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Investigation of distances covered by fattening pigs measured with VideoMotionTracker®

Julia Brendle*, Steffen Hoy

Department of Animal Breeding and Genetics, Justus Liebig University, Bismarckstraße 16, D-35390 Giessen, Germany

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ABSTRACT

The investigation was carried out with altogether 144 pigs kept in groups of 6 or 12. Every pen was equipped with perforated floor. Water and the in-house compound feed with different elements depending on the fattening period were available *ad libitum* during the whole fattening period. At the beginning of each fattening period all pigs were weighed and the individual rank place was calculated based on 72 h continuous infrared video-recordings. At the beginning, in the middle and at the end of the fattening period the distances covered by focus animals during 24 h were measured using the VideoMotionTracker® (VMT) software tool (Mangold). The VideoMotionTracker® is a software solution to allow tracking animals on a video recording using the PC mouse or a touch-screen terminal to measure distances that were covered. This measurements on pigs resulted in highly significant differences between the covered distances at the different fattening stages (at the beginning: 582 m; in the middle: 391 m; at the end: 261 m on average). Fattening pigs kept in groups of 12 each covered longer distances during the fattening period compared with pigs kept in groups of 6 (459 m versus 333 m). The differences between the means were highly significant ($p < 0.001$). On average female pigs covered a longer distance than castrated male pigs (443 m versus 349 m).

The factor rank position did not show any significant influence on the covered distance of each focus animal. Pigs with high rank positions on average covered 399 m whereas pigs with low rank positions covered with 393 m a marginally shorter distance. Furthermore the interaction between fattening period and rank position was examined but did not show any significance either. The influence of the factor pen within group size was highly significant ($p < 0.001$) and the parameters live weight and covered distances were negatively correlated.

1. Introduction

Locomotion defined as the motion of an animal in connection with the change of location may lead to conclusions concerning behavioural disorders, health status and well-being of farm and laboratory animals. In literature only marginal information about distances covered by pigs in pens can be found. The only information about distances covered by pigs in free-range is based on estimations (Jensen, 1986; Lachica and Aguilera, 2000). The existing methods to describe the locomotion of farm animals (e.g. treadmill, pedometer, photoelectric barriers, telemetry, Local Positioning System – LPS, Global Positioning System – GPS, ETHOSYS or video tracking systems) offer limited possibilities of using in conventional housing systems. Automatic tracking systems (e.g. EthoVision®, Noldus) require high standards concerning the individual identification of the focus animal. If it is possible to define standardized test conditions these programs offer the opportunity to measure the locomotion of individu-

* Corresponding author. Tel.: +49 641 99 37647; fax: +49 641 99 37639.
E-mail address: Julia.Brendle@agrar.uni-giessen.de (J. Brendle).

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als automatically (Lind et al., 2005). When lacking well defined conditions in practice (light-dark; different materials and backgrounds) it is difficult if not impossible to take reliable measurements. Measuring distances covered by pigs is even more challenging since the transponder – contrary to cows or sheep (Gygax et al., 2007; Neisen et al., 2009) – cannot be fixed to the animal directly. Another option is the manual capturing of distances with the help of a raster process which is very time-consuming and cost-intensive.

The aim of this study was the investigation on distances covered by pigs in conventional housing systems in dependence on group or pen size and fattening period as well as sex and rank of the individual animal. At the same time this study evaluates the VideoMotionTracker® (Brendle and Hoy, 2010) as a newly developed technical solution of computerized measurements of distances covered by farm animals in their usual housing environment.

