Cow body shape and condition scoring

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Summary

A feasibility study on the introduction of body-shape parameter that may lead, in the future, to the development of automatic monitoring of cow body reserves on live animals is described. The hypothesis tested in this study was that 'if a cow is fatter, her body shape is more likely round and therefore the parabola may fit better to the shape of a fat cow rather a thin cow'. About two hundred Holstein-Friesian cows were monitored by means of thermal camera, ultrasound and manual body condition scoring (BCS). An image-processing model was designed and implemented. The model calculates the parameter of cow body shape. The model outputs were validated against two reference measurements (1) the thickness of fat and muscle layers using ultrasound and (2) manual BCS. The correlation found in this study between the thermal camera and the fat and muscle thickness was 0.47. The thermal camera overcomes some of the drawbacks of a regular camera. The hooks and the trailhead nadirs of a thin cow diverge from the round shape drawn by the parabola. Further research is needed in order to reach full automatic, accurate, body conditioning scoring.

Key words: *Dairy cows, Body conditioning scoring (BCS), Thermal camera, Image processing.*

Introduction

Body condition scoring (BCS) is a technique to estimate an animal's body energy reserves, i.e. estimating fatness or thinness of cows according to a five-point scale (Edmondson *et al.*, 1989). In dairy herds, BCS is probably the most useful management tool available to dairy producers for assessing the nutritional status of cows. Additionally, there are nutritional, health, reproductive, and environmental decisions made by the dairy producer that have a major impact on changes in body reserves for both individual cows and groups of cows. In high-yielding dairy cows, the peak of daily feed intake usually occurs after the peak of milk output. This state is commonly known as negative energy balance and is negatively associated with a range of health traits (Gillund *et al.,* 2001) and fertility (Dechow *et al.,* 2002). Body condition influences productivity, reproduction, health and longevity (Heinrichs and Ishler 2004). However, the current method of measuring BCS is manual and subjective. The values depend on the individual who performs the measurements; sometimes, the same individual might score the same cow differently, depending on the previous cows seen (Schröder & Staufenbiel, 2006). BCS is a time-consuming task especially on large farms and requires trained labour (Leroy *et al.,* 2005; Pompe *et al.,* 2005). Therefore the development of a device for automatic, objective monitoring of body condition scoring is of interest.

A number of feasibility studies have already been conducted into the automation of BCS, including those by Coffey *et al.* (2003), Leroy *et al.* (2005), Pompe *et al.* (2005), Ferguson *et al.*, (2006), and Bewley *et al.*, (2007, 2008). Coffey *et al.* (2003) examined the feasibility of automating BCS using structured red laser light to create light lines across the tail-head areas of a cow After software enhancement of the resulting images, body shape curves were extracted after and were identified using image editing software and a mouse to isolate the lines. Leroy *et al.* (2005) used a digital camera, positioned 1.5-2 m from the rear of the cow, to obtain a silhouette image of the cow from the tail to the legs. The contours of nineteen predefined points, corresponding to visual features were incorporated to determine the overall contour of each animal from which a BCS was calculated. Pompe *et al.* (2005) used a black and white charge coupled device (CCD) camera and a line laser to collect a series of images from the rear of a cow. A 3 dimensional analysis of the images provided an outline of the left pin, left hook, and tailhead. Ferguson *et al.* (2006) investigated the ability to assign a body condition score (BCS) to a dairy cow from digital photographs or videos. Bewley (2008) used a digital camera placed above a stationary weighting station.

The literature reports the developments of an objective method for BCS by using ultrasound (Mizrach *et al.,* 1999; Williams, 2002). Mizrach *et al.* (1999) used a method for the measurement of subdermal fat thickness in dairy cows by digitizing cross-sections of ultrasonic scans. Williams (2002) describes ultrasound applications as a non-invasive method for estimating fat and muscle accretion and body composition in live cattle. Keren & Olson (2007) used thermal imaging software for cattle grazing on a winter range. Sharony (2003) described the application of a digital camera for the purpose of BCS (not thermal camera and using a different algorithm). Kriesel and McQuilkin (2005) described the high potential for applications of digital camera (not thermal) for the dimensional measurement of livestock, but not for BCS. As yet, none of the above scientists or practitioners has reached the point of a low-cost commercial device capable of working in every farm. Therefore the aim of the study was to advance the development of automatic and objective monitoring of cow body reserves. The hypothesis tested in this study was that 'if a cow is fatter, her body shape is more likely to be rounded and therefore a parabola may fit better to the cow shape. The hooks and the trailhead nadirs of a skinny cow diverge from the round shape drawn by the parabola'.

