Animal 15 (2021) 100069

Contents lists available at ScienceDirect

Animal
The international journal of animal biosciences

Thermoregulation at birth differs between piglets from two genetic lines divergent for residual feed intake

O. Schmitt [a,b,c,*,1], S. Reigner [d], J. Bailly [d], L. Ravon [d], Y. Billon [d], L. Gress [e], L. Bluy [e], L. Canario [e], H. Gilbert [e], A. Bonnet [e], L. Liaubet [e]

[a] Pig Development Department, Teagasc Animal and Grassland Research and Innovation Centre, Fermoy P61 P302, Ireland
[b] Department of Animal Production, Easter Bush Veterinary Centre, Royal (Dick) School of Veterinary Studies, The University of Edinburgh, Roslin, Midlothian EH25 9RG, UK
[c] Animal Behaviour and Welfare Team, Animal and Veterinary Sciences Research Group, SRUC, West Mains Road, Edinburgh EH9 3JG, UK
[d] INRAE, GENESI, F-17700, Saint Pierre d'Amilly, France
[e] GenPhySE, Université de Toulouse, INRAE, ENVT, F-31326 Castanet Tolosan, France

ARTICLE INFO

Article history:
Received 26 February 2020
Received in revised form 21 August 2020
Accepted 25 August 2020
Available online 10 December 2020

Keywords:
Feed efficiency
Infrared thermography
Neonatal
Pig
Survival

ABSTRACT

Thermoregulation is essential to piglets' neonatal survival. This study used infrared thermography (**IRT**) to assess thermoregulation abilities of piglets from two lines divergent for residual feed intake (**RFI**). At birth, morphology (weight, length, width and circumference), vigour (respiration, mobility and vocalisation), and rectal temperature were recorded from piglets of the 11th generation of the low RFI (**LRFI**, more efficient; $n = 34$) and the high RFI (**HRFI**, less efficient; $n = 28$) lines. Infrared thermography images were taken at 8, 15, 30 and 60 min post partum. Temperatures of the ear base and tip, and of the back (i.e. shoulders to rumps) were extracted (Thermacam Researcher Pro 2.0) and analysed with linear mixed models (SAS 9.4). Piglets had different average hourly weight gain (HRFI = 7.1 ± 1.3 g/h, LRFI = 3.6 ± 1.3 g/h; $P < 0{,}001$) but did not differ in morphology or vigour. All temperatures increased overtime. At birth, piglets' rectal temperature was correlated with the initial temperature of the ear base and the maximum back temperature (0.37 and 0.33, respectively; $P < 0.05$). High residual feed intake piglets had lower ear tip temperatures than LRFI piglets at 15 (24.7 ± 0.37 °C vs. 26.3 ± 0.36 °C, respectively; $F_{1, 63.5} = 9.11$, $P < 0.005$) and 30 min post partum (26.2 ± 0.47 °C vs. 27.6 ± 0.44 °C, respectively; $F_{1, 66.9} = 4.52$, $P < 0.05$). Moreover, thermal pattern of the ear tip differed between the two genetic lines. In conclusion, IRT allowed non-invasive assessment of piglets' thermoregulation abilities and indicated an influence of genetic selection for RFI on neonatal thermoregulation abilities.

Implications

The infrared thermography is a reliable non-invasive technique for measuring the evolution of piglet body temperature during the first hour after birth, which allows detecting piglets at risk of hypothermia and to act upon it. Infrared thermography showed differences in neonatal thermoregulation between two genetic lines divergent for feed efficiency, which suggests differences in robustness.

Introduction

Hypothermia is a well-known cause of mortality in neonatal piglets (Herpin et al., 2002), hence the ability to thermoregulate shortly after birth can be considered a trait of robustness. While body characteristics such as (low) body mass index (**BMI**) and (low) ponderal index (**PI**) influence perinatal mortality, (low) rectal temperature and (low) vigour at birth are predictors of postnatal mortality (Baxter et al., 2008, 2009). Thermoregulation abilities of neonatal piglets are relative to their body energy and metabolism (Mellor and Cockburn, 1986), which can be influenced genetically. Indeed, Herpin et al. (2004) found differences in thermoregulation abilities between piglets from Chinese (Meishan) and European (Pietrain × (Landrace × Large White)) breeds. In particular, BW did not affect the thermoregulation abilities of Chinese piglets but it did affect those of European piglets with piglets below 1 150 g identified as a higher risk of heat loss (Herpin et al., 2004). This was proposed to reflect a side effect of selection for lean meat on the thermoregulation abilities of piglets, as piglets from Chinese breeds have higher body energy reserves at birth compared to piglets from European breeds (Herpin et al., 1993).

Genetic selection for improved food efficiency in pigs, associated with the production of leaner individuals, can be perceived as a risk factor for neonatal mortality. For instance, carcasses of pigs selected for low residual feed intake (**LRFI**) have a greater lean meat percentage and

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* Corresponding author.
E-mail address: schmitt.oce@gmail.com (O. Schmitt).
[1] Animal Welfare and Behaviour, School of Veterinary Sciences, University of Bristol, Langford House, Langford, BS40 5DU, UK.

https://doi.org/10.1016/j.animal.2020.100069

lower lipid content at slaughter, but limited differences of lipid content in subcutaneous fat, loin and liver at 19 kg BW, despite some metabolic differences in liver at that stage (Le Naou et al., 2012). It suggests that energy metabolism differences may be in place since birth between these lines, which might place low RFI (**LRFI**) pigs at greater risk of depletion of body reserves at birth for ensuring thermoregulation. On the other hand, selection did not affect pigs abilities to cope with stress and challenges, and pigs selected for LRFI might be more robust and/or resilient than pigs selected for high RFI (**HRFI**) (Gilbert et al., 2017). This highlights the need to investigate the effect of genetic selection for feed efficiency traits on the thermoregulatory abilities of neonatal piglets.

