MITIGATION OF GREENHOUSE GASES IN LIVESTOCK VIA GENETIC SELECTION: INCORPORATION OF METHANE EMISSIONS INTO THE BREEDING GOAL IN DAIRY CATTLE UNDER DIFFERENT SCENARIOS

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INTRODUCTION

One of the main challenges of dairy farming in Europe is to obtain profitable and sustainable product with lower greenhouse gas emissions (GHG). Livestock is responsible for 13% of GHG emissions (Leip et al., 2010). Methane (CH_4) from enteric fermentation represents the main source of these emissions, which also means a loss of energy for the cow and a waste of money for the producer. However, at present, GHG emissions are not included into the breeding goals in any livestock specie. This study aims 1) to include enteric CH_4 emissions in the breeding goal of Spanish dairy cattle and 2) to evaluate the expected genetic response of traits in the selection objective under different scenarios; i. Current ICO as benchmark (i.e. economic value for CH_4 emissions = 0), ii. Carbon tax on CH_4 emissions, iii. CH_4 emissions in a carbon quota and iv. CH_4 as a loss of net energy.

MATERIAL AND METHODS

Data. Production and economic parameters, including incomes and costs of the production system, were obtained from the Spanish Holstein Association (CONAFE).

Economic values. A detailed bio-economic model was computed in R software, to calculate the changes in benefits per cow per year in response to one unit of change in the biological traits of interest under study. The profit function was described as follows:

$$B\left(\frac{\frac{€}{cow}}{yr}\right) = R - C - C_{CH_4}$$

B is the benefit expressed in euro per cow per year, R and C are revenues and costs, and C_{CH_4} is the cost due to CH_4 emissions. The revenues include incomes from milk volume, fat and protein yield, as well as sales of calves and the culled cow.

Genetic parameters. The (co)variance matrix between the traits in the index, and the (co)variance matrix between the traits in the breeding goal and the index were provided by CONAFE, except for CH_4. Heritability of CH_4 and its correlation (genetic and phenotypic) estimates with other traits were obtained from the scientific literature (Kandel et al., 2017; Haque et al., 2015; Bell et al., 2016; Zetouni et al., 2018; Breider et al., 2018).

Response to selection. The annual response to selection was predicted for each scenario using selection index theory (Hazel, 1943), implemented in the software developed by J. van der Werf. Genetic parameters, the expected number of observations of the progeny, and the economic values of the traits in the aggregate genotype were used for this calculation.

RESULTS AND DISCUSSION

The estimated economic values were 0.01, 1.94, and 4.48 (€/kg) for milk, fat and protein yield. The economic values for CH_4, were negative:-1.21, -5.76 and -0.43 (€/kg) for scenarios 2, 3 and 4, respectively. The economic value estimated in the case of a carbon tax is close to the value reported by Bell et al., (2016) of -1.68 £ per kg of CH_4 (≃ 1.77 €/kg of CH_4).

The expected genetic responses under the four scenarios are presented in Table 1. Selection under the current benchmark scenario generates an increase in benefits of 43.51€ per cow and year. Incorporating CH_4 leads to a reduction of CH_4 emissions (kg/cow/year) in all scenarios by -31%, -156%, and -11%, respectively, with respect to the baseline scenario. On the other hand, the benefits (€/year) decrease by -0.35%, -8.33% and -0.04% for scenarios 2, 3 and 4 respectively.

Penalizing for CH_4 emissions through a carbon tax (i.e. scenario 2) resulted in shorter days open (DO) by 6%, and improvement of functional traits (Udder Composite Index (UCI) and Feet and Legs Index (FLI)) by 2%. However, somatic cell count (SCC) decreased by -8% and longevity by -16%. Moreover, there was a reduction in the annual response (-1%) for production traits (Milk, Fat and Protein).

In the case of a CH_4 quota (i.e. scenario 3), all traits tend to improve slower. The largest change in genetic gain was expected in longevity, SCC and milk yield. Restricting CH_4 emissions reduces the economic responses for all the productive and functional traits in the selection index between 10% to 82%, except for DO which resulted in an improved genetic response of -0.34 days/cow per year, in comparison to the benchmark scenario.

