Genetic variation in resilience to climate effects on beef carcass traits

H. Bunning[1*], E. Wall[1]

[1] SRUC, Edinburgh, UK, EH9 3JG; [*]harriet.bunning@sruc.ac.uk

Abstract

Breeding climate resilient cattle is an important strategy to mitigate the effects of climate change (Doeschl-Wilson et al., 2019). Resilience of beef cattle is less well understood compared to dairy, especially in temperate climates. This study aims to compare resilience to climate, both average weather and extreme weather events, for carcass weight, age at slaughter and carcass growth rate. Linear models were used to analyse these traits in over 1.7 million records from UK abattoirs. Resilience was estimated using regression coefficients for interactions between breed type and weather parameters. Results show variation between breeds for resilience to climate with British breeds showing the greatest resilience. Our results suggest an increase in heatwaves by 1 per 100 days of life would reduce cold carcass weights of dairy and continental animals by about 150g but increase that of British breed animals by about 360g.

Introduction

Climate change is a challenge facing livestock production globally and mitigation strategies are needed to reduce its impact (Rojas-Downing et al., 2017). The impact of climate change is already seen in tropical climates, but we also expect a significant impact in temperate regions (Wreford and Topp, 2020). Climate resilience is the capacity of the animal to be minimally affected by changes in the climate and there is good evidence of genetic variation for this trait (Doeschl-Wilson et al., 2019).

Between-breed variation in climate resilience has been shown for a range of weather parameters and traits in cattle. Variation in resilience to heat stress is well documented, particularly in the tropics between tropically adapted *Bos indicus* breeds and less adapted *Bos taurus* breeds. For example, extreme heat led to reductions in dry matter intake in taurine Angus cattle, but no significant change in indicine Brahman cattle (Gaughan et al., 2010). In temperate climates, studies have shown variation in the effect of climate on dairy cattle traits, where high producing dairy breeds, particularly Holsteins tend to be less resilience to heat stress than other more robust breeds, such as Simmentals (Gantner et al., 2017) or Jerseys (Bryant et al., 2007).

Climate resilience for beef traits, particularly in temperate systems, is less well understood. This study aims to compare how carcass traits are affected by weather across beef and dairy breeds. For traits expressed repeatedly over time, the effect of weather can be seen within an individual, allowing estimation of individual lifetime resilience by, for example, fitting reaction norm functions (Sánchez-Molano et al., 2019). However, carcass traits are typically measured at the end of life so this is not possible. We also investigate grouping offspring by sire to produce a slope for each sire, which could be used as phenotypes in genetic analysis.

Materials & Methods

We analysed data of over 1.7 million slaughter records (2000-2019) from UK abattoir companies (Pritchard et al., 2021). Traits included cold carcass weight (CCW) and age at slaughter (AAS). A measure of daily carcass growth rate was calculated by dividing CCW by AAS (CGR). Breeds were grouped into 3 types: British beef, continental beef and dairy. Other data about animals were extracted to use as factors and covariates in the model. Sex was defined using data from the abattoir as castrated male, female or entire male. We also included age of the dam and the proportion of dairy breed in the dam's pedigree (Pritchard et al., 2021). We accounted for varying management practices, which might be regionally distributed and linked with weather, by including two contemporary groups in our model: Birth herd-year-season (HYS) and Finishing (HYS). Only animals in groups containing more than 4 were included. Location of death (i.e., abattoir) was also included.

We used weather data from the Met Office HadGrid-UK database, a data set of gridded climate variables derived from the network of UK land surface observations (Perry and Hollis, 2004). This was combined with animal locations and dates of stay, allowing the calculation the average daily maximum temperature (Tmax), average daily minimum temperature (Tmin) and average daily precipitation (Rain) for the lifetime of each animal. Daily weather was also used to define the occurrence of extreme weather events, including heatwaves (at least 3 days maximum temperature over threshold of 28°C, 27°C, 26°C or 25°C, depending on region), coldwaves (at least 3 days maximum temperature under 0°C), dry days (less than 0.12mm rainfall) and wet days (more than 7.65mm rainfall). The frequency of each extreme weather event for an animal was calculated by dividing by AAS.

