Identification of cows and individual feed intake records using a 3D camera system in commercial farms

J. Lassen, J. R Thomasen and S. Borchersen

VikingGenetics, Ebeltoftvej 16 8960 Randers, Denmark
Corresponding author: jalas@vikinggenetics.com

Abstract

A system has been developed to make identification of cows and individual feed intake records in commercial farms using a 3D camera system. Cameras are installed in the lock after milking where the RFID eartag is identified and images of the cows back is stored to generate reference images. These reference images are used to predict a given cow when she is eating. Individual feed intake is estimated at any visit during the day. The last image of the feed before a visit is stored together with the first image of the feed after a visit. These 2 surfaces is subtracted to estimate an intake for a visit. Based on feed density the volume is transformed to kilos. All visits are summed to daily intake and later on to weekly mean of daily intake and reported throughout lactation. The system is installed in 7 herds (5 Jersey, 1 Holstein and 1 Red dairy cows) measuring in 1292 Jersey, 536 Holstein and 222 Red Dairy cows in a two-year period.

Mean daily feed intake measured was 54.7 kilo for Jersey, 60.6 for Holstein and 59.7 for Red dairy cattle. Corresponding standard deviation was 8.5, 11.2 and 9.5 kilos respectively.

A mixed linear model was used to analyse the data for each breed separately. The model contained a fixed effect of herd (for Jersey), week of year, week in lactation, year, a random effect of animal and a residual term. Repeatabilities (animal variance divided by total variance) of daily individual feed intake as a weekly mean were moderate to high across the three breeds. For Jersey repeatability was 56%, for Holstein 60% and for Red Dairy cattle 61%.

The results suggests that data from 3D cameras can be used to make large-scale individual records for feed intake in indoor-housed dairy cattle. This data can be used to make genetic evaluations and management decisions. Further data over a longer time period and from more herds is needed to confirm these results. Therefore, the system will be installed in new herds in 2021 and more than 3000 cows will be added to the CFIT registration system.

The data is measured throughout lactation, which opens up for estimation of genetic correlation between efficiency and health traits in early lactation. Using 3D camera data opens up for individual measures of other phenotypes. This includes weight but also health, welfare and behavioral traits.

Keywords: Feed intake, identification, artificial intelligence, Holstein, red dairy cattle, Jersey.

Introduction

Feed cost is up to 70% of the running cost for a farmer, so only a marginal save of feed will make a huge impact on the return on farm. A part of the variation in feed intake and efficiency is heritable, which make selection for improved feed efficiency possible (Løvendahl *et al.*, 2018). A limitation to implement this is lack of data on an individual level which is recorded in commercial settings throughout lactation. So far, equipment for making individual feed intake records has primarily been on research farms and based on scale system that are expensive and time consuming to manage (Seymour et al., 2019). Feed intake measured in research farms is repeatable (0.66) as well as heritable (0.34) (Berry *et al.*, 2014), so selection can be performed in order to change the trait in the preferred direction. The ideal system measures, controls, and monitors individual feed intake of the free-housed cow while not interfering with feeding habits and not introducing additional work or inhibiting workflow on the farm (Halachmi *et al.*, 1998).

A 3D camera system to identify cows and make individual feed intake records have been developed (WO 2017/001538; WO 2014/166498). The system works without disturbing daily behavior of either the cows or the farmer. The cameras records data around the clock and based on image analysis cows are identified at the feeding table (Thomasen *et al.*, 2018) and the amount of feed eaten is quantified (Lassen *et al.*, 2018). In these studies, the data was collected in a limited time period and identification percentage and repeatabilities of the feed intake between days and weeks were reported and showed promising results. Other camera-based systems have been initiated to make individual feed intake records. Bezen *et al.* (2020) used the CNN approach to quantify feed intake and showed a MSE of 0.119 kg^2 feed pr meal based on 63 meals recorded on 6 cows in 36 hours. Identification relied on observing digits related to the cow ID on collars on the neck of the cow.

The aim of this study was to analyze individual measures of feed intake recorded in commercial farms using 3D cameras. This was studied by estimating the repeatability of the phenotypes recorded in three different breeds.

Materials and methods

To make individual feed intake measures 3D cameras from Kinect was used (Microsoft). Each camera is placed 2.5 meter apart and 4.5 meter from the empty feeding table covering the entire feeding table. In addition, an ear tag reader and a 3D camera is placed outside the milking parlor in the exit corridor. Three types of images are recorded from the 3D camera: normal pictures, IR pictures and depth pictures indicating the distance from the camera to the object that is within the range of the camera.