2. Materials and methods

2.1. Animals and housing conditions

The investigation was carried out at the research station of the University of Giessen, Germany. A total number of 144 pigs (rotational cross with Pietrain) in six fattening rounds of 12 weeks each were kept in standard pens with perforated floor. The group size was 6 or 12 (two groups of 6 animals and one group of 12 animals in each round) with 0.75 m^2/pig each. Originally, the fattening unit contained pens measuring 2.09 m × 2.15 m for 6 pigs each with one feeder for dry food and two nipple drinkers. The pen for 12 fattening pigs was arranged by removing the partition wall between two pens for 6 pigs each. Feed (in-house compound feed with different elements depending on fattening stage) and water was available *ad libitum*. The duration of the artificial light period was 8 h (from 8 am to 4 pm). Natural lighting through windows was available as well. The piglets were weaned at an age of 28 days, raised for 35 days and transported to the fattening unit. The duration of each fattening period was 12 weeks. The animals were slaughtered at a weight of 105 kg on average. Pigs showing signs of diseases were examined, treated with pharmaceuticals if necessary and separated from the group.

2.2. Methods

At the beginning of the fattening period, all pigs (24 pigs in each round) were weighed, sexed, examined for body lesions, marked with an individual number stamped with colour at the back and randomly distributed to either pen for 6 or 12 pigs. During the fattening period (after two, six and ten weeks) the pigs were weighed again and daily weight gain was calculated.

2.3. Behavioural observations

A camera was installed on the ceiling directly above the middle of each pen. The behaviour of the pigs in the pens was continuously infrared video-recorded at the beginning of each fattening period during 72 h to define the individual rank position for each individual in the group. The social hierarchy with individual rank places (1–6, 1–12 respectively) was calculated on the basis of wins, defeats, number of defeated group mates, number of group mates against was lost and group size as described by Puppe et al. (2008). For further analysis of social hierarchy pigs with individual rank positions 1–3 (in groups of 6), 1–6 (in groups of 12) respectively were characterized as "high" ranking whereas pigs with individual rank positions 4–6, 7–12 respectively were characterized as "low" ranking.

In a second step infrared video-recordings took place during 2 × 24 h after two weeks (80 days old pigs), in the middle (110 days old pigs) and at the end (140 days old pigs) of the fattening period. The distances covered by selected focus animals (depending on the individual rank place: 1, 3, 6 in groups of 6 and 1, 3, 6, 9 and 12 in groups of 12) during 2 × 24 h at each fattening period were measured using the VideoMotionTracker® tool (Mangold). Due to technical reasons, use of animals in other investigations and sale of animals not all of these 66 focus animals could be considered later in the statistical analysis. The VideoMotionTracker® is a software tool that allows tracking objects (animals) on a video recording by using the computer mouse or a touch-screen terminal stylus to measure covered distances. The precondition for the application of the VideoMotionTracker® is the ability to survey the whole pen with video technique and with a minimal distortion of the original view. The first step is to digitize the video-recordings with the program Canopus MediaCruise® or a similar program. After opening the created media file in the VideoMotionTracker® tool the user has to define the length and the width of each pen in an *x*–*y*-coordinate system. The measurement starts with the placing of the mouse pointer at the back (between the shoulder blades) of the focus animal. To measure the distance this animal covers the user has to follow the animal with the mouse pointer or alternatively with a stylus on a touch-screen-terminal. It is possible to play the media file with different levels of reduced or increased speed and to interrupt the measurement at any point of the media file. Eventual slight tremble of the hand can be excluded from measurement by setting a marginal value (e.g. 30 pixels) in the tool. At the end of the measurement (e.g. after analyzing a 24-h recording) the VideoMotionTracker® calculates the length of the line generated with the mouse pointer or stylus as distance covered by the animal in cm based on the sum of all lines created in the *x*–*y*-coordinate system (Fig. 1).

Additionally after the measurement a "heat map" can be generated in which the tool shows so-called "activity hot spots". Those markings represent areas in the pen where an increased frequency of activity of the analyzed animals took place (e.g. feeder, drinkers) (Fig. 2).

Methodological investigations illustrated a very good conformity of distances measured with VideoMotionTracker® and distances measured automatically by the software EthoVision® (Noldus) which requests standardized test conditions (Brendle and Hoy, 2010). It is assumed that the distances measured with the

Fig. 1. Screen of VideoMotionTracker® tool.