Analyses were carried out using linear fixed effect models using AS-REML (Butler et al., 2018) and R. Two models were produced for each trait to assess the resilience of each breed group (i) to average weather and (ii) to frequency of extreme weather events. Interaction effects between breed group and the weather parameter were fitted. For CCW, AAS was included as a covariate and for AAS, CCW was included as a covariate. We expected interactions between weather to be important so an interaction between Tmax and Tmin and another between Tmin and Rain were included in the average weather models. The generalised model was therefore:

*Trait ~ weather parameters*breed group* + *other traits* + sex + breed + BirthHYS + FinishHYS + death location + dam age + dam % dairy (1)

To compare the genetic potential for resilience of different sires, we selected Limousin animals with a sire with more than 4 offspring. After edits, the data consisted of 1,945 animals with 237 sires. 94% of records were lost for lack of sire information and small contemporary group sizes. We fitted an interaction between sire and number of heat wave days in our model for CCW. The solutions give an indication of the genetic value for climate resilience of each sire, where sires with values closer to zero can be considered more resilient.

Results

Average Weather. CCW increased for animals which experienced higher Tmin and Tmax and lower Rain. For CCW, continental breeds were least affected by changes in Tmin but most affected by changes in Tmax and Rain (Table 1). Animals which experienced higher Tmin and Rain but lower Tmax were younger at slaughter. For AAS, the most affected breed group varied across the different weather parameters. British breeds were the most affected by changes in Tmin, dairy breeds the most affected by Tmax and continental breeds the most affected by Rain. Animals which experienced higher Tmin, lower Tmax and lower Rain tended to have to have a greater CGR. For this trait, dairy cattle were affected more by changes in all three parameters (Tmin, Tmax and Rain) than the other breed groups.

Table 1. Regression coefficients (and standard errors) for each level of breed group with lifetime average daily weather parameters.

		British	Continental	Dairy
CCW	**Tmin**	2.44 (0.37) ^{ab}	2.22 (0.37) ^{a}	2.99 (0.37) ^{b}
(kg)	**Tmax**	1.16 (0.16) ^{ab}	1.46 (0.15) ^{a}	1.02 (0.16) ^{b}

	Rain	-1.14 (0.45) [a]	-2.26 (0.44) [b]	-0.90 (0.45) [a]
AAS (days)	**Tmin**	-2.59 (0.54) [a]	-2.04 (0.53) [ab]	-1.19 (0.54) [b]
	Tmax	10.18 (0.23) [ab]	9.94 (0.22) [a]	10.50 (0.23) [b]
	Rain	-19.56 (0.65) [a]	-21.19 (0.64) [b]	-19.15 (0.65) [a]
CGR (kg/day)	**Tmin**	0.000944 (0.00067) [a]	0.000169 (0.00066) [a]	0.00242 (0.00067) [b]
	Tmax	-0.00549 (0.00028)[ab]	-0.00499 (0.00027) [a]	-0.00577 (0.00029) [b]
	Rain	0.00819 (0.00080) [a]	0.00732 (0.00079) [a]	0.0100 (0.00081) [b]

[abc] Values with difference letters within a row are significantly different from one another other ($p<0.05$).

Extreme Weather Frequency. CCW tended to be greater for animals which experienced lower extreme weather frequencies, although there were some differences between breed groups (Table 2). An increased frequency of heat waves had negative effects on the CCW of both continental and dairy breeds, but a positive effect in British breeds. Conversely, an increased frequency of extreme dry days had positive effects on both continental and dairy but a negative effect on British breeds. An increased frequency of extreme wet days had negative impacts on CCW of all breed types, but continental and dairy breeds were significantly more affected than British breeds. Animals which experienced more frequent extreme weather tended to be older at slaughter, although British breeds were less affected by heat waves and wet days, whereas dairy breeds were least affected by dry days. For CGR, increased growth rates were seen when animals experienced lower frequencies of extreme weather across breed types. British breeds were less affected by heat waves and wet days, but more affected by dry days than continental and dairy breeds.

