Towards new breeding tools in a context of climate change: Fertility results of the RUMIGEN project on new phenotypes for heat tolerance traits

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Abstract

RUMIGEN is a project financially supported by the EU that aims to develop breeding programs capable of managing the trade-offs between efficient production and resilience to extreme climate conditions. Previous results on heat tolerance indicators derived from milk recording data and meteorological information showed differences of magnitude of the effects and heat load threshold for heat stress between countries. In this study, we estimated the effect of heat load on fertility in three countries by analysing simultaneously fertility data registered from 2010 through 2020 in national reproductive recording systems and meteorological information from the closest to farm weather stations. More specifically, fertility data were defined as the success or failure in first insemination (CR) from first lactation Holstein cows in France (N=4,450,637), Spain (N=471,793) and The Netherlands (N=417,548) and from first lactation Montbéliarde cows (N=835,751) in France. The heat load was measured from the average of a temperature and relative humidity index (THI) in the day of the record and the seven days post AI. In all countries, the effect of heat load on CR was estimated using animal mixed models including a class effect for THI values together with other fixed and random effects used in national fertility evaluations. Heat stress thresholds and slopes of decay in CR after the threshold were estimated from THI effect solutions using segmented regression models, assuming a fixed number of break-points. Considering a single heat stress threshold (value after which a considerable reduction in CR is observed) showed that this threshold is around 70 for THI in all countries. Slopes of decay in CR did show substantial differences across countries, ranging from 0.79 points per degree of THI in Holstein cows in Spain to 2.25 points per degree of THI in Holstein cows in France.

Keywords: heat tolerance, breeding criteria, dairy cattle.

Introduction

Climate change is spurring demands from farmers to provide tools to adapt animal production to increasing temperatures. Developing new breeding strategies to help ruminants to adapt to climatic changes is one of the goals of the Rumigen project (https://rumigen.eu/), financed by the EU. A first step in breeding programmes is to find measures for the desired selection objectives. In this context, using already available information in breeding schemes, such as productive or reproductive performance of animals to produce heat tolerance indicators is appealing, since no additional cost would be required for the introduction of this new selection objective. Joining performance recording with meteorological information around the date of recording to estimate the response of animals to changes in heat load was initially proposed by Misztal *et al*. (1999) and later developed in many populations. Previous to implementation of genetic evaluations of individual heat tolerance, knowing the overall response to heat load in the target population is needed to quantify the heat stress impact and the characterisation of heat stress (HS) thresholds and productive loss. In a previous contribution within the Rumigen project, Mattalia *et al*. (2022) evaluated differences in response to increased heat loads for production and udder health traits in a range of dairy cattle populations across Europe. Different patterns across countries and breeds were found, probably associated with differing climatic characteristics and production systems. Reproductive performance is also a highly important trait for animal production which is negatively affected by HS (Hansen, 2009). In this study, our goal was to compare patterns of response in reproductive performance to increasing heat loads across dairy cattle populations in Europe as a previous step to establish heat tolerance phenotypes for selection.

Material and methods

Historical data from years 2010 through 2020 including artificial insemination (AI) results were provided by breeder associations (France Génétique Elevage for Holstein France = HOL-FRA, and for Móntbeliarde = MON-FRA, CRV for Holstein Netherlands = HOL-NLD and CONAFE for Holstein Spain = HOL-SPA). Conception rate (CR) for each insemination was coded as success or failure using country rules for routine genetic evaluations of this trait. After edits for abnormal data and selecting records from first inseminations in first lactation, 4,450,637/ 417,548/471,793/835,751 records were available for HOL-FRA/HOL-NLD/HOL-SPA/MON-FRA, respectively.

Meteorological data to match with AI dates were provided by the national meteorological agencies (Météo-France (Safran database) for France, the Koninklijk Nederlands Meteorologisch Instituut (KNMI) for The Netherlands and National Meteorological Agency (AEMET) for Spain). Daily average and relative humidity were the meteorological variables used to compute a combined temperature and humidity index (THI) according to the formula by NRC (1971):

$$THI = (1.8*T+32) - (0.55 - 0.0055*RH)*(1.8*T - 26)$$

with T being the average daily temperature (degrees Celsius) and RH the average daily relative humidity (in percentage).

According to previous results (not shown), the average of THI values for the day of AI and the seven days after AI was used to define the heat load used in the subsequent models to analyse its effect on fertility.

The effect of THI on CR in each population was obtained by using the following statistical model:

$$y = X_1 hl + X_2 \beta + Z_1 a + e \quad [1]$$

where y, hl, β, a and e are the vectors of phenotypes (CR at first insemination in first lactation), heat load (class for average THI for days 0 and subsequent seven days after AI), other environmental effects, cow additive genetic and the random residuals, respectively, and X1, X2, Z1 and Z2 are the corresponding incidence matrices.