No change in genetic gain was found in the productive traits when CH_4 was included as a net energy loss cost in the selection index. Besides, this index resulted in a better fertility (+2%), and similar longevity and SCC with respect to scenario 1.

Figure 1 presents the relative importance of the traits in the selection index, which is the result of the product of the weighing factor with the genetic standard deviation of the trait and then divided by the total of all traits, expressed in percentage. The relative importance of CH_4 varies from 3% in scenario 4 to 28% in scenario 3. This shows that in a situation of carbon quota, CH_4 tend to be the second important trait after the protein.

In summary, scenario 2 would select for more fertile and efficient cows that have less CH_4 emissions, with a small repercussion on production and moderate impact on longevity and SCC. Scenario 3 results in selecting cows that are low emitting and fertile, but less productive with reduced lifespan. Scenario 4 leads to selecting more productive, fertile and efficient cows, with a slow reduction in CH_4 emissions compared to scenario 2 and 3.

In order to understand the consequences of selection including CH_4 emissions when some key parameters were changed, the sensitivity of response to selection was assessed considering different situations. i. varying the genetic correlations (GC) between CH_4 and the traits in the selection index by ±50%; ii. varying the economic weights (EW) of CH_4 in the selection index by ±50% and iii. considering the low and high scenario for the shadow prince of CO_2 in scenario 2. The results showed that in all the tested situations, the profit was insensitive, except for scenario 3 in which the profit was moderately sensitive when the EW and GC between CH_4 and other traits was increased by 50%. The most sensitive traits in terms of response to selection were longevity, SCC, DO and CH4 for all the scenarios, but this response was highly sensitive in scenario 3. Response to selection for productive traits (Milk, fat and protein) and functional traits (UCI and FLI) was insensitive to the changes, except for scenario 3 where the response ranges from -11% to +8% with respect to the same response in the baseline index.

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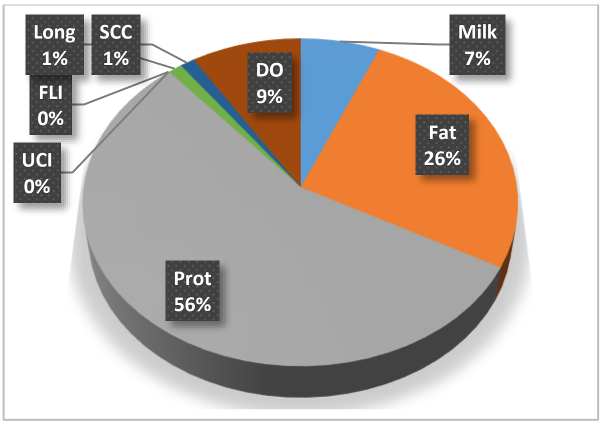
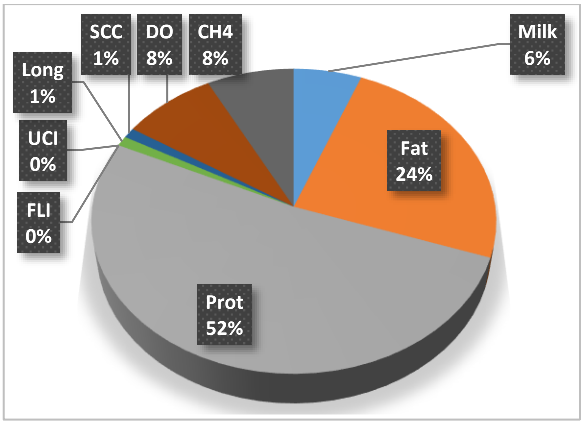
Table 1. Expected annual responses to selection (in units and €) for the traits in selection index per cow and per annum for the four scenarios

