Genetic and environmental effects on fitness traits in dairy cattle

Eileen Wall, Mike Coffey and Marie Haskell
Sustainable Livestock Systems Group, SAC, Edinburgh

Talk outline

- Introduction
- Genotype × environment interaction in the Langhill lines of cows for fitness traits
  - Production, health and fertility, body energy
- Effects of management system characteristics on fitness traits
- The future "fitness" traits

What is fitness?

- Fitness =
  - Evolutionary theory: capability of an individual of certain genotype to reproduce compared to other genotypes
    - proportion of the individual's genes in all the genes of the next generation
- Limitations to the "fitness" of a genotype include:
  - Direct: fertility, longevity
  - Indirect: health, production

Aim

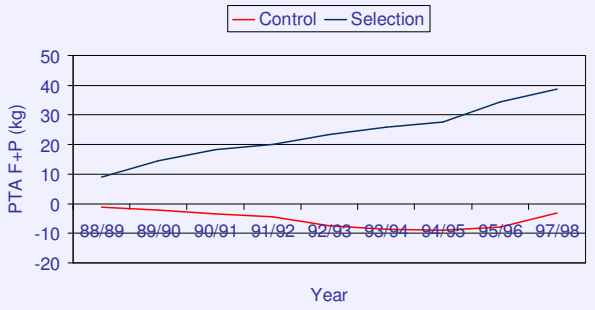
- This talk will describe some of the genetic and environmental effects on fitness traits

Langhill Lines of Dairy Cattle

Langhill cows

- Langhill dairy selection experiment established in 1973
  - Consequences of long term selection for production on biological & system parameters
  - Select line: cows mated to 4/5 bulls with the highest PTAs kg fat + protein
  - Control herd (1976): national average merit
  - Environment (1988): high and low input system (2×2 design)

PTA F+P Langhill select & control lines



Differences between the genetic lines

- Biological and economic consequences of selection for production
  - Higher yield (17%)
  - Higher intake (5%)
  - Lower body condition score (5%)
  - Higher gross efficiency (14%)

Veerkamp et al., 1995, BSAS Occasional Mtng

Differences between line & system

- Consequences of selection in a high and low input system

	High input		Low input		
	Select	Control	Select	Control	
Daily milk (kg)	32.9	26.6	27.2	22.7	**
Dry matter intake (kg)	17.0	15.0	16.1	15.0	*
Liveweight (kg)	603	592	588	587	
Condition score (1-5)	2.35	2.55	2.26	2.51	

Veerkamp et al., 1995, BSAS Occasional Mtng

Differences between line & system

- Consequences of selection in a high and low input system

	High input		Low input	
	Select	Control	Select	Control
305d milk	9,250	7,520	8,660	6,870
£/cow	1,285	986	1,287	1,005

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits
  - Fertility
  - Health
  - Body tissue mobilisation

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits on **fertility**

	Select	Control	
1st service conceptn	0.39	0.45	*
Calving interval	395	384	**
Days to 1st heat	53	42	***
Days to 1st service	77	72	***
Days open	124	107	***

Pryce et al., 1999

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits on **fertility**

	Select	Control	
1st service conceptn	0.39	0.45	*
Calving interval	395	384	**
Days to 1st heat	53	42	***
Days to 1st service	77	72	***
Days open	124	107	***

- No genotype × system effect

Pryce et al., 1999

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits on **fertility**

	Select	Control	High	Low	Gen	Sys
Calving interval	410	405	404	412		*
Days to 1st service	85	78	82	81	*	
Number of services	2.32	2.36	2.26	2.41		*

- No genotype × system effect
- Fewer years of records
- Larger system differences

Wall et al., *in prep*

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits on **fertility** (progesterone)

	High	Low	Sys	Gen
Luteal phase (days)	9.79	10.81	*	
Inter luteal phase (days)	4.94	4.42	*	

- Samples taken from all cows from Sept 03 - Aug 05
- Low input cows had a longer luteal phase (~1 day)
- High input cows had a longer inter-luteal interval (~0.5 day)
- Differences partially cancel each other out to give no difference in cycle length

Pollott et al., *in press*

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits on **health**
- No significant line or system (or interaction) effects for health disorders
  - Low incidence
  - Suggestive that there is poorer health (SCC, mastitis, calving ease) in the select line compared to control line and in the high input cows compared to the low input cows

Wall et al., *in prep*

Summary of Langhill results

- Genetic, environmental and G×E effect in production traits and overall profit
- Genetic and environmental effect in some fertility traits
  - Genetic line effect in the commencement of luteal activity as measured by progesterone
    - Differences independent of body condition
- Suggestive genetic effect in health traits

