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Rebalancing breeding objectives towards the dairy cow of 2050: including methane and feed intake in selection Indices

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Introduction

Achieving Net-Zero emissions has become a central objective across many sectors, including livestock production. Ruminants play a unique role in agricultural systems, relying on natural and cultivated land while contributing methane emissions derived from microbial fermentation in the rumen. Both methane output and land use are recognised as anthropogenic sources of greenhouse gases. Although the accounting of livestock emissions in climate assessments remains subject to debate, there is broad scientific and technical agreement on the need to reduce emissions. Selective breeding has been proposed as one of the most efficient strategies to improve dairy cattle productivity and sustainability because it is permanent, cumulative and cost-effective. It exploits the genetic variation in production, health, feed efficiency and other traits related with sustainability (Gonzalez-Recio et al., 2014; de Haas et al., 2021a). Consequently, an increasing number of countries are incorporating methane emissions and feed efficiency into the breeding goals of their national improvement programmes. For instance, Jong et al. (2019) included feed cost in the maintenance index of the total merit index, and Gonzalez-Recio *et al*. (2014) and Pryce *et al*. (2015) defined farm cost as a trait in the Australian population. The inclusion of methane in the breeding goals has also been proposed in the selection indexes together with feed efficiency (Byrne *et al*., 2016; Amer *et al*., 2018; de Haas *et al*., 2021b; a), with potential economic and sustainability benefits in dairy populations. The availability of feed intake and methane related traits facilitate the development of selection indices that aims at reducing environmental impact while increasing productive efficiency. Hence, the objective of this study was to develop economic selection indices for several dairy production systems in Spain: conventional, cheese-oriented, and organic incorporating production traits, functional traits, and sustainability-related traits such as enteric methane emissions and feed intake. The weight in the index for each trait and the expected genetic gain were compared. Comparison with *business as usual* index was performed.

Materials & Methods

Economic values for the traits in the breeding objective were provided by CONAFE using the methodology described in (Charfedinne, 1998), and using updated prices from 2024. Economic value for methane was obtained based on carbon price projected to 2050 (standard and voluntary markets), using the average of the expected range. Selection index theory (Hazel, 1943) was used to develop total economic merit indices (IM€T) under three production systems for Spanish dairy cattle: conventional intensive (IM€T_milk), cheese focused (IM€T_cheese) and organic (IM€T_organic). Relative importance of each trait in the indexes was estimated as where b_i was the economic weight of the trait i and σ_i is the additive standard deviation of trait i. The expected annual genetic responses to selection under each index were predicted

according to (Hazel, 1943), and using average GEBV reliabilities for heifers and genomic bulls.

Results & Discussion

Trait relative weights in each index are shown in Table 1. Expected genetic responses per generation from each selection index are presented in Table 2. Genetic gains differed significantly for most traits depending on the selection index. The Benchmark index (business as usual without including sustainability traits of methane emissions and feed intake), generated the largest gains in production traits. Functional traits also improved moderately, although methane productions showed only minimal reduction of 2 g/day, whereas DMI would still increase 0.77 kg/day.

The inclusion of methane and feed intake in the breeding goals would substantially reduce the expected response in production traits, being even negative for milk in the cheese focus IM€T, and for fat in the IM€T for organic systems. However, they maintained positive gains for most functional traits. As expected, the largest differences were observed for methane and feed intake traits. Genetic gains towards the reduction of these traits for a milk system under IM€T selection was thrice those obtained in the benchmark scenario, whereas the expected reduction on methane production under organic systems was 8 folds. In terms of feed intake, IM€T indices that directly account for feed efficiency resulted in a negative expected genetic gain for DMI, which means a reduction of daily feed intake of almost 1 kg per cow (2 kg per cow under IM€T in organic systems). This is a reduction between 1.5 and 1.8 kg/day compared to the benchmark index. In terms of feed efficiency, the expected response would be favourable with a net positive increase of milk production and a reduction of feed intake, which implies a more efficient use of feed.

Table 1. Relative weight for each trait in each selection index, and average reliability of genomic estimated breeding value in the candidate population.