Materials and methods

Data were collected at the Scottish Agricultural College Crichton Royal Farm in Dumfries, Scotland, UK, September 2007. The study involved 186 cows; the nutrition, selection strategy and management are described in detail by Pryce *et al.* (2001).

The reference numbers for body reserve were:

1. the thicknesses of the muscles and fat layers, and
2. manually observed body condition scoring.

The thicknesses of the muscles and fat layers was measured using the ultrasound device, Sonovet 2000 (Medison, Korea), linear probe PB-MYL 2-5/1 170 mm, 2-5 MHz, 96 elements. The Sonogram of the longissimus dorsi muscle (LDM) was carried out from the 12th and the 13th vertebrae. The thickness of the fat is the distance between the dorsal fascia of LDM and the ventral layer skin. The converting factor from the thicknesses of the fat and muscle layers (in millimetre, so called Tot_mm) on the 1-5 BCS scale was:

Ultrasound scoring =5*[log(Tot_mm)-3.6] (Eq. 1)

where:

Tot_mm was the thickness of the fat and muscle layers(in millimetre, not pixels);
5 and the 3.6 normalized the ultrasound units into the 1-5 BCS scale;
the log function depressed the large variation found in the our ultrasound measurements in the large values.

The manual BCS was obtained from two different technicians according to a five-point scale (Edmondson *et al.,* 1989). BCS was measured manually in the same week as measurement by ultrasound and by thermal camera.

A thermal camera (FLIR systems®, model InfraCAM SD™, detector type: focal plane array 120 x 120 pixels, spectral range 7.5 to 13 µm) was linked to the barn ceiling above the cow body weighing scale, at the exit of the milking parlour. The cow identification was done electronically (RFID); the antenna being built into the weighing scale.

The video from the camera was divided into frames by using 'Serif movie plus 4'. The frames were manually observed in order to select the best frame from each cow. Identified frames, those that were associated with cow number and fitted to the cow timing on the scale, were fed into Matlab software for image processing analysis (Anonymous, 2005).

The size of the frames were 787 x 576 pixels, 1.3 MB BMP files. Figure 1 presents the raw thermal images of two typical cows, a fat cow and a thin cow. The images were read using Matlab's '*imread*' function then degenerated to grey (using the '*rgb2gray*' function). The black cursors that indicate the temperature points of measurement were erased by using the '*roifill*' function. The place where the cow was expected to be found was cropped from the original picture to a specified rectangle (Matlab's '*imcrop*' function). '*Imcontour*' found that unique cow individual boundary and '*polyfit*' fitted a parabola to the boundary of each individual cow.

The visual difference between fat and thin cows is presented in figure 2. It can be seen (Figure 2) that in a fat cow, only the tailhead diverge from the rounded shape of the fitted parabola, while many deviations can be noticed in a thin cow. The converting factor from 'distance from parabola' to 1-5 BCS scale was:

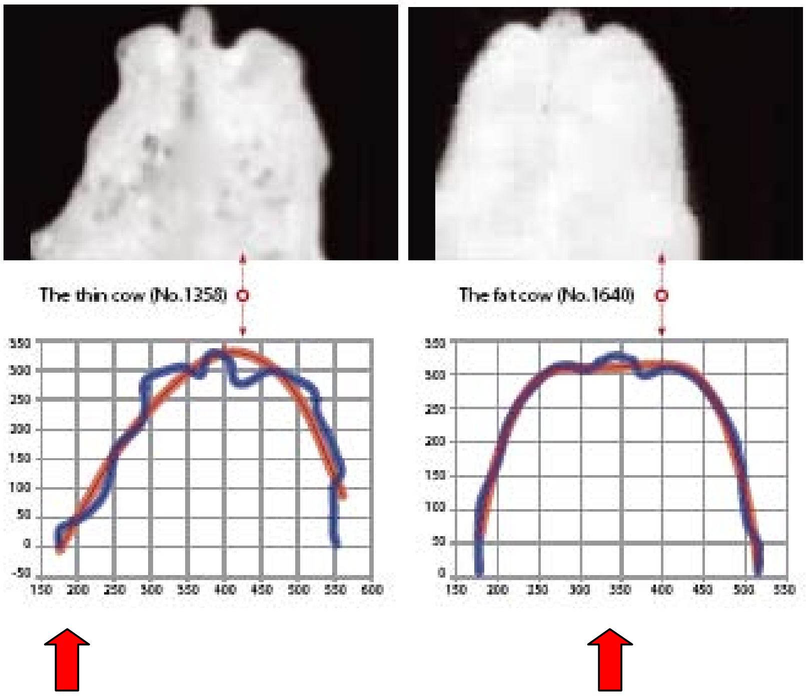
TBCS= 5*9*(1./MAE) (Eq. 2.)

where:

TBCS stands for thermal BCS.
9 is the best fit ever reached in our herd (i.e. only the tailhead diverges from the parabola shape),
5 normalized the model output into 1-5 BCS scale.

The distance between the fitted parabola and the cow contour was expressed in MAE (mean absolute error) units. If a cow is thin, her body shape is less round and therefore her MAE is larger.

The Image processing is presented by Halachmi *et al.* (2008). The process is almost automatically executed. The selection of the best frame for each cow requires further programming.



The thin cow (No. 1358)
Manual BCS = 1.25
Thermal BCS = 1.30
Ultrasound total thickness = 40 mm
(1.44 in BCS unit)

The fat cow (No. 1640)
Manual BCS = 3.00
Thermal BCS = 3.50
Ultrasound total thickness = 74 mm
(3.52 in BCS unit)

Figure 1. Model inputs: thermal images taken from bird's eye view (upper pictures). Model outputs: Cow contour vs. fitted parabola (lower pictures).

Results

The model outputs measured by the thermal video camera (so called Thermal Body Condition Scoring, TBCS) were compared with two reference values:

1. the thicknesses of the fat and muscles layers measures by the ultrasound; and
2. the manual body conditioning scoring (so called BCS).

It can be seen that a correlation between the TBCS and the manual BCS; was 0.32 and a correlation between the TBCS and the thickness of fat and muscle layers (which was measured by the ultrasound) was 0.47. A correlation between the ultra sound and manual BCS was 0.38. All the correlation coefficients are presented together with the averages and standard deviation in table 1. The higher correlation was found between TBCS and the ultrasound (0.47).

The consistency check is presented in table 2. The daily averages are within 5% difference and the variation is within the 10% limits. The correlation between days reached 0.67.

In table 3 it can be seen the manual BCS had a constant shift of 0.25 score. Technician 2 was higher.

Table 1. Model validation: comparison thermal camera, ultrasound and manual body condition scorings.

	Average	STD	Cross Correlation Coef.		
			BCS	TBCS	US
BCS	2.17	0.30	1	0.32	0.38
TBCS	2.14	0.62		1	0.47
US	2.16	0.69			1

US=Ultrasound; TBCS= Thermal camera; BCS=Manual body condition scoring

Table 2. Model validation: Consistency check; thermal camera body condition scorings (TBCS) measured in days 1, 2 and 3.

	Average	STD	Cross Correlation Coef.		
			Day 1	Day 2	Day 3
Day 1	1.99	0.62	1	0.46	0.67
Day 2	1.99	0.66		1	0.61
Day 3	1.95	0.59			1

Table 3. Consistency check of the reference numbers; manual BCS measured by technicians 1 and 2.