Some preliminary work investigated the use of infrared thermography (**IRT**) as a non-invasive technique to measure pigs' temperature and temperature changes (Llamas Moya et al., 2006; Tabuarici et al., 2012; Kammersgaard et al., 2013). As still being a novel technique, IRT studies should consider factors of influence on the data and control or account for external factors as much as possible. Llamas Moya et al. (2006) found that the skin temperature was not correlated with birth weight but was influenced by the huddling behaviour of the piglets and their location relative to a heat source. The authors further recommended drying piglets before taking the thermal images as the emissivity of wet skin is different from emissivity of dry skin. Tabuarici et al. (2012) used IRT images of neonatal piglets' ear base, ear tip and back to assess the potential use of IRT to detect piglets at risk of hypothermia. They found that the IRT data were not predictive of mortality risk but they could be used to predict shivering (Tabuarici et al., 2012). Although not all hypothermic piglets would shiver (Herpin et al., 2002), IRT could be used to identify and help piglets in need to limit morality.

Selection for better thermoregulation abilities could help to reduce preweaning mortality on commercial farms. To do so, it is necessary to investigate if neonatal thermoregulatory abilities of piglets are modulated by genetic selection objectives, and in which direction. Therefore, this study investigated the thermoregulatory abilities during the first hour post partum of piglets from two genetic lines divergent for RFI.

Material and methods

Animals and experimental design

The present experiment was conducted in January 2018 on the INRA UE1372 research facilities (UE GenESI, Surgères, France). In total, 34 piglets from 3 LRFI sows and 28 piglets from 4 high HRFI sows were involved in the study. These piglets represented the eleventh generation of the genetic lines. Each sow was inseminated with a different boar of its line to capture most of the lines variability. Piglets were born in free farrowing pens (300×246 cm), in which sows were crated at the time of birth. A heat lamp (Interheat Inc., Seongnam-si, Korea; 175 W) was suspended in the pen, on the side of the sow. Piglets had access to a creep area (180×90 cm). At birth, piglets were immediately dried and physical measures were taken. The handling procedure lasted for 8.2 ± 0.43 min after which piglets were placed in a plastic box for acquisition of thermal images. Piglets were then returned to their farrowing pen, at the back of the sow and their behaviour was observed until the next image acquisition (i.e. 15, 30 and 60 min post partum).

Measurements

Neonatal morphological measures and vitality scoring

Piglets were weighed and their body length (crown-to-rump), shoulder width and chest circumference were measured just after birth. These measurements were used for the calculation of BMI (birth weight/crown to rump length^2) and PI (birth weight/crown to rump length^3) as per Douglas et al. (2016). Rectal temperature was measured with a rectal thermometer (SC12; SCALA Electronic GmbH, Stahnsdorf, Germany). The handling time was recorded. Piglets were weighed again about 24 h post partum ('standardised weight'; as per normal farm procedure). This weight was used to calculate the average weight gain between birth and the standard weighing.

When being weighed, piglets were scored for vitality using three characteristics: mobility (score 0 = no movement, score 1 = moves around in half of the box and score 2 = moves around in the whole box), vocalisation (score 0 = no vocalisation, score 1 = some vocalisations (grunts or squeals) and score 2 = frequent high-pitched screams) and respiration (score 0 = normal and regular rate with no mucus, score 1 = increased rattling sound when breathing and score 2 = fast or irregular breathing with rattling sound and mucus).

Neonatal thermoregulation

The thermoregulation of piglets was measured by collecting thermal data at 8 min (i.e. birth), 15, 30 and 60 min post partum. Piglets were placed in a transparent plastic box (55.4×38.0×31.7 cm; Carrefour®) and images of their back were acquired from an upside view by a single experimenter who was standing next to the box and held the camera at 1 m distance from the piglet's back, with an angle of 75° (Fig. 1a). The emissivity of the camera was set at 0.98 (as validated by Soerensen et al. (2014)), the ambient temperature was set during image analysis according to the records (average 23.2 ± 0.07 °C), and the reflected temperature was set according to the measure done before data collection (average 22.8 ± 0.1 °C).

Between two image acquisitions, piglets were returned to their pen with the sow. At the time of each image acquisition, piglets' behaviour was scanned and scored as present or absent: suckling (i.e. having a teat in the mouth), huddling (i.e. resting in close contact with at least one other piglet) and locomotor (i.e. being in motion) behaviours were observed, as well as their proximity (i.e. being at less than 10 cm) with the sow and the heat lamp. Behaviours were scored as present (score 1) or absent (score 0) and were not analysed as such but used as covariates in the analyses of thermal images.