Data was recorded in seven commercial dairy herds in Denmark with Jersey cows. Data was recorded from 1st of February 2019 to 1st of March 2021. In 5 of the herds there were Jersey cows, in one there were Holstein cows and in 1 herd there were red dairy cattle. In all herds cows were kept indoors year around.

When cows leave the milking system their electronic ear tag was read and at the same time a 3D picture is taken of the back of the cow. These pictures were stored and used as a reference to predict the same cow based on the contours, color and patterns of the back of the cow, when eating at the feeding table based on the MASK-CNN algorithm (He *et al.*, 2018; Thomasen *et al.*, 2018; WO 2017/001538). This approach was tested in a validation study where cows id was manually annotated to visits at the feeding table over a 14 day period. The validation was conducted in comparing the real ID of the cow with the predicted id based on the MASK-CNN algorithm.

When a cow enters the head to the feeding table the last image of the feeding pile before she put in her head and began eating was stored from vbiruel boxes defined in the feeding table. When the cow has finalized the meal and takes the head out again the first new image of the feeding pile is stored. The height in each pixel from two stored images are now subtracted from each other and the removed feed is quantified on pixel level. From each specific visit 5 variables are stored: the ID of the cow, the placement in the barn, time when the meal was initiated, time when the meal was finalized, and the amount of feed eaten. During a meal feed will be allocated to a specific cow from 5 virtual boxes. The virtual box right below the cow as well as he two virtual boxes to the left and the right. If two cows share a virtual box during a feeding visit, they will also share the feed taken from this box during the two cow specific visits.

The feed intake approach been validated in a controlled experiment where 325 liters of feed where put in a pile below the cameras. Feed were then removed as bits from various places of the pile to mimic how a cow would remove feed 19 liters at the time with 2 minutes interval. The standard error on how well the sum of the pixels predicted the feed removed was then estimated to see how well the algorithm worked.

In order to obtain repeatability, data was analyzed using the mixed procedure in SAS. The model used to estimate the repeatability, looked as follows:

$$FI = h + w + y + wil(dim) + dim + lac + animal + res$$

where h is the fixed class effect of herd, w is the fixed class effect of week, y is the fixed class effect of year, wil(dim) is a wilmink regression on days in milk, dim is a regression on days in milk, lac is a fixed class effect of lactation, animal is the random animal variation and res is the random residual variation.

Results and discussions

A total of 2050 cows were measured. This was 1292 Jersey cows (JER), 222 Red Dairy Cows (RDC) and 536 Holstein cows (HOL). These cows were distributed in 5 JER herds, 1 RDC herd and 1 HOL herd. Mean feed intake in kilo with corresponding standard deviation and minimum and maximum value is presented in table 1.

This is done both overall for each breed and for the 7 herds. Mean intake was higher for RDC (59.7 kg) and HOL (60.6 kg) than for JER (54.7 kg). The standard deviation of the mean was also higher in HOL (11.2 kg) and RDC (9.5 kg) than for JER (8.5 kg).

Repeatability estimates for daily feed intake was 0.56, 0.61 and 0.60 for JER, RDC and HOL respectively (table 2).

These estimated were based on animal variances of 30.55, 46.41 and 58.53 for JER, RDC and HOL, respectively. The magnitude of these estimates corresponds to the difference in magnitude seen in the standard deviation of the mean of the feed intake. The JER animal variance might also be somewhat lower due to the larger number of animals in the study. The measured repeatability was at the same level as several other studies have reported in the past based on research farm data (Berry *et al.*,

Table 1. Data description including breed, number of cows, mean feed intake in kilos, and standard deviation.

Breed	# of cows	Mean	Std
Jersey	1292	54.74	8.53
Red Dairy Cattle	222	59.72	9.53
Holstein	536	60.59	11.20

Table 2. Breed, animal variance, residual variance and repeatability.

Breed	V(a)	V(e)	rep
Jersey	30.55	24.01	0.56
Red Dairy Cattle	46.41	29.67	0.61
Holstein	58.53	39.02	0.60

2014). The feed intake in comparable with feed intake measured in a research farm with Jersey cows (Li *et al.*, 2016), RDC cattle (Liinamo *et al.*, 2012; Li *et al.*, 2016) and HOL cows (Li *et al.*, 2016).

The identification algorithm was tested in a validation study over a 2-week period for all three breeds. Results showed that id was correct in more than 99% of the visits independent on breed. The system is not dependent on freeze marking the cows, various neck collars or physical installations in the stable.