Table 2. Regression coefficients (and standard errors) for each level of breed group with frequency of extreme weather days.

		British	Continental	Dairy
CCW (kg)	**Heatwave**	36.48 (9.52) [a]	-14.95 (8.402) [b]	-15.47 (10.48) [b]
	Dry	-2.585 (2.152) [a]	25.86 (1.945) [b]	12.52 (2.293) [c]
	Wet	-15 (1.369) [a]	-26.19 (1.159) [b]	-25.62 (1.402) [b]
AAS (days)	**Heatwave**	38.3 (13.8) [a]	54.3 (12.2) [a]	172.2 (15.2) [b]
	Dry	133.0 (3.1) [a]	142.6 (2.8) [b]	108.9 (3.3) [c]
	Wet	20.6 (2.0) [a]	35.5 (1.7) [b]	14.5 (2.0) [c]
CGR (kg/day)	**Heatwave**	-0.0019 (0.0171) [a]	-0.0974 (0.0151) [b]	-0.0728 (0.0188) [b]
	Dry	-0.0647 (0.0039) [a]	-0.0348 (0.0035) [b]	-0.0290 (0.0041) [b]
	Wet	-0.0225 (0.0025) [a]	-0.0339 (0.0021) [b]	-0.0346 (0.0025) [b]

[abc] Values with difference letters within a row are significantly different from one another other ($p<0.05$).

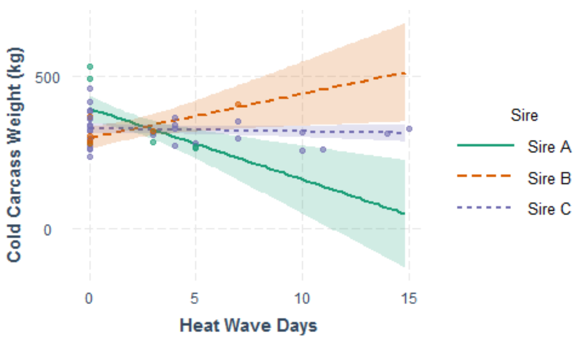

Figure 1. The effect of heat wave days on CCW for offspring of three sires. Solutions for the interaction term are used to produce the slopes of the lines with 95% confidence intervals illustrated by the shaded regions.

Sire Resilience. Results showed that the interaction between sire and number of heat wave days had a significant effect on CCW. The solutions varied between -18.24 (s.e. 14.70) and +12.67 (s.e. 9.01) although the standard errors were large. A sample of slopes for three sires are shown in Figure 1. Here, results suggest that the CCWs of offspring of sires A and B are more affected (although in opposite directions) than sire C. Sire C has a higher genetic value for resilience as the slope is closer to 0.

Discussion

Results show variation between breeds for resilience to climate for CCW, AAS and CGR, both for average weather across the lifetime of the animal and frequency of extreme weather events. We might expect the British breeds to show more resilience as they are thought to be more robust and typically less strongly selected for production traits, which may lead to higher resilience. There is evidence in dairy cattle that animals with lower production levels may be more resilient (Gantner et al., 2017). Our results broadly follow this expectation, with British breeds coefficients being closer to 0. In particular, the positive correlation between heat wave frequency and CCW in British breeds suggests that these breeds may be less affected by heat stress compared to continental and dairy breeds. Results suggest an increase in heatwaves by 1 per 100 days of life will reduce CCWs of dairy and continental animals by about 150g but increase that of British breed animals by about 360g.

In addition to physiological differences between these breeds, its important to consider that these differences may also reflect varying management strategies. For example, the positive correlation seen between dry day frequency and CCW for dairy and continental breeds (rather than the negative seen for British breeds), may show that dairy animals are less likely to have a forage-based diet, rather than having a genetic resilience. To account for this, we can compare offspring of sires within a breed. Our preliminary results suggest there is variation between the genetic value for resilience of sires. However more offspring per sire may be needed to test if resilience is significantly different between sires within and across breeds.

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