Body tissue mobilisation

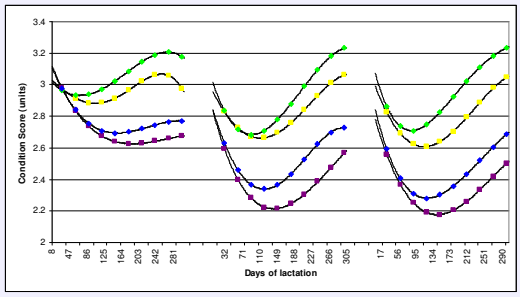
- Previous selection policies that emphasised production have led to a greater reliance on body tissue to support lactation
- Many studies have shown that cows lose body energy early in lactation which can lead to poorer health and fertility
- Body energy state may create a legacy affecting current and future fitness

Differences between line & system

- Consequences of selection in a high and low input system on fitness traits on **body tissue mobilisation**
  - Condition score: method of assessing body reserves (1-5)

Body condition score

low input control (- ■ -) low input select (- ■ -),
high input control (- ◆ -) high input select (- ◆ -).



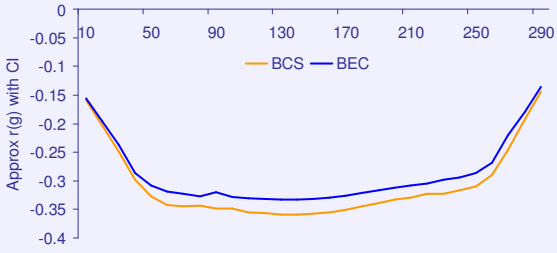
Coffey et al., 2002

Body tissue mobilisation

- Condition score
  - Method of assessing body reserves (1-5)
- Select line cows mobilise more body tissue
  - For every 1 unit increment in yield of fat plus protein, only 0.5 unit increase in intake
  - Body tissue mobilisation is related to fitness traits
    - thinner cows, or those that lose more condition, have poorer reproductive performance

Correlation with fertility (calving int.)

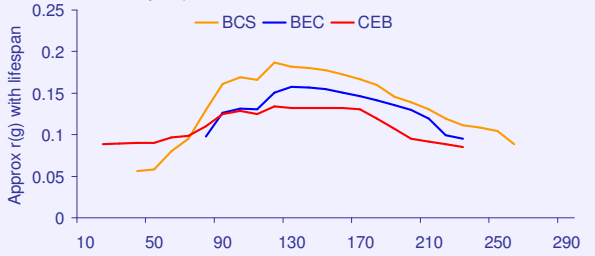
- Body condition score (BCS) and energy content (BEC) unfavourably correlated with fertility (thinner cows, poorer fertility)



Wall et al., 2007 s.e. = 0.035-0.05

Correlation with longevity

- BCS, BEC and cumulative energy balance (CEB) unfavourably correlated with longevity (thinner cows, shorter lifespan)



Wall et al., 2007 s.e. = 0.035-0.05

Body tissue mobilisation

- Genetic, environmental and G×E effect on body tissue mobilisation
  - Genetic differences in how the cows utilise body energy in national data (Wall et al., 2005)
- Correlated to traditional "fitness" traits
  - Negative energy balance in first lactation is related to shorter lifespan
- Useful indicator of "fitness"
  - Included in UK (& other) dairy breeding index

Management effects on fitness traits

Management effects on fitness traits

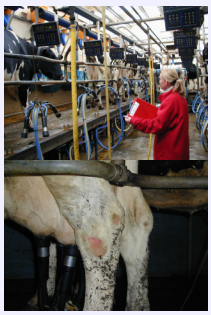
- There is a diversification of dairy farming systems in the UK
  - Intensive vs Extensive
- Trend that intensive systems are continuing to increase intensification
  - Zero-grazing systems, increasing mechanisation (e.g. robotic milking), increasing herd size
- What management factors are impacting on health and welfare of the dairy cow?