Thermal images were then analysed using the software Thermacam Researcher Pro 2.0. Measures of temperature were acquired from points of interest: base of the ear (maximum ear temperature), tip of the ear (minimum ear temperature) and 'back area' minimum, mean and maximum temperatures, which was drawn from the shoulders to the rumps and along the ribs (rectangle-like shape) (Fig. 1b). Reliability of the method was assessed with the intraclass correlation coefficients on SPSS Statistics 24 (IBM Corp., Armonk, NY, USA). Several images of the same piglet were rated by the same experimenter to obtain the inter-image reliability: coefficients were 0.47 for minimum, 0.95 for maximum, 0.96 for average, 0.89 for ear base and 0.82 for ear tip. The same experimenter rated the same images several times to obtain intra-observer reliability: coefficients were 0.44 for minimum, 1.00 for maximum, 1.00 for average, 0.99 for ear base and 0.86 for ear tip. Given the low reliability of the minimum temperature of the back, this measure was not retained for further analysis.

Statistical analyses

To determine the contribution of each variable to the line differences observed between piglets, data were first processed in a principal component analysis (**PCA**) using the factoextra_1.0.5, ggplot2_3.2.0, FactoMineR_1.42 (Lê et al., 2008) and missMDA_1.14 packages of R version 3.5.3. Following the recommendation included in the FactoMiner package, missing data were imputed using the imputePCA function of the missMDA package (Josse and Husson, 2016). When plotting the individual piglets against three first principal components, an ellipse representing the 75% confidence range for each line was drawn to show differences between the two genetic lines.

The other analyses were performed using the software SAS 9.4. A Pearson rank correlation test was used to investigate the correlations between birth rectal temperature and temperature data obtained from

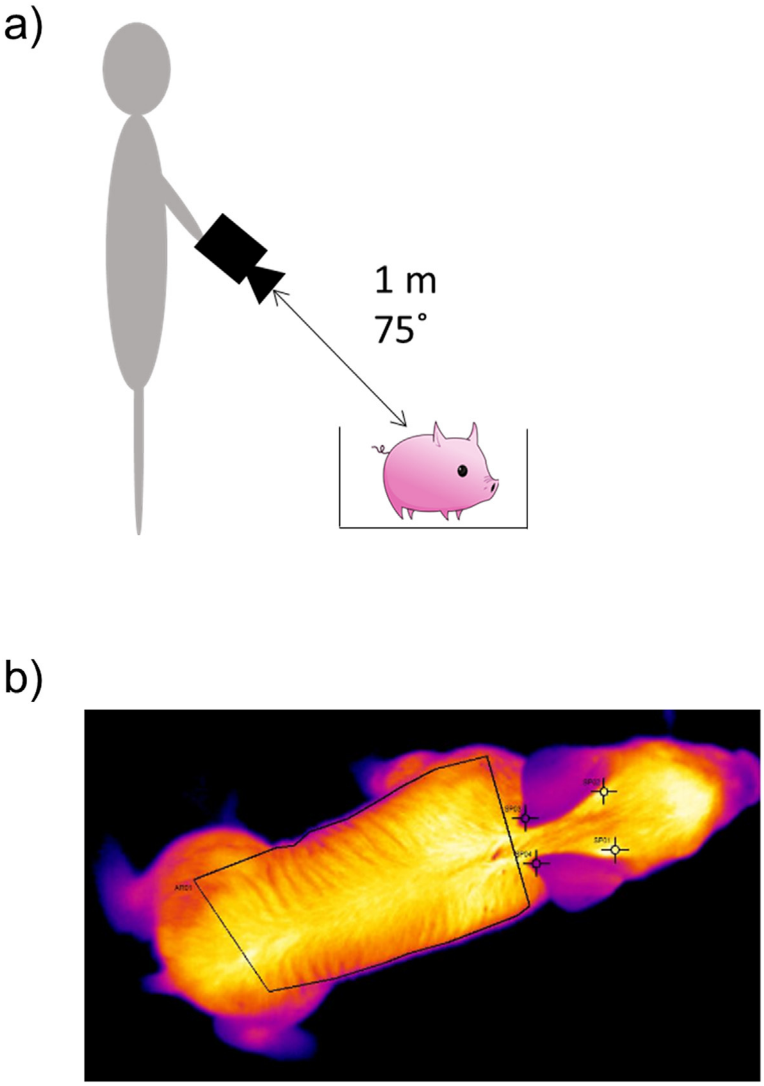

Fig. 1. (a) Schematic representation of the positioning of the camera for image acquisition and (b) Example of the infrared thermography images acquired from piglets.

thermal images at birth. General linear models were used to perform the analysis of morphological and temperature data. General linear mixed models with a Poisson distribution and a log link function were used to analyse the vitality data, except for the respiratory score which was analysed with a binary distribution and a logit function (because only scores 0 and 1 were given). Adjusted (Tukey–Kramer) means and associated SE, F-values, or t-values for pair-wise comparisons, and corresponding degrees of freedom are reported together with the level of significance of the test (*P*-value). From these analyses, significance of a factor was determined when the adjusted P-value associated was below 0.05. Tendencies were stated when the *P*-value was between 0.05 and 0.1.

The model for analysis of morphological and vitality data included the genetic line as a fixed factor. The models to analyse the standardised weight and average weight gain included the birth weight as a covariate.