A major priority for developing this system was to obtain data throughout lactation. In relation to genetic analysis several studies have shown that genetic correlation change during lactation between feed intake, milk yield and body weight (Manzanilla-Pech *et al.*, 2014; Li *et al.*, 2017). Estimates for the genetic correlation between feed intake and milk yield varies from -0.80 in early lactation up to 0.8 in mid and late lactation (Manzanilla-Pech *et al.*, 2014). Selection for improved efficiency in early lactation where feed intake specifically needs to be improved based on records obtained in mid lactation then might lead to even lower feed intake in early lactation. From a management perspective also feed intake records are interesting throughout lactation. In early lactation the absolute majority of health problems occurs both related to mastitis, reproduction and nutrition. In mid lactation the farmer wants to know which cow are most efficient to optimize culling strategy and in late lactation the feed intake is interesting in order to optimize strategies in relation to drying off cows. With this system all information will be available for the farmer.

The system will be installed in herds covering more than 7000 cows during 2021.

Conclusions

Individual feed intake measures can be made using a 3D camera system that both identifies the cow and quantifies the amount of feed eaten by the cow. Repeatability was between 0.56 and 0.61 for daily feed intake measured as a weekly average over a time period of more than two years.

List of references

Berry, D. P., M. P. Coffey, J. E. Pryce, Y. de Haas, P. Løvendahl, N. Krattenmacher, J. J. Crowley, Z. Wang, D. Spurlock, K. Weigel, K. Macdonald, and R. F. Veerkamp. 2014. International genetic evaluations for feed intake in dairy cattle through the collation of data from multiple sources. J Dairy Sci 97(6):3894 3905.

He K., G Gkioxari, P. Dollar and R Girshick 2018 Mask R-CNN. arXiv:1703.06870v3 [cs.CV] 24 Jan 2018.

Bezen, R., Y Edan, I. Halachmi 2020 Computer vision system for measuring individual cow feed intake using RGB-D camera and deep learning algorithms Computers and Electronics in Agriculture 172:105345

Halachmi, I., Y. Edan, E. Maltz, U. M. Peiper, U. Moallem, and I. Brukental. 1998. A real-time control system for individual dairy cow food intake. Comput. Electron. Agric. 20:131–144.

Lassen, J., J. R. Thomasen, R. H. Hansen, G. G. B. Nielsen, E. Olsen, P. R. B. Stentebjerg, N. W. Hansen, and S. Borchersen. 2018. Individual measure of feed intake on inhouse commercial dairy cattle using 3D camera technology, Proceedings of the World Congress on Genetics Applied to Livestock Production, vol. Technologies   Novel Phenotypes, p. 635, 2018.

Li, B., W. F. Fikse, J. Lassen, M. H. Lidauer, P. Løvendahl, P. Mäntysaari, and B. Berglund. 2016. Genetic parameters for dry matter intake in primiparous Holstein, Nordic Red, and Jersey cows in the first half of lactation. J. Dairy Sci. 99 (9): 7232-7239.

Li, B., B. Berglund, W. F. Fikse, J. Lassen, M. H. Lidauer, P. Mäntysaari, and P. Løvendahl. 2017. Neglect of lactation stage leads to naive assessment of residual feed intake in dairy cattle. J Dairy Sci 100 (11), 9076 9084.

Liinamo A-E, Päivi Mäntysaari, EA Mäntysaari 2012 Genetic parameters for feed intake, production, and extent of negative energy balance in Nordic Red dairy cattle J Dairy Sci 95:6788-6794.

Løvendahl, P, GF Difford, B Li, MGG Chagunda, P Huhtanen, MH Lidauer, J Lassen, P Lund 2018 Selecting for improved feed efficiency and reduced methane emissions in dairy cattle Animal 12:336-349.

Manzanilla Pech CIV, RF Veerkamp, MPL Calus, R Zom, A Van Knegsel, JE Pryce, Y De Haas 2014 Genetic parameters across lactation for feed intake, fat- and protein-corrected milk, and liveweight in first-parity Holstein cattle J. Dairy Sci 975851-5862.

Seymour DJ, A Cánovas, Christine Francoise Baes, T.C.S. Chud, V.R. Osborne, J.P. Cant, L.F. Brito, B. Gredler-Grandl, R. Finocchiaro, R.F. Veerkamp, Y. de Haas, F. Miglior 2019 Invited review: Determination of large-scale individual dry matter intake phenotypes in dairy cattle. J Dairy Sci 102:7655-7663.

Thomasen, J. R., J. Lassen, G.G.B. Nielsen, C. Borggard, P.R.B. Stentebjerg, R.H. Hansen, N. W. Hansen, and S. Borchersen. 2018. Individual cow identification in a commercial herd using 3D camera technology, Proceedings of the World Congress on Genetics Applied to Livestock Production, vol. Technologies   Novel Phenotypes, p. 613, 2018.

WO 2017/001538 System and method for identification of individual animals based on images of the back.

WO 2014/166498 System for determining feed consumption of at least one animal.