Environmental factors (housing)

- A farmer questionnaire was sent out to over 300 volunteer farmers and ~ 110 returned
  - PCA analysis identified that housing type and production level were classifying factors
- Five main groups of farm types
  - Cubicle housing: high production
  - Cubicle housing: medium production
  - Cubicle housing: low production
  - Straw courts: medium production
  - Zero grazing, cubicle housing, high production

Haskell et al., 2006

Lameness and injury

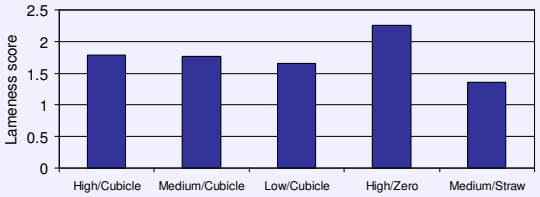


- Visited 37 farms across the UK
- 5-day visit to take a range of behaviour and health-related data
- Scored locomotion/lameness on a 1-5 scale
  - 1=not lame to 5= recumbent
- Number of rubs (calloused areas), scratches and presence of swelling in hocks and knees

Haskell et al., 2006

Lameness

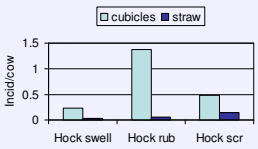
- Lameness is higher in cubicle housing (P<0.05) and in zero-grazing farms (P<0.05), but is not affected by level of production



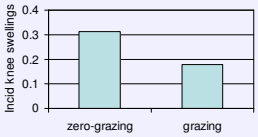
Haskell et al., 2006

Injury

- Fewer hock injuries on straw farms, but no effect of zero-grazing or level of production



- More knee swellings on zero-grazing farms, and at lowest level of production



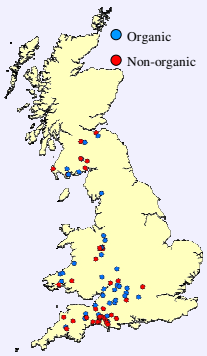
Haskell et al., 2006

Impact of housing on fitness

- Are zero-grazing systems bad for cow welfare?
  - Lameness & injury (cubicles only) is increased
  - No evidence of stereotypy/abnormal behaviours in any farm type
  - Welfare of cows on zero-grazing systems promoted by good stockpersonship
- Straw courts appear to be better for health (and welfare?)
  - Reduced lameness and fewer hock injuries

Impact of organic farming on "fitness"

- 80 (paired) farms sampled in Spring and Autumn from Oct 03 - Sept 06
- Production, health, welfare and behaviour information collected
  - e.g. lameness, hock damage, aggression and mastitis
- Management information and potential risk factors collected
  - e.g. parlour hygiene, bedding, stocking density



Locomotion scores

- 200 visits with 30,000 locomotion scored
- Mean lameness = 17.4% (1.4% to 49%)
- Lameness increased with the number of lactations
- Lameness was higher in spring than in autumn
- There was no significant effect of organic status over and above management differences
  - At pasture for longer
  - Calved at an older age

Rutherford et al., 2008

Effects on other "fitness" traits

- There was a tendency for subclinical ketotic cows to be organic (P=0.07)
- No significant body condition difference between organic and non-organic farms
- Organic heifers are first served and calve down at an older age than non-organic heifers
- Type of housing and some management factors have a greater effect than organic status

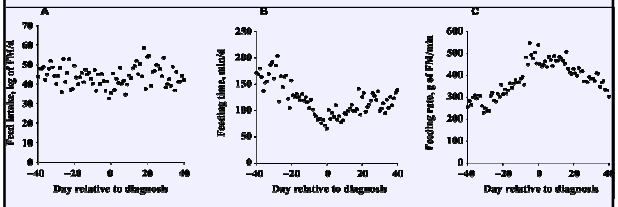
Langford et al., *in press*

Management effects on fitness traits

- Specific components of systems and management practices have a larger impact on "fitness" traits rather than generic categories
- Better health and welfare with good stockmanship
- Indication that components of behaviour (e.g., aggression) are affected by components of the environment which may have a knock-on effect on general "fitness"

Future for "fitness" trait recording

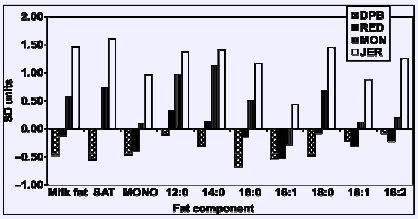
- Feeding behaviour
  - Short-term feeding behaviour changes with the onset of disorders
  - Early disease detection system



Foul of foot, González et al., JDS, 2008

Future for "fitness" trait recording

- Milk fatty acid and lactoferrin content
  - Variation within & across breeds



Soyeurt et al. JDS, 2006

- This information could also be used to predict "fitness" (EU funded RobustMilk project)

Conclusions

- Traditional "fitness" traits in dairy cattle are influenced by genetics, environment and their interaction
- Underlying biological traits are also affected
- New traits could be useful in predicting animal "fitness"
  - Important to record and monitor old and new fitness traits to guard against future deterioration

Acknowledgements

- Funders
- Many colleagues involved in data collection and analysis
- Farmers for providing data
- The cows!

The Scottish Government

defra

Supporting the land-based industries for over a century

SAC