VideoMotionTracker® tool represent the actual distances covered in the pen.

2.4. Statistical analysis

Statistical data analysis was carried out with the program package SAS Version 9 using the MIXED procedure. The analyzed trait "distances covered" was normally distributed (tested with Kolmogorov–Smirnov and Shapiro–Wilk) and showed equal variances within subgroups of fixed effects (Levene-Statistic) so that the analysis of variance could be used. In the analysis the impact of group size, sex, rank position, fattening period, pen and pig on "distances covered" were calculated using the following model:

$$Y_{ijklmn} = \mu + gs_i + s_j + rp_k + fp_l + p(gs)_{im} + (rp_k \times fp_l) + p_{ijklmn} + e_{ijklmn}$$

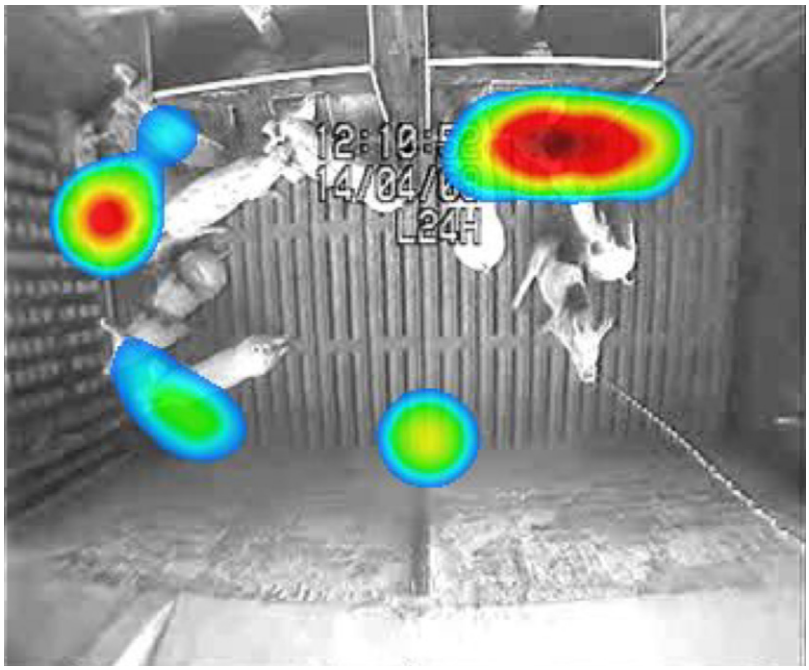

Fig. 2. Heat map for the activity of a fattening pig in a group of 12 during 24 h.

Table 1
Descriptive statistics concerning distances covered by fattening pigs (in m) during 24 h at the beginning, in the middle and at the end of the fattening period (averages from 2 days per animal).

Stage of fattening period	*n*	Mean	SD	Maximum	Minimum
Beginning	62	582.3	204.0	1211.7	245.0
In the middle	40	391.1	196.1	948.7	95.5
End	38	261.1	135.2	636.9	77.4

Y_{ijklmn} = "distance covered" from each focus animal;
μ = overall mean;
gs_i = fixed effect of group size (group of 6/group of 12);
s_j = fixed effect of sex (castrate/female);
rp_k = fixed effect of rank position (high/low);
fp_l = fixed effect of fattening stage (beginning, middle, end);
$p(gs)_{im}$ = fixed effect of pen within group size;
$(rp_k \times fp_l)$ = interaction between rank position and fattening stage;
p_{ijklmn} = random effect of the individual pig;
e_{ijklmn} = random residual error.

Other interactions between fixed effects were tested and did not show significances. Therefore they were removed from the used model.

The correlations between live weight and distances covered at the beginning, in the middle and at the end of the fattening period were calculated using the SAS-REC procedure.