Models for the analysis of temperature data included genetic line, time post partum and their interaction as fixed effects, time within animal as a repeated effect, and sow nested within genetic line as a random effect. Behavioural measures (binary variables: the presence/absence of behaviour) were kept in the models as fixed effects if their effect on temperatures was significant: only the proximity to the lamp was a covariate in the model for ear tip, maximum and average back temperature. Birth weight was also included as a covariate in all models except for the ear tip temperature, as it was not significant. Finally, temperature changes at the different locations between times of measure were also calculated from the thermal data and analysed. We only kept and presented the results of these analyses if the effect of the interaction between time and genetic line was significant. The statistical unit for all analyses was the individual piglet. Retrospective analysis of the power of our analyses showed a power of 0.78. Codes for the statistical models are shown in the Supplementary File.

Results

Neonatal morphological measures and vitality scoring

There was no effect of genetic line on the measures taken at birth, for the average hourly weight gain between birth and standard weighing (Table 1). Indeed, HRFI piglets had a higher average hourly weight gain between birth and standard weighing, compared to LRFI piglets (6.8 ± 0.51 g/h vs. 4.0 ± 0.44 g/h, respectively, $F_{1,5.4} = 17.05$, $P < 0.001$).

Table 1
Values of the morphological measurements performed on neonatal piglets (presented as adjusted mean (SE)). Piglets were either born from sows from the high residual feed intake line (HRFI, $n = 28$) or from sows from the low residual feed intake line (LRFI, $n = 34$).

	HRFI	LRFI	F-value	*P*-value effect of line
Birth weight (kg)	1.4 (0.07)	1.3 (0.07)	$F_{1,\,4.2} = 1.1$	NS
Standardised weight (kg)	1.5 (0.02)	1.4 (0.02)	$F_{1,\,3.35} = 3.77$	NS
Average weight gain (g/h)	6.8 (0.51)	4.0 (0.44)	$F_{1,\,5.4} = 17.05$	<0.001
Crown to rump length (cm)	28.4 (0.78)	26.6 (0.81)	$F_{1,\,4.52} = 2.52$	NS
Width (cm)	13.1 (0.22)	13.5 (0.22)	$F_{1,\,4.7} = 1.66$	NS
Circumference (cm)	24.9 (0.28)	25.2 (0.29)	$F_{1,\,5.53} = 0.42$	NS
Ponderal index	59.3 (5.99)	73.5 (6.31)	$F_{1,\,4.53} = 2.66$	NS
Body mass index	16.9 (1.04)	18.9 (1.08)	$F_{1,\,4.33} = 1.92$	NS
Rectal temperature (°C)	37.0 (0.28)	37.2 (0.28)	$F_{1,\,3.83} = 0.27$	NS
Mobility score	1.3 (0.22)	1.5 (0.24)	$F_{1,\,3.78} = 0.28$	NS
Vocalisation score	1.0 (0.38)	1.1 (0.43)	$F_{1,\,5.03} = 0.07$	NS
Respiration score[1]	0.0 (0.00)	0.4 (0.05)	–	–

[1] Raw data are presented as the analysis could not be performed.

Table 2
Adjusted mean (SE) rectal temperature, and temperatures collected using infrared thermography (IRT) at the ears (base and tip) and in the back area (maximum and average) of neonatal piglets (approximately 8 min post partum), together with Pearson correlation coefficients with rectal temperature. The *P*-value informs on the significance of the correlations.

	Mean (SE)	Pearson correlation coefficient	*P*-value
Rectal temperature	37.2 (0.17)		
Back temperature			
Maximum	35.6 (0.14)	0.33	0.03
Average	34.1 (0.16)	0.25	0.11
Ear tip temperature	25.9 (0.37)	−0.08	0.60
Ear base temperature	35.1 (0.21)	0.37	0.02

Neonatal thermoregulation

At birth (8 min post partum), only the maximum back temperature and the ear base temperature had significant correlations with rectal temperature (Table 2). The correlations were positive and moderately strong, which indicates that the ear base and the maximum back temperatures could be valid predictors of rectal temperature.

Time had a significant effect on all the temperature measures taken, as they increased over time (Table 3). Briefly, for both ear and back, the temperature was higher at 60 min post partum than at any other time points. Only the average back temperature showed a significant increase between birth and 15 min post partum ($t_{61.1} = -3.21$, $P < 0.05$).

Principal component analysis

The PCA computed the following morphological and thermal variables:

Morphological variables: crown-to-rump length, circumference, width, BMI, PI, weight at birth, official weight (at approximately 24 h post partum), average hourly weight gain between weight at birth and official weight.

Temperature variables: rectal temperature, minimum/maximum/average back temperature at birth/15/30/60 min post partum, temperature of the ear tip and base at birth/15/30/60 min post partum.

Three dimensions (or principal components) were retained from the analysis, as they explained 35.7% (dimension 1), 14.2% (dimension 2) and 12.9% (dimension 3) of the total variance of the data (Supplementary Figure S1). Dimension 1 was mostly characterised by positive loadings of temperature collected at 15, 30, and 60 min post partum at the back (maximum and average) and at the ear base (Fig. 2). Dimension 2 was mostly characterised by positive loadings of the birth temperatures of the back (minimum, average and maximum) and of the ear base, and negative loadings of the piglets' width, circumference and BMI (Fig. 2). Finally, dimension 3 was mostly characterised by negative loadings of the crown-to-rump length, and positive loadings of PI, BMI, minimum temperature of the back at 15 min post partum, and temperatures of the ear tip at birth and 15 min post partum (Fig. 2). When plotted against these dimensions, piglets of the two genetic lines appeared to cluster differently (Fig. 3 and Supplementary Figure S2), which suggested that at least some of the temperature (e.g. minimum temperature of the back at 15 min post partum, temperature of the ear tip at birth and 15 min post partum) and morphological (e.g. crown-to-rump length, PI and BMI) variables differed between the genetic lines.

