of lactation and a subsequent decrease. Second-parity animals showed a constant trend in the first 60 days and then decreased similarly to the other 2 parities.

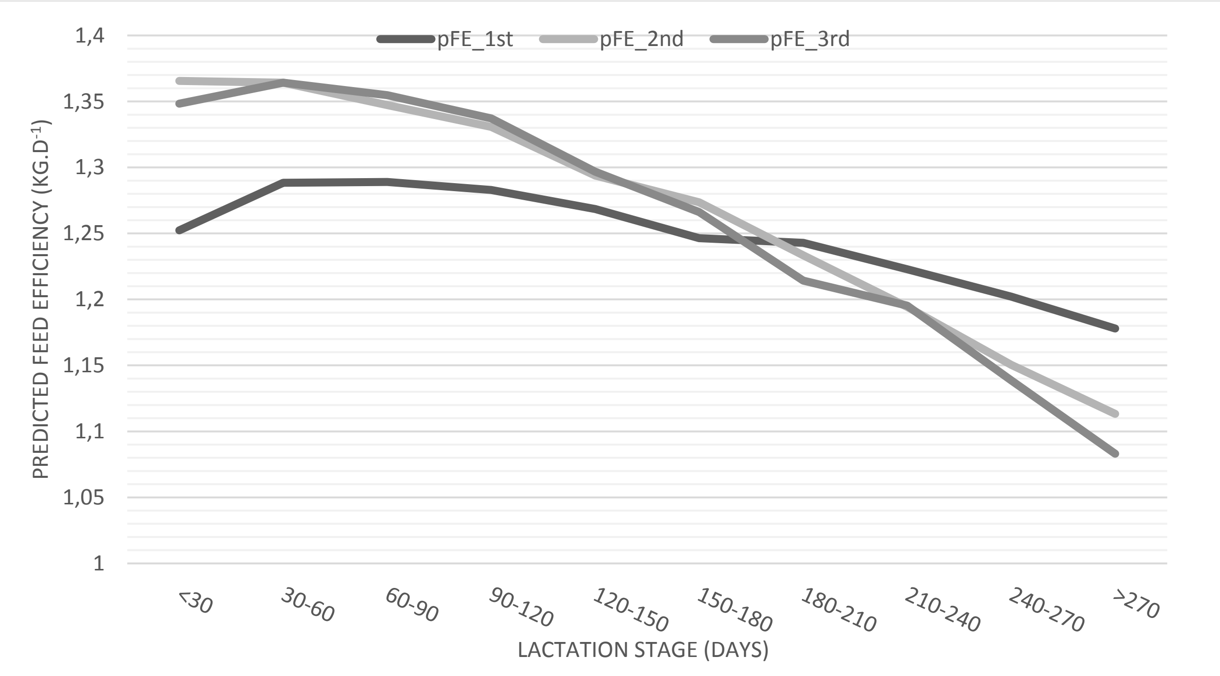

Figure 1 Predicted feed efficiency for Italian Holstein Friesian cow population in different parities

Heritabilities of pFE, FPCM and pDMI were 0.32, 0.33 and 0.31, respectively. Figure 2 shows the genetic trend of pFE for traditional and genomic breeding values. Phenotypic correlation between EBV for pFE and EBV for the official selection index of Italian Holstein Friesian cattle (Production, Functionality, Type – PFT) was 42%. Figure 3 reports EBV of bulls for PFT and pFEi. From both Figures 2 and 3 it is clear that selection has been indirectly addressed towards more efficient animals. Moreover, Figure 2 shows the phenotypic trend of bull's daughters and also in this case a positive trend is highlighted.

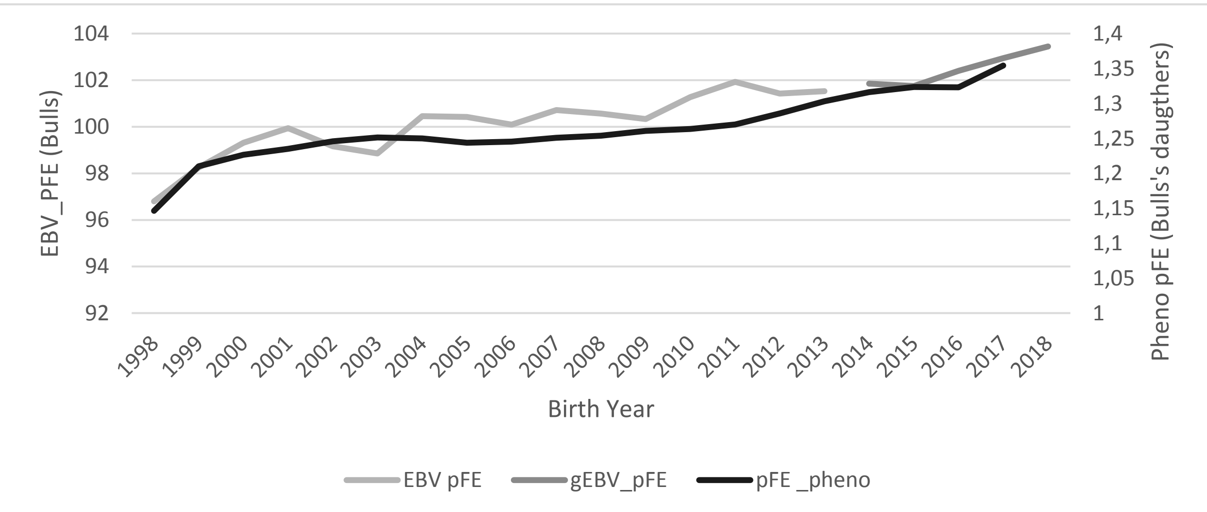

Figure 2 Genetic (EBV_pFE-100±5) and genomic trend (gEBV_pFE-100±5) for pFE of tested bulls, and phenotypic efficiency (pFE_pheno) of bulls' daughters

