

Implementation of Ketosis breeding value in Italian Holstein

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Abstract

An increase of circulating ketone bodies is associated, particularly at the onset of the lactation, with (sub)clinical ketosis, which may reduce cows' health, production and increase culling rate. The aim of the current research was to develop a genetic evaluation for subclinical ketosis for Holstein dairy cattle using data routinely available from the national milk recording system and linear type classification. For this breeding value three traits were considered: 1) β -hydroxybutyrate (BHB), 2) fat-to-protein ratio (FPR), both measured during routine milk recording, and 3) linear body condition score (BCS) measured by a classifier. Both FPR and BCS were used as indicator traits for sub-clinical ketosis. Currently milk BHB and FPR were available on more than 2.2 million test-days records belonging to Holstein cows in the first 90 days-in-milk from first, second and third lactation. These records were subsequently matched to the closest linear classification date when body condition score (BCS) was scored. The pedigree of phenotyped cows was traced back up to 4 generations. (Co)variance components were estimated using trivariate linear mixed models; in particular, for BHB and FPR the fixed effects of herd-test-day, the two-way interaction between week of lactation and parity, and the three-way interaction between classes of age at calving, parity and year of calving were considered. The additive genetic effect and, only for BHB and FPR, the permanent environment were the random effects. Heritability estimates were 0.093, 0.090 and 0.157 for BHB, FPR and BCS, respectively, while repeatability estimates were 0.179 (BHB) and 0.209 (FPR). Phenotypically, milk BHB was positively correlated with FPR (0.279) and weakly with BCS (-0.038), similarly to the correlation estimated between FPR and BCS (-0.049). Milk BHB was genetically correlated with FPR (0.159) and BCS (-0.161), while the genetic correlation between FPR and BCS was -0.14. The results from the present study demonstrated the presence of exploitable genetic variation for breeding purposes resulting in EBVs.

Key words: breeding value, ketosis, Holstein

Introduction

At the initial phase of the lactation, high-yielding dairy cows often experience a period of negative energy balance, i.e. more energy is consumed than supplied by the energy intake (Häggman *et al.*, 2019). The energy balance is negative because consumption minus supply is negative. This results in body fat mobilization, reflected by a loss of body condition, and an

increase of circulating ketone bodies, particularly β -hydroxybutyrate (BHB). This physiological condition, known as hyperketonaemia, can result in (sub)clinical ketosis with adverse implications on milk production and cow functionality, including health and fertility.

The costly determination of individual fatty acids in milk creates barriers for grouping of

fatty acids into saturated, mono- and polyunsaturated fatty acids. Novel approaches include the potential of mid-IR (MIR) based predictions of BHB and acetone in milk, although the latter are not directly measured, but only estimated via indirect associations of concomitantly altered milk composition during (sub)clinical ketosis, use of these predictions at the population level and for groups of animals is considered reliable (De Marchi *et al.*, 2014).

The objective of the present study was to develop a genetic evaluation for resistance to subclinical ketosis for Italian Holstein dairy cattle using data routinely available from the national milk recording system and linear type classification.

Material and methods

Three traits were considered: 1) β -hydroxybutyrate (BHB), 2) fat-to-protein ratio (FPR), both measured during routine milk recording, and 3) linear body condition score (BCS). The latter two traits are considered as indicator traits. Milk BHB and FPR were available on more than 2.2 million test-days records belonging to Holstein cows in the first 90 days-in-milk from first up to the third lactation (Table 1). Very clear that Lombardy is the major dairy region. BCS was classified by an expert classifier and matched to the closest test-day record.

Table 1. Italian BHB phenotypic data by region of origin.

Area	Records	Percentage
Lombardy	7 001 708	76.90%
Veneto	1 066 378	11.71%
Emilia-Romagna	333 297	3.66%
Trentino-Alto Adige	189 381	2.08%
Apulia	135 561	1.49%
Piedmont	101 632	1.12%
Other regions	19 177	3.05%
ITALY	9 104 948	100%

The pedigree of cows was traced to at least 4 generations. Test-day records with a BHB

concentration of BHB ≥ 0.20 mmol/L are considered as affected by subclinical ketosis. For each lactation the highest value within 90 days is taken. BHB was normalized using a log conversion: $2 + \log_{10}(\text{BHB})$. (Co)variance components were estimated using trivariate linear mixed animal models; in particular, for BHB and FPR the fixed effects of herd-test-day, the two-way interaction between week of lactation (1-13) and parity (1-3), and the three-way interaction between classes of age at calving (1-9), parity (1-3) and year of calving were considered. The linear model for BCS included the fixed effects of herd-year-round of classification, year of calving and the two-way interaction between age at calving and stage of lactation. The additive genetic effect and, only for BHB and FPR (which resulted from multiple lactations), the permanent environment were the two random terms. The models hence were:

1. $\text{BHB} = \text{CGbhb} + \text{week} * \text{parity} + \text{age-class} * \text{parity} * \text{year-of-calving} + \text{animal} + \text{perm. environment} + e$
2. $\text{FPR} = \text{CGfpr} + \text{week} * \text{parity} + \text{age-class} * \text{parity} * \text{year-of-calving} + \text{animal} + \text{perm. environment} + e$
3. $\text{BCS} = \text{CGbcs} + \text{age} * \text{stage} + \text{year-of-calving} + \text{animal} + e$

where, CGbhb = contemporary group for BHB records (i.e., herd-test date); CGfpr = contemporary group for FPR records (i.e., herd-test date) and CGbcs = contemporary group for BCS records (i.e., herd-year-round of classification).

Due to computational constraints, (co)variance components were estimated on ten different subsets including 400 herds each, and subsequently averaged.