Genetic differences in thermoregulation

Overall, maximum and average temperatures were similar between the two genetic lines (Table 4). The interaction between genetic line and time did not influence the maximum ($F_{3,\,96.5} = 1.32$, $P > 0.2$) or average ($F_{3,\,92.4} = 1.07$, $P > 0.3$) back temperatures (Table 4).

Overall, HRFI and LRFI piglets had similar temperatures at the base of the ear (35.3 ± 0.28 °C vs. 35.6 ± 0.28 °C, respectively; $F_{1,\,4.76} = 0.49$, $P > 0.1$) and at the tip of the ear (26.5 ± 0.28 °C vs. 27.1 ± 0.30 °C, respectively; $F_{1,\,78.2} = 2.63$, $P > 0.05$). There was a significant effect of the

Table 3
Adjusted mean (SE) temperatures of neonatal piglets' ear base, the ear tip and the back area (maximum and average temperatures) at the different collection times (birth, 15, 30 and 60 min post partum). Data of piglets born from both genetic lines, i.e. low residual feed intake (LRFI, $n = 34$ piglets) line or high residual feed intake (HRFI, $n = 28$ piglets) line, were pooled. Different superscript letters indicate significant differences between time points ($^{a,\,b\cdots}$ $P < 0.05$; $^{A,\,B\cdots}$ $P < 0.005$).

	Birth (8 min pp.[1])	15 min pp.	30 min pp.	60 min pp.	F-value	P-value effect of time
Ear base	34.9 (0.26)^{A}	35.0 (0.20)^{Aa}	35.4 (0.23)^{Ab}	36.6 (0.21)^{B}	$F_{3,\,89.6} = 39.53$	<0.001
Ear tip	26.2 (0.40)^{ABC}	25.5 (0.25)^{B}	26.9 (0.31)^{C}	28.5 (0.25)^{D}	$F_{3,\,107} = 31.51$	<0.001
Back maximum	35.7 (0.19)^{A}	36.0 (0.11)^{A}	36.2 (0.17)^{A}	37.0 (0.15)^{B}	$F_{3,\,103} = 20.45$	< 0.001
Back average	34.1 (0.20)^{Aa}	34.7 (0.12)^{Ab}	34.8 (0.17)^{Ab}	35.6 (0.16)^{B}	$F_{3,\,98.1} = 23.1$	< 0.001

[1] pp. = post partum.

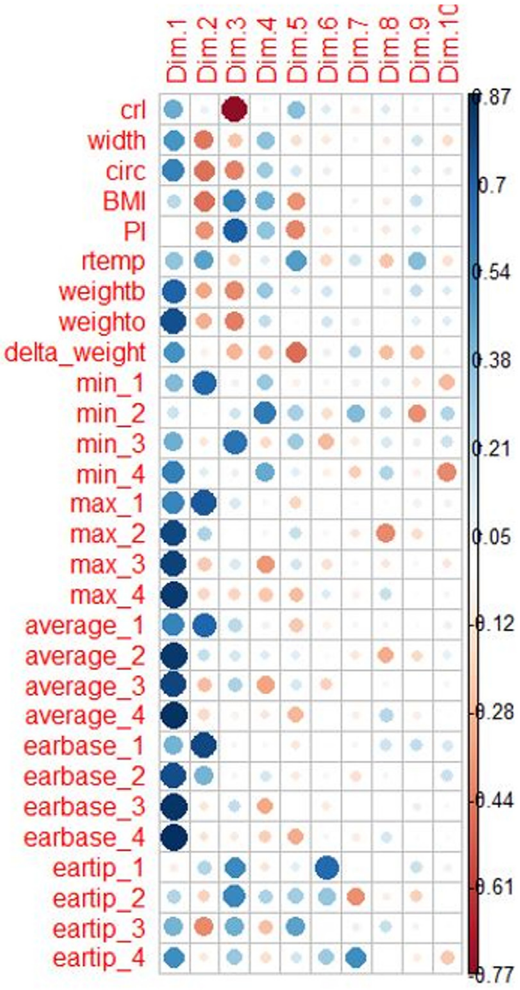

Fig. 2. Contribution of the variables to the eigenvalues of the 10 first dimensions generated by the principal component analysis. The colour scale on the left-hand side indicated the importance (darker = stronger) and direction (blue = positive, red = negative) of the contribution of each of the measures acquired from neonatal piglets. Abbreviations used: crl = crown-to-rump length; circ = chest circumference; BMI = body mass index; PI = ponderal index; weigthb = weight at birth; weighto = official weight (at approximately 24 h post partum); delta_weight = average hourly weight gain between weight at birth and official weight; rtemp = rectal temperature; min_X = minimum back temperature at X; max_X = maximum back temperature at X; average_X = average back temperature at X; eartip_X = temperature of the tip of the ear at X; earbase_X = temperature of the base of the ear at X (X values: 1 = birth, 2 = 15 min post partum, 3 = 30 min post partum, 4 = 60 min post partum).

interaction between time and genetic line on the ear tip temperature ($F_{3,\ 101} = 4.22$, $P < 0.05$), since HRFI piglets had lower ear tip temperatures than LRFI piglets at 15 (24.7 ± 0.37 °C vs. 26.3 ± 0.36 °C, respectively; $F_{1,\ 63.5} = 9.11$, $P < 0.005$) and 30 min post partum (26.2 ± 0.47 °C vs. 27.6 ± 0.44 °C, respectively; $F_{1,\ 66.9} = 4.52$, $P < 0.05$) (Fig. 4a).