Other environmental effects included in all countries were the herd-year of calving effect (random effect in Spain), class of interval from calving to first insemination, and age at calving, and, day of the week (France and The Netherlands), service sire (France and The Netherlands), sexed semen class (France and The Netherlands), season of calving (France), year-month of calving (The Netherlands) and age of service sire (The Netherlands).

Variance components and the different effects were estimated with software commonly used in animal breeding.

From estimated THI effects (one per THI unit) in equation [1], a smoothed curve was fitted using a cubic polynomial. Change points (CP) and slopes of decay (slp) after the CP were estimated using the R package "Segmented" (Muggeo, 2008) in order to provide values for HS threshold and fertility loss associated with HS.

Results and discussion

Figure 1 shows the estimated THI effects in equation [1] and the polynomial smoothed fit used to estimate change points and slopes of decay under HS.

Figure 1 shows that the response to increasing values of THI corresponds to the classical response in the broken line model defined by Misztal (1999), with a thermoneutral region where no response to increases in heat load is observed followed by a HS region where the negative impact of HS can be observed. For the different populations, different HS thresholds for THI and slopes of decay were observed, although to a smaller extent to differences in the pattern of HS response in production traits observed in Mattalia *et al.* (2022) for the same populations.

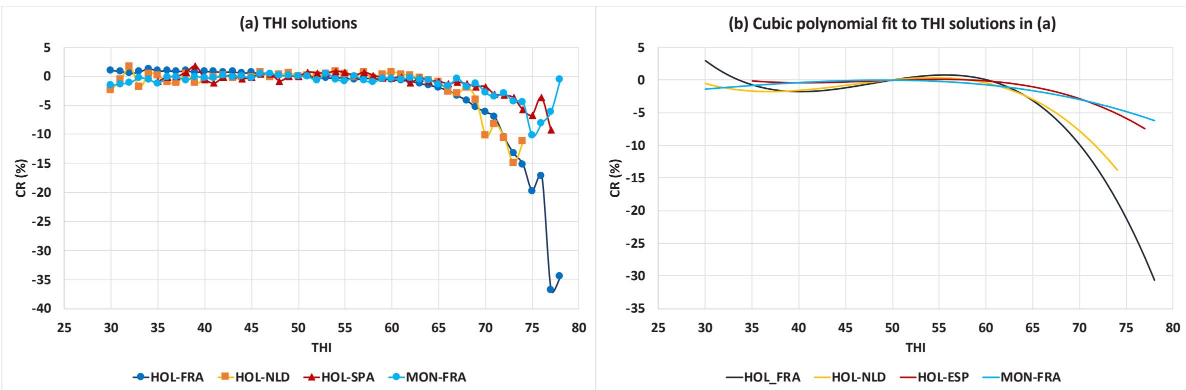

Figure 1. (a) Estimated effects for the temperature and humidity index (THI); (b) Cubic polynomial fits for the estimated THI effects used in the change point analyses.

Table 1. Estimated change point and subsequent slopes of decay obtained from the response curve of conception rate (CR) to the temperature and humidity index (THI).

Breed-Country	Change point (THI)	Slope (%CR/unit THI)
HOL-FRA	63	-1,29
HOL-NLD	62	-1,04
HOL-SPA	64	-0,51
MON-FRA	61	-0,48

Table 1 presents the estimated change points and subsequent slopes of decay under heat stress for each population. Estimated change points were similar across populations, with values ranging from 61 to 64 for HS thresholds. Our estimates of HS thresholds are similar to that reported by Gernand *et al*. (2019) for pregnancies per AI in Germany and Biffani *et al*. (2016) for non-return rate (NRR) in Italy, and smaller to the estimated thresholds found also for NRR by Ravagnolo and Misztal (2002) in the USA and Santana *et al*. (2017) in Brasil. The estimated HS thresholds were higher/similar/smaller for CR than the values obtained for production traits for the French (HOL, MON)/Dutch (HOL)/Spanish (HOL) populations participating in this study, respectively (Mattalia *et al*., 2022).

Loss in CR due to HS, depicted by the slopes of decay, was substantially larger for HOL-FRA and HOL-NLD (around 1% decrease per THI unit above the threshold) than in HOL-SPA and MON-FRA (around 0.5%) (Figure 1; Table 1). Acclimation of cows to chronic HS during summer and heat abatement in the barns in the Spanish population might explain these results. In the case of MON-FRA, lower productive levels than Holstein cows might result in less compromised energy balance and better fertility under HS.

Conclusion

This study provided base results for the development of breeding schemes that include heat tolerance as a selection objective in terms of modelling and quantification of heat stress response on fertility in European dairy cattle populations. The pattern of response agrees well with broken line models defined by a HS threshold and a subsequent slope of decay. HS thresholds (61-64 THI degrees) were similar across dairy populations but decays were substantially different, with a smaller impact for the population in Southern areas with chronic HS in summer and in barn heat mitigation devices and for a less intensively selected breed than Hosltein cattle.

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