Trait[1]	Benchmark	Milk	Cheese	Organic	Average GEBV reliability
MILK	30.6	26.3	-12.8	24.2	0.77
FAT	10.5	9.4	25.6	5.8	0.75
PROT	17.5	14.1	23.2	4.9	0.63
LONG	22.7	18.2	16.5	19.3	0.54
LRCS	2.6	2.3	1.7	2.4	0.71
DA	9.1	8.1	5.3	8.5	0.64
VOR	2	1.7	0.9	2.4	0.85
ISP	1.4	1.4	0.8	2.3	0.43
ICAP	-0.2	0.1	0	0.1	0.69
MCE	3.5	3	1.8	4.3	0.41
METP	-	-1.6	-1.1	-11.7	0.15
DMI	-	-13.8	-10.2	-14.3	0.15

[1] MILK (kg milk per generation); FAT (kg fat per generation); PROT (kg milk per generation);LRCS (log of somatic cell score); MC (Clinical mastitis occurrence); ISP (feet and foot index); DO (days open); LONG (Longevity); METP (Methane production); DMI (Dry matter intake).

Table 2. Expected genetic gain per generation for each trait in the breeding goal, and overall profit, from each selection index.

		Scenario			
Trait[1]	Unit	Benchmark	Milk	Cheese	Organic
MILK	Kg per lactation	809	344	-141	38
FAT	Kg per lactation	20	2	18	-9
PROT	Kg per lactation	28	14	11	2
LRCS	Log somatic cell count	5	6	5	6
MC	Clinical mastitis occurrence (%[1])	0.00814	0.00887	0.00499	-0.0027
ISP	Feet and legs index	3.4	3	3	4
DO	Days open	2	5	6	7
LONG	Days of productive life	7	13	12	14
METP	g/d	-2	-7	-3	-16
DMI	Kg/d	0.766	-0.952	-0.8203	-2
Profit	€/cow/year	222	229	306	172

[1] MILK (kg milk per generation); FAT (kg fat per generation); PROT (kg milk per generation);LRCS (log of somatic cell score); MC (Clinical mastitis occurrence); ISP (feet and foot index); DO (days open); LONG (Longevity); METP (Methane production); DMI (Dry matter intake); PROFIT (€/cow/year).

Strong differences were also observed for longevity and fertility. Genetic progress on longevity increased between 59% with cheese focused IM€T. However, an unfavourable genetic response on fertility would be expected. An increase in days open of up to 7 days resulted for the IM€T for organic systems. This needs to be carefully taking into account as fertility has been subject of selection during the last 2 decades, in order to invert the decline in fertility due to intense selection on milk yield. Despite the economic optimization from the index selection theory on economic values, caution may be applied by increasing the relative emphasis on fertility traits.

The IM€T milk was used to compare expected genetic gain for profit compared to the benchmark scenario, as the same economic values were used. The net increase in profit was +6.4€/cow/year with the inclusion of METP and DMI in the breeding goals, regardless of a lower increase of milk, fat and protein yields. This is mainly driven by a relevant reduction of feed costs.

Under the Cheese index, which prioritises components over volume, genetic gain was redistributed from milk yield to fat and protein. Milk yield showed a negative expected change (–141 kg), while fat (+17.83 kg) and protein (+11.41 kg) remained favourable.

The Organic IM€T produced the most conservative production responses, with close to zero gains for milk and protein and negative genetic change for fat (–9 kg). This index places more emphasis on longevity, feed costs and methane production (-16g/d), despite the low reliabilities for methane and DMI EBV. This is due to the largest economic values assign in this index.

Conclusions

Overall, these results illustrate the substantial impact of index design on the direction and magnitude of expected genetic gains. Indices that put more emphasis on emissions (Organic) consistently achieved greater reductions in methane emissions and feed intake, while those focused on production (Benchmark, Milk, Cheese) maximised output traits and profitability. The patterns highlight the inherent trade-offs between production efficiency and environmental sustainability and underscore the importance of tailored breeding objectives for different production systems.

Sustainability and efficiency are complex concepts. Breeding dairy cattle has historically pursued improvements in efficiency (productive efficiency, feed efficiency, reproductive

efficiency). It needs to incorporate new challenges like sustainability and social acceptability. Selection indexes are tools that can accommodate to changing goals to modulate dairy cattle populations for a better global adaptation. The implementation of phenotyping systems for methane and dry matter intake that allows obtaining a reliable genetic/genomic evaluation of these traits is necessary. Some countries have already started to implement phenotyping strategies for these traits, although this is not routinely implemented yet. Optimal management of a reference population to allow implementing genomic selection should be a priority in the coming years.

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