Consequently, the changes in ear tip temperature between time points were affected by genetic line. High residual feed intake piglets had a decrease in ear tip temperature between birth and 15 min post partum while LRFI piglets did not (−1.2 ± 0.58 °C vs. 0.9 ± 0.58 °C, respectively; $F_{1,\ 2.91} = 6.33$, $P = 0.09$); and they had a greater temperature increase between 30 and 60 min post partum (2.0 ± 0.38 °C vs. 0.8 ± 0.35 °C, respectively; $F_{1,\ 51} = 5.2$, $P < 0.05$) (Fig. 4a). However, the temperature change at the ear tip was the same for both genetic lines between 15 min and 30 min post partum (1.4 ± 0.51 °C vs. 1.2 ± 0.49 °C, respectively; $F_{1,\ 48} = 0.03$, $P = 0.9$) (Fig. 4a). On the contrary, piglets' ear base temperatures did not differ across time (Fig. 4b).

Discussion

This experimentation aimed at researching if selection for RFI would influence the thermoregulatory abilities of neonatal piglets. Morphological and vitality measures did not differ between the genetic lines, except the average hourly weight gain, consequently these results will not be discussed further. The technique of IRT was used to assess the thermal status of piglets within the first hour after birth and seemed to be a valid tool to detect differences in the thermal status of neonatal piglets over the first hour post partum.

Similarly to other studies, the present study identified the ear base and the maximum back temperatures as most correlated to the rectal temperature of piglets at birth, thus they might be the most valid points of measure to approximate internal temperature. However, the present correlations are lower than those reported in Tabuarici et al. (2012) and Kammersgaard et al. (2013), probably because they had a greater sample size and a lower time gap between rectal and IRT measures. Drying piglets at birth are advised to limit errors in IRT measure due to differences in the wetness of the piglets' skin but it removed a great challenge that they normally encounter in the thermoregulation process, as wet skin increases heat loss. However, drying piglets is a recommended management technique on farms to help piglets at birth, and even doing so we identified differences in thermoregulation abilities. The time of acquisition of images relative to the piglet's birth was controlled in the present study, as well as environmental factors (isolation in a plastic box); which reduce the risk of variability due to external factors, compared to other studies (Tabuarici et al., 2012; Kammersgaard et al., 2013). Indeed, comparing piglets temperature at 24 h is good to detect piglets' failure to thermoregulate but might not allow to detect subtle differences in piglets' thermoregulation abilities since most piglets would have reached normal temperature (39 °C as reported by Herpin et al. (2002)). We also considered other external factors of influence, such as the locomotion, feeding and heat exposition of the piglets between image acquisitions. Only exposition to the heat lamp appeared to influence temperature of the ear tip, and the maximum and average temperatures of the back. Unsurprisingly, being exposed to the heat lamp resulted in higher temperatures (Malmkvist et al., 2006; Andersen et al., 2009). However, other factors such as birth interval can influence neonatal thermoregulation, in particular in the event of prolonged farrowing resulting in hypoxia. Such influence could not be addressed in the present study due to the small sample size. Infrared thermography is a novel technique and requires identification of external factors of influence to be used at its best.

Piglets' temperatures increased over time at the locations of interest (ears and back area). Herpin et al. (2002) reported a drop of 2 °C in piglets' rectal temperature shortly after birth but the decreases observed in the present study were only numerical, probably due to the handling time and drying procedure that may have interfered with the initial heat loss at birth. Nevertheless, IRT could detect differences in the minimal temperature of neonatal piglets' back and ear tip across time, depending on the genetic line. Ear tip temperature was lower in HRFI piglets than in LRFI piglets at 15 and 30 min post partum and this effect deserve more discussion. Ear base temperature gradually increased over time for all piglets, not different between the two genetic lines. Therefore, LRFI piglets seemed to better maintain their core and external temperature across the first hour post partum, thereby showing optimal thermoregulation process. However, HRFI piglets had a difference of thermal pattern at the ear tip and the ear base, as the ear tip temperature dropped between 8 and 15 min post partum while the ear base temperature was maintained. This suggests that in HRFI piglets thermoregulation process involved migration of the body heat from the extremities (ear tips), which became cooler, to the internal organs (ear base, close to the brain area), which became warmer. Therefore, they may have used their vascularised ears as a regulatory organ (Andersen et al., 2008) to ensure thermoregulation. Furthermore, it might indicate greater difficulties to reach thermal comfort in HRFI piglets, compared