3. Results

On average the investigated focus animals ($n = 62$) covered a distance of 582 m (±204 m) in 24 h at the beginning of the fattening period, 391 m (±196 m) in the middle ($n = 40$) and 261 m (±135 m) at the end ($n = 38$) of the fattening period. Summarizing all values during the whole fattening period the distances covered by the individuals ranged from 77 m (at the end of the fattening period) to 1211 m (at the beginning of the fattening period) during 24 h having analyzed clinically healthy animals only (Table 1).

The statistical significances of fixed effects with *F*-values are shown in Table 2.

The least square means of group size and sex are listed in Table 3. Focus pigs kept in groups of 6 covered with 333 m a shorter distance than pigs kept in groups of 12 with 459 m. The differences between the means were highly significant ($p < 0.01$) (Table 2). The factor sex of the focus animal also indicated significant differences ($p < 0.05$). On average female pigs covered with 443 m a considerably longer distance than castrated male pigs with a total of 349 m (Table 3).

The factor rank position did not show a significant influence on the covered distances. Pigs declared as high ranking individuals covered 399 m (±21.39) in contrast to low ranking individuals with 393 m (±28.18). In Table 4 the least square means for the stage of the fattening period are shown. Although the interaction between fattening period and rank position did not show any significance, the results showed a tendency to differences between high and low ranked animals within the stage of fattening period. At the beginning of the fattening period pigs declared as high ranking individuals covered with 619 m a longer distance than pigs declared as low ranking individual (565 m). In the middle of the fattening period this relation changed and subdominant animals covered longer distances than dominant animals (386 m versus 349 m). At the end of the fattening period both groups of pigs (high and low ranking) covered nearly the same distances with 230 m (high ranking individuals) and 227 m (low ranking animals) (Table 4).

The consideration of the different stages of the fattening period (beginning, middle, end) showed highly significant differences ($p < 0.001$) between the covered distances by focus animals. At the beginning pigs covered distances of 592 m, in the middle 367 m and 229 m at the end of the fattening period (Table 4).

The influence of the factor pen within group size showed highly significances ($p < 0.001$). The random effect of the focus animal was also calculated and explained 45 percent of residual variance.

Table 2
Significances of fixed effects including *F*-values.

Effect	*F*-value	Significance
Group size	14.22	**
Sex	6.59	*
Rank position	0.04	n.s.
Fattening period	105.93	***
Pen (group)	3.81	***
Fattening period × rank position	1.87	n.s.

n.s., not significant.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 3
Results of univariate analysis of variance – influence of group size and sex on distances covered by focus animals.

Parameter	LSQ-mean	SE
Group size		
6	333.7	22.20
12	459.1	26.92
Sex		
Female	443.0	28.02
Male	349.8	23.22

Table 4
Distances covered by pigs (in m) with high and low rank position during the fattening period (univariate analysis of variance).

Stage of fattening period	LSQ-mean	SE	Rank position	LSQ-mean	SE
Beginning	592.2[a]	19.95	High	619.1	23.75
			Low	565.3	31.29
In the middle	367.8[b]	24.57	High	349.4	28.70
			Low	386.1	38.18
End	229.2[c]	25.06	High	230.5	29.10
			Low	227.0	39.27

Different types showed highly significant differences ($p < 0.001$).

The parameters live weight and covered distances at the beginning ($r = -0.108$), in the middle ($r = -0.319$) and at the end ($r = -0.474$) of the fattening period were negatively correlated (coefficient of correlation by Pearson), i.e. with increasing live weight the pigs covered shorter distances during a day.

4. Discussion

In literature, no investigations on distances covered by pigs in conventional housing systems and in different stages of the fattening period could be found. The available information about distances covered by pigs kept in free-range is only estimated (based on the distance between feeding ground and resting place). Jensen (1986) carried out examinations on sows in an open-air enclosure and found out that these animals moved as far as 6 km shortly before parturition. Lachica and Aguilera (2000) estimated that Iberian pigs (*Sus mediterraneus*), observed in natural habitat, cover distances of 1.5–3 km on a day.