Results & Discussion

Phenotypes of milk BHB and FPR and BCS averaged 0.056, 1.152 and 2.99, respectively. Heritability estimates were 0.093, 0.090 and

0.157 for BHB, FPR and BCS, while repeatability estimates were 0.179 (BHB) and 0.209 (FPR) (Table 2). The genetic (phenotypic in parenthesis) correlations were 0.159 (0.279; BHB vs FPR), -0.161 (-0.038; BHB vs BCS) and -0.140 (-0.049; FPR vs BCS) (Table 3). The present study suggest that an exploitable additive genetic variation exists for milk BHB, and it could be used to set up breeding strategies aiming at improving resistance to subclinical ketosis through genetic selection. The indicator traits FPR and BCS have a modest contribution.

Table 2. Heritability and repeatability estimates with standard errors

Trait	Heritability	Repeatability
BHB	0.093 ± 0.01	0.179 ± 0.01
F:P ratio (FPR)	0.090 ± 0.01	0.209 ± 0.01
BCS	0.157 ± 0.02	

Table 3. Phenotypic (above diagonal) and Genetic correlations (below diagonal) between traits

rG \ rP	BHB	F:P ratio	BCS
BHB		0.279	-0.038
F:P ratio (FPR)	0.159		-0.049
BCS	-0.161	-0.140	

EBV for BHB were then standardized, as all functional indices in Italian Holstein evaluation, to have a mean of 100 and a standard deviation of 5, with values above 100 indicating animals more resistant to ketosis than the genetic base. Pearson correlations with all other single and composite traits were quite low, between -0.20 and 0.20 (Figure 1). This indicates that selection against ketosis does not have substantial conflicting effects on other traits. The actual realized genetic trend without any direct breeding against ketosis occurrence is shown in Figure 2.

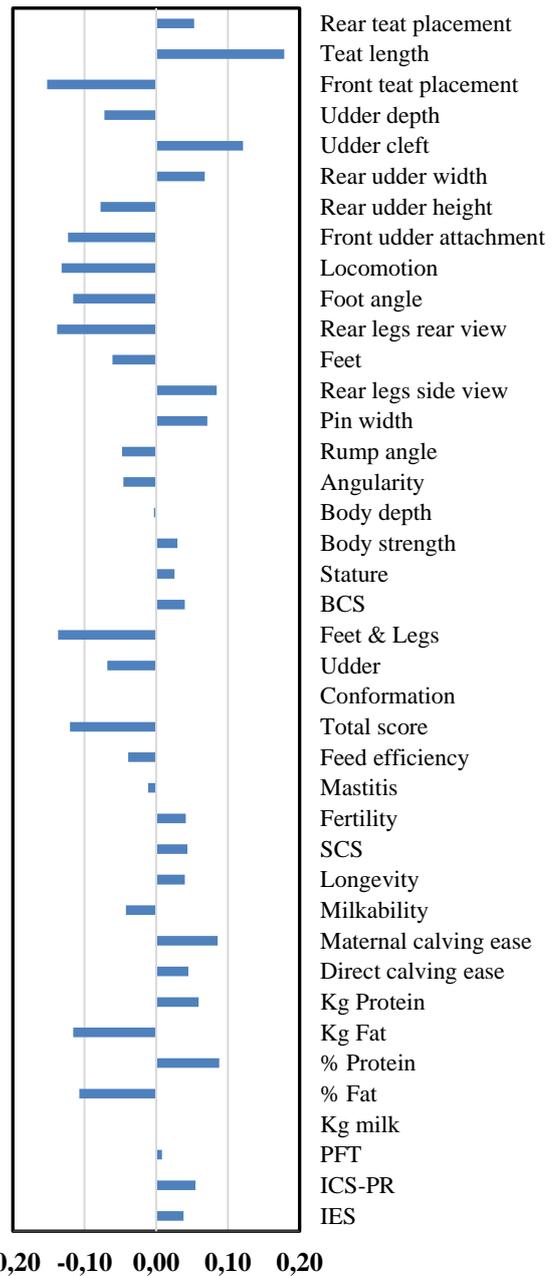


Figure 1. Correlations of the ketosis breeding value with single and composite traits.

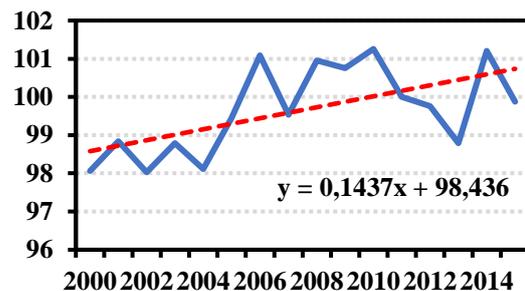


Figure 2. Modest positive genetic trend for ketosis in proven bulls

Stability of breeding values was verified by comparing correlations (Table 4) calculated as the correlation between standardized EBV for ketosis computed in the different runs based on date then available.

Table 4. Stability of the ketosis breeding values for proven bulls with reliability above 95%

	2104	2012	2008	2004	1912
2104	1	0.998	0.994	0.986	0.979
2012		1	0.994	0.987	0.981
2008			1	0.992	0.985
2004				1	0.991
1912					1

Conclusions

A ketosis breeding value has been developed for Italian Holsteins. For this breeding value three traits were considered: 1) β -hydroxybutyrate (BHB), 2) fat-to-protein ratio (FPR), both measured during routine milk recording in 3 lactations, and 3) linear body condition score (BCS) measured by a classifier. Correlations with all other traits were quite low, allowing for selection without adverse effects on other traits.

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