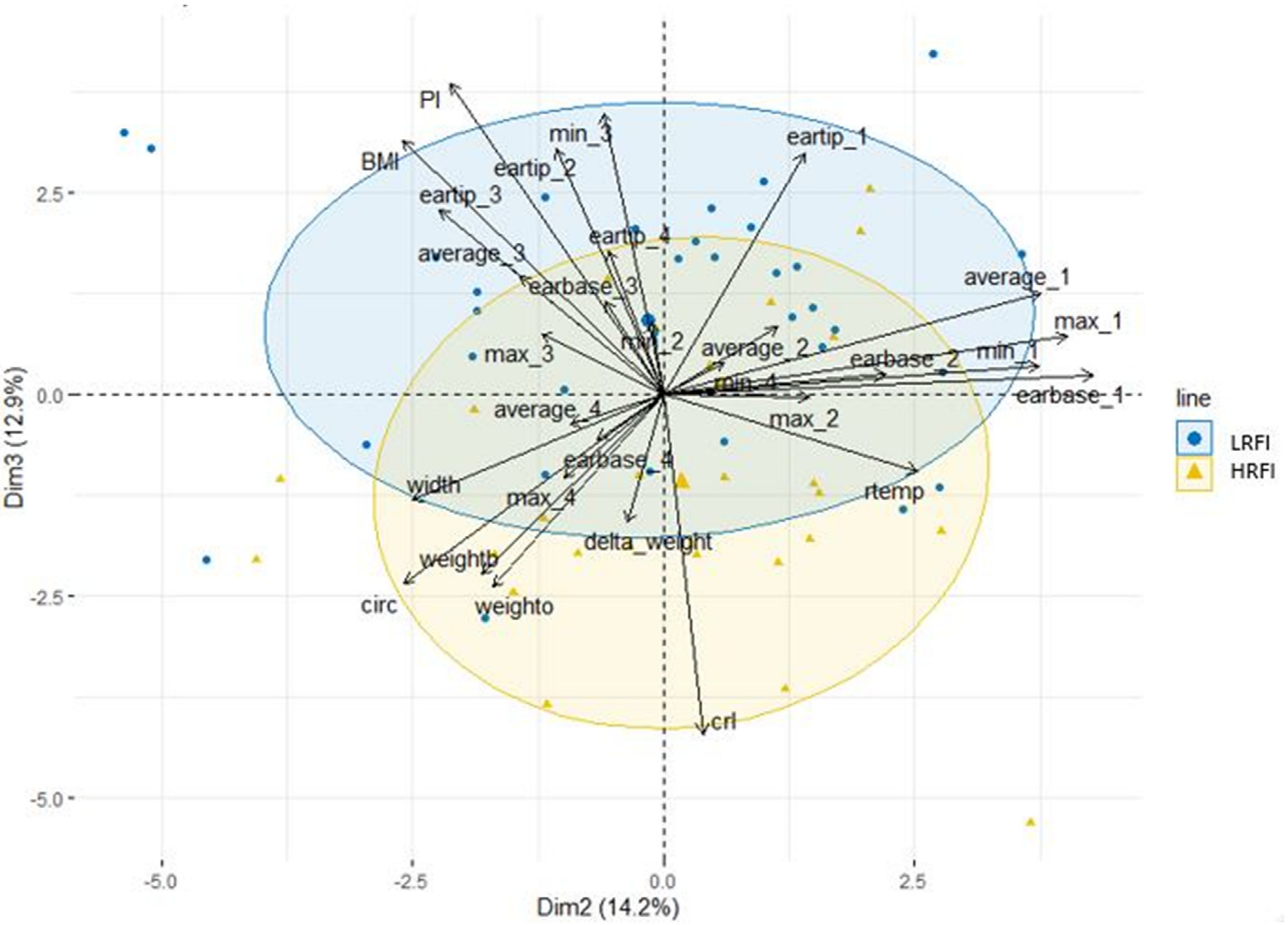

Fig. 3. Graphical representation of the clustering of piglets according to their loadings on the dimensions retained from the principal component analysis. Dimension 2 explained 14.2% of data variance and dimension 3 explained 12.9% of data variance. Abbreviations used: crl = crown-to-rump length; circ = chest circumference; width = shoulder to shoulder width, BMI = body mass index; PI = ponderal index; weigthb = weight at birth; weighto = official weight (at approximately 24 h post partum); delta_weight = average hourly weight gain between weight at birth and official weight; rtemp = rectal temperature; min_X = minimum back temperature at X; max_X = maximum back temperature at X; average_X = average back temperature at X; eartip_X = temperature of the tip of the ear at X; earbase_X = temperature of the base of the ear at X (X values: 1 = birth, 2 = 15 min post partum, 3 = 30 min post partum, 4 = 60 min post partum). LRFI: low residual feed intake, HRFI: high residual feed intake.

to LRFI piglets. Another explanation for the drop in ear tip temperature after birth is that HRFI piglets could be more susceptible to stress and have been experiencing acute stress during the neonatal handling procedures (morphological measurements and blood sampling). Indeed, stress reactions seem to result in a reduction of body surface temperature (Herborn et al., 2015). Nonetheless, it would still be attributable to the genetic line of the piglets. Indeed, Campos et al. (2014) investigated the difference in thermoregulatory abilities of pigs from the same genetic lines as piglets in the present experiment. They exposed weaned pigs of the seventh generation of divergent selection to the ambient temperature of 30 °C for 14 days, and found that pigs selected for LRFI had a better long-term thermoregulatory response (lower skin temperature) to the elevation of ambient temperature (Campos et al., 2014). This suggests better coping abilities to heat stress

Table 4

Adjusted mean (SE) maximum and average temperatures of neonatal piglets' back area. Piglets were either born from sows from the low residual feed intake line (LRFI, $n = 34$ piglets) or the high residual feed intake line (HRFI, $n = 28$ piglets).