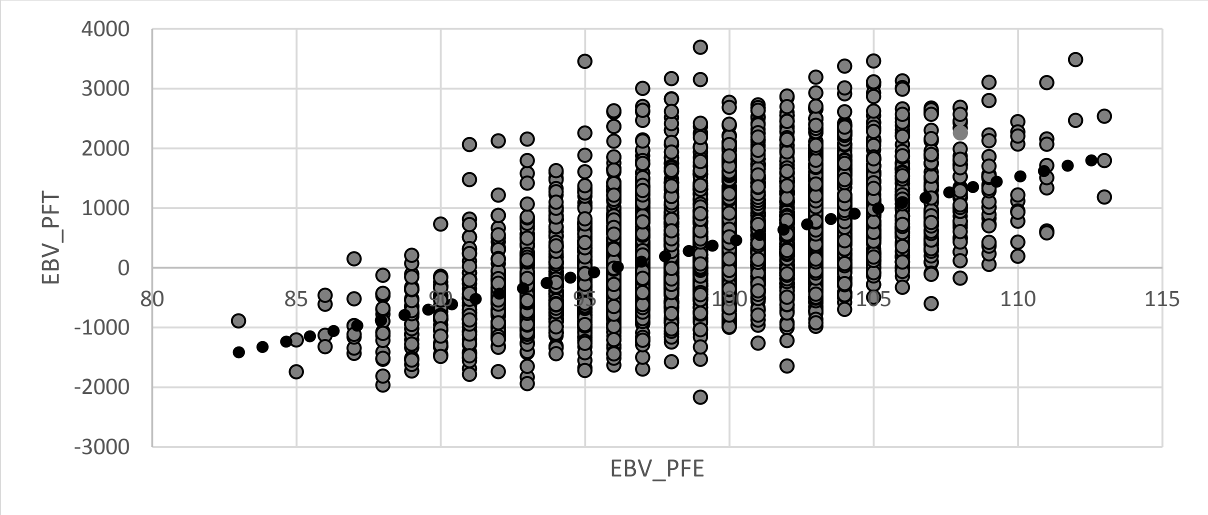

Figure 3 Correlation between EBV for pFE (EBV_pFE) and EBV for PFT (EBV_PFT). The PFT (Production, Functionality, Type) is the current official selection index of the Italian Holstein Friesian cattle

The pFE has already been adopted as an official index since December 2019 by ANAFIJ. An important point to take in account is the weight specific productive periods could have on pFE. In particular, during post-partum, negative energy balance is quite normal, especially for high producing cows. In fact, this peculiar physiological period is characterized by reduced DMI and mobilization of fat depots, turning in higher feed efficiency that could be misleading on the real efficiency of each individual cow (Hurley et al., 2018). Selection on feed efficiency has been correlated with higher negative energy balance. The latter is also implicated in health and fertility traits of dairy cows (De Vries and Veerkamp, 2000), for this reason it is important to investigate feed efficiency in relation to body condition score, reproductive and health-related indicators. Research is in progress at international and national level aimed to gather more accurate data to work on; in particular, in Italy a consortium is working to collect individual DMI data on heifers, cows and young bulls. The importance and the potential of selecting for feed efficiency is very high also at farm level. To give a very practical idea, a simple economic simulation on farmers value when selecting for highly efficient cows was made (Table 1) using milk price of 0.40 €/kg and feed cost of 0.26 €/kg dry matter: the results show that farmers' income could be increased up to 317 €/year/head.

Table 1 Farmers' returns of selecting for highly efficient cows. Milk price fixed at 0.40 €/kg and feed cost fixed at 0.26 €/kg dry matter

	MY (kg/day)	DMI (kg/day)	€ Milk	€ Feed	Profit	Comparison
High pFE cow	31.18	23.62	12.47 €	6.61 €	5.86 €	121.6%
Low pFE cow	28.58	23.62	11.43 €	6.61 €	4.82 €	82.3%
					1,04 €	39.3%
			x 305-day lactation		316.98 €	
			1 SD		~ 109 €	

pFE – predicted feed efficiency; MY - daily milk yield; DMI - dry matter intake; SD – standard deviation

4 Conclusions

In conclusion, the pFEi can further facilitate selection for feed efficiency in Italian Holstein Friesian cattle, a process started with the introduction of the PFT index (2002). At this stage pFE can be derived from the official recording system. The pFEi has already been adopted by ANAFIJ as an official index since December 2019. However, although the correlation between pFE and PFT is positive, the pFEi should be corrected for body condition score and reproductive performance to avoid any risks of selecting for animals with an excessive post-partum negative energy balance. Current efforts from an Italian consortium are aimed at increasing the accuracy of pFE phenotypes by gathering individual DMI data for heifers, cows and young bulls.

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