In our investigation, with pigs kept in conventional housing systems in groups of 6 or 12, a high range between the individuals concerning the covered distance in 24 h during the fattening period was found. The maximum was observed at the beginning of the fattening period with 1.2 km in 24 h. In contrast the minimal distance with 0.07 km in 24 h was found at the end of the fattening period. On average the investigated animals covered distances between 0.6 km at the beginning, 0.37 km in the middle and 0.26 km at the end of the fattening period. The pigs were kept following EC directive 88/2001 and the German regulation on animal protection. For the first time scientific data concerning the covered distances in 24 h by fattening pigs are available. All pigs were declared as healthy after a visual appraisal before starting the observation. A group of 12 is representative for the traditional housing conditions of fattening pigs in Germany and in other countries. There is however a tendency towards larger group sizes connected with modern liquid feeding systems (30–60 pigs/group). There are even MEGA group sizes with 200–400 fattening pigs per group which definitely leads to discussions on animal welfare (Hoy, 2005). In future, the use of VideoMotionTracker® offers the possibility of scientific evaluation of the ethological aspects of these group sizes. A group of 6 fattening pigs is not representative for the German housing conditions but the comparison of group sizes of 6 or 12 animals shows that there are significant differences in the mean distances covered by pigs in 24 h. Obviously pigs kept in smaller groups (and smaller pens) covered shorter distances compared with larger group sizes (and larger pens) as there are very short distances to the feeder, to the water nipple as well as to the dung and lying area. With increasing live weight and increasing age the distance covered by fattening pigs per day decreases.

In the investigation a significant effect of the factor sex of the focus animal could be shown. During the fattening period female animals covered a longer distance on average than their castrated male group mates. This effect might be related to the different hormone status and the beginning of the sexual maturity.

The consideration of the factor rank position and the investigation between rank position and fattening period did not show any significance. At the beginning of the fattening period pigs declared as high ranking individuals in tendency covered longer distances than their subdominant pen mates. In the middle of the fattening period this relation changed and at the end of the fattening period both groups (high ranking animals and low ranking animals) covered nearly the same distances. At the beginning of the fattening period both dominant and subdominant pigs are involved in fights for rank positions (Puppe et al., 2008) which leads to the assumption that the distances in this period might be longer than those covered in the middle and at the end of the fattening period. In the middle of the fattening period the social hierarchy is established. Pigs with lower rank places obviously covered longer distances to avoid the conflict with high ranked pigs. Furthermore it can be assumed that the restricted space at the end of the fattening period, due to the increased live weight, age and body height of the pigs, is the possible reason for nearly the same distances which were covered by both dominant and subdominant pigs.

Summarizing all results VideoMotionTracker® tool allows for the first time ever a computerized method to continuously measure distances covered by pigs (or other farm or laboratory animals) in their conventional housing conditions during 24 h.

The hypothesis that pigs cover longer distances with increasing pen or group size could be confirmed. We can further confirm that the covered distance per day decrease with increasing age and live weight. Those results correspond with Elkmann (2007) who found out that the activity of fattening pigs is reduced with increasing age and live weight.

5. Conclusion

The investigation leads to the conclusion that the tool VideoMotionTracker® (Mangold) offers a practical computer-based method to measure distances covered by pigs (or other farm or laboratory animals) living in conventional housing conditions in differently sized pens during flexible time frames. The precondition for the application of the VideoMotionTracker® tool is the ability to survey the whole pen with video technique. In combination with infrared technology the program could also be used to analyze the behaviour of nocturnal animals.

The results show that group size, fattening period and pen size have an impact on the covered distances whereas the rank position of the animal did not show a significant effect on covered distances. The live weight is negatively correlated with covered distance.

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