Item	Units	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Traits		Units	€	Units	€	Units	€	Units	€
Milk	kg	203.59	2.89	201.69	2.86	180.93	2.57	203.09	2.88
Fat	kg	5.98	11.59	5.94	11.50	5.37	10.39	5.97	11.56
Protein	kg	5.94	26.62	5.90	26.45	5.36	24.03	5.93	26.59
FLI	-	0.14	0.00	0.15	0.00	0.15	0.00	0.14	0.00
UCI	-	0.16	0.00	0.16	0.00	0.16	0.00	0.16	0.00
Longevity	days	0.31	0.06	0.27	0.05	0.06	0.01	0.30	0.06
SCC	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DO	days	-1.49	2.35	-1.58	2.50	-1.82	2.88	-1.52	2.40
CH4	kg	0.80	0.00	0.55	-0.66	-0.45	2.57	0.71	-0.30
Total profit (with CH4) (€)			43.51		42.69		42.46		43.19
Total profit (without CH4) (€)			43.51		43.36		39.89		43.49

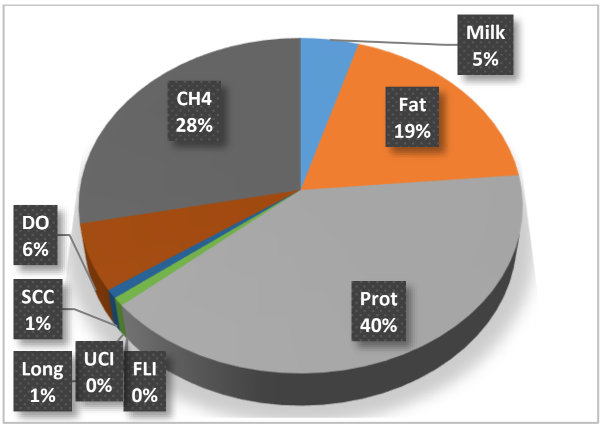
FLI: Feet and Legs index; UCI: Composite udder index; DO: Days Open; CH_4: Methane



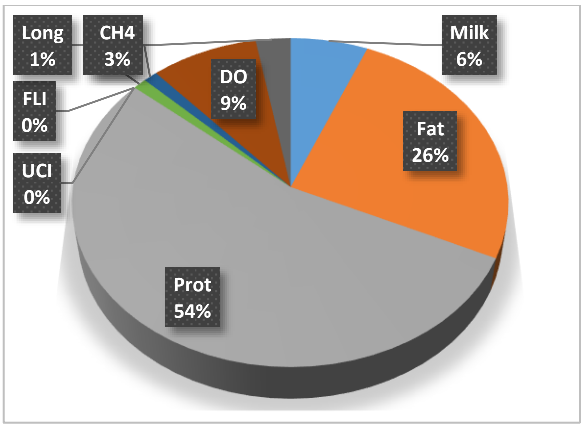
Scenario 1



Scenario 2



Scenario 3



Scenario 4

Figure 1. *Relative importance of traits in selection index for scenario 1, Scenario 2, scenario 3 and scenario 4*

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ABSTRACT
This study aimed to include CH_4 emissions in the breeding goal of dairy cattle, under foreseen scenarios that aim to reduce the carbon footprint of dairy cattle in terms of lower CH_4 emissions: i. Current situation as benchmark; ii. Penalization of CH_4 emissions through a carbon taxes; iii. CH_4 emissions in a carbon quota; and iv. Including CH_4 as a net energy loss cost. A bio economic model was developed to estimate economic values (EV) of milk production traits and CH_4 emissions. The estimated EV were 0.01, 1.94, and 4.48 (€/kg) for milk, fat and protein yield in scenario 1. For CH_4, the EV were -1.21, -5.76 and -0.43 (€/kg) for scenarios 2, 3 and 4, respectively. The incorporation of CH_4 to the baseline index, results in a response to selection for CH_4 emissions (kg/cow/year) in scenarios 2, 3 and 4 of 0.55, -0.45, and 0.71, respectively, while in scenario 1 the response was 0.80. On the other hand, the profit (€/year) decreases when an EV is attributed to CH_4 by -0.35%, -8.33% , and -0.04% for scenarios 2, 3 and 4 respectively, compared to scenario 1. This study showed that there is a potential in mitigating CH_4 emissions by genetic selection in dairy cattle, at expenses of lower genetic gain on the overall benefits.
Keywords: dairy, methane, selection index, bio economic model.