	HRFI	LRFI	Test statistics	*P*-value effect of line
Maximum	36.2 (0.16)	36.3 (0.17)	$F_{1,\ 3.49} = 0.28$	N.S.
Birth (8 min pp[1].)	35.6 (0.25)	35.8 (0.25)	$t_{16.4} = -0.62$	N.S.
15 min pp.	35.9 (0.16)	36.1 (0.16)	$t_{3.7} = -0.88$	N.S.
30 min pp.	36.0 (0.25)	36.3 (0.24)	$t_{17} = -0.87$	N.S.
60 min pp.	37.1 (0.21)	36.9 (0.20)	$t_{7.22} = 0.81$	N.S.
Average	34.6 (0.18)	35.0 (0.18)	$F_{1,\ 4.35} = 2.56$	N.S.
Birth (8 min pp.)	34.0 (0.28)	34.3 (0.28)	$t_{18.9} = -0.89$	N.S.
15 min pp.	34.4 (0.17)	34.9 (0.17)	$t_{3.97} = -1.77$	N.S.
30 min pp.	34.5 (0.25)	35.2 (0.25)	$t_{14.8} = -1.9$	N.S.
60 min pp.	35.5 (0.22)	35.7 (0.22)	$t_{7.63} = -0.6$	N.S.

[1] pp. = post partum.

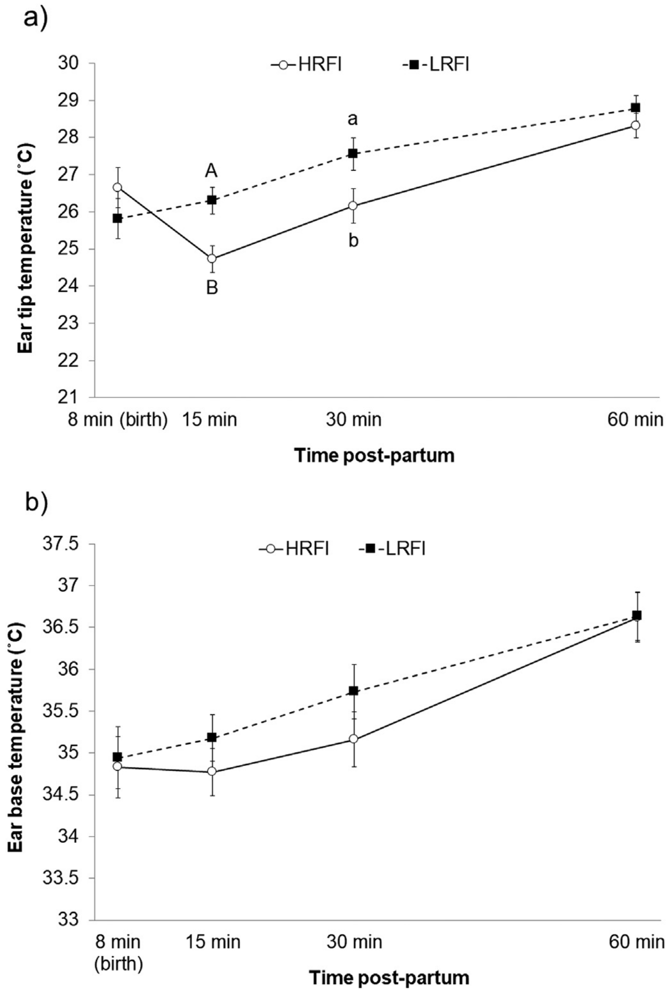

Fig. 4. Adjusted mean (SE) temperature of neonatal piglets' ear base (a) and ear tip (b), as measured by infrared thermography. Piglets were either born from sows of low residual feed intake line (LRFI, $n = 34$ piglets; black squares and dashed line) or of high residual feed intake line (HRFI, $n = 28$ piglets; white circles and full line). Different at each time point letters indicate significant differences between the genetic lines (uppercase: $P < 0.005$; lower case: $P < 0.05$).

and, together with the results of the present study, might imply that LRFI pigs have better thermoregulatory abilities overall due to better robustness.

Even if the present study did not identify differences between the two genetic lines in terms of body characteristics and vigour at birth, both were previously shown to be important characteristics influencing prenatal and postnatal survival (Baxter et al., 2008). Thermoregulation is closely related to birth weight and size, with smaller piglets being at a higher risk of hypothermia because they experience greater heat loss due to their greater surface to body mass ratio (Herpin et al., 2002). Furthermore, BMI is positively correlated with the relative fatness of the neonates (in humans: De Cunto et al., 2014), which can be related to their thermoregulation abilities (Herpin et al., 2004). The two genetic lines used in the present study differs at slaughter age in their back fat depth (Le Naou et al., 2012), which suggests metabolic differences related to fat deposition and resources that could already at play at the time of birth.

Finally, these thermal data need to be compared to the results from gene expression data and metabolomic analysis, to identify potential molecular and metabolic indicators associated with survival. This could explain how the piglets from the LRFI line are more robust than piglets from the HRFI line. More practically, this could help orientating the genetic selection towards better thermoregulation abilities, to reduce neonatal mortality.