	Average	STD	Cross Correlation Coef.	
			Technician 1	Technician 2
Technician 1	1.99	0.41	1	0.78
Technician 2	2.22	0.33		1

Discussion

Coffey *et al.* (2003) found that the correlation between tail head curvature and condition score was 0.55 and between Pin bone and body condition score was 0.59. In our case, the correlation between the manual BCS and TBCS was 0.36 and between TBCS and ultrasound measurements was 0.48. The difference between the studies (Coffey *et al.*, 2003 and the current study) can be explained by the number of cows rejected from the database. In our experiment only 9 cows (had hooks or tailhead exceed the visual area of the camera lens) were removed from the database. Coffey *et al*. (2003) reports that out of 190 cows, only 36 cow images were suitable for data extraction. Perhaps, if more cows had been filtered out of the database our correlation might have been higher. Coffey *et al.* (2003) advised the development of body shape parameter. The correlation between both technicians (observers) was 0.78 and is in agreement with the result reported by Ferguson et al. (2006). Their correlation coefficients between observer 1 and observer 2 through 4 were 0.78, 0.76 and 0.79, respectively.

The thermal camera's zoom should capture most of the cow back. Those cows where the hooks were outside the visible area were most likely to be expelled from the model. This result is in agreement with Bewley (2008) who also found the hooks as the easiest to identify and that angles around the hooks and tailhead have the highest correlations with BCS. Correlation between USBCS (Edmondson *et al*, 1989) and hook posterior angle is 0.52, between USBCS and hook angle is 0.48 and between USBCS and tailhead is 0.31. Correlations between UKBCS (Lowman *et al.*, 1976) and all three body traits are lower, but still significant. Correlation between UKBCS and hook posterior angle is 0.46, between UKBCS and hook angle is 0.33 and between USBCS and tailhead is 0.19. Higher camera installation or wider lens angle may improve the results. A 3D picture, i.e. using an additional camera, may further improve the accuracy of the device.

The main advantage of using a thermal camera over a regular digital camera is the ease of recognition of cow pattern; in our case almost all the cows' images were suitable for analysis. However, our measurements were taken in September in Scotland, at 5am to 8am. Perhaps in hot climate conditions, such as in an Israeli summer, where the ambient temperature might be similar to the temperature of the cow skin temperature, identifying the cow contour may not be so easy. In further research the influence of hot climate on the cow appearance by the thermal image should be investigated.

In further research, body shape parameters should be adjusted for other dairy breeds, beef or dual purpose breeds. It is also possible that the parabola shape might not fit other breeds, if a thin cow also exhibits a rounded shape.

In the development of a new device, accuracy may be validated against a reference number. The manual BCS is commonly used but is subjective. It depends on the technician and has a discrete-points scale i.e. 1.5, 1.75, 2, 2.5 etc. Our study proposed a continuous scale. Trying to correlate the results from continuous scale (the new device output) with a discrete-points (manual BCS, our reference number) is statistically inferior. Grouping the continuous results into discrete clusters may improve the statistics but degenerate important feature of the new device – the continuous scale. Ultrasound has a continuous scale and our initial thought was that it is objective. During the experiment in the barn and later whilst analysing the results in the lab it appeared, however, that an ultrasound operator might influence the results by (1) not returning to the exact location in every different cow and (2) by his reading of the ultrasound picture. In further research, the selection of the objective method is crucial if higher statistically correlation is desired. Both drawbacks the discrete-points scale and the subjective issues can be overcome by examining a large number of cows using several technicians on one occasion.

Our study focused on dairy cattle, however, a low-cost, moveable device, after calibrating its parameters, may be potentially applicable to beef cattle. Applications include informing decisions on moving a group from one grazing field to another grazing field, and in determining the optimal marketing time in feedlots. The functionality of "a low cost, automatic and accurate BCS" in daily herd management is not under question. However for genetic purposes, Pryce *et al.* (2006) stated that there would be little benefit in including BCS as an independent trait in the breeding worth dairy index. BCS is already included in New Zealand as a predictor in the genetic evaluation of fertility; breeding values for BCS will be estimated routinely from the fertility model.

Conclusion

A thermally sensed body condition scoring model was designed and implemented on a small number of cows. Results suggest that further study with more cows may open the gate for automating the BCS monitoring. Suggestions were made for further research. The onus is now on industry to take the methodology described above through further steps into a commercial working device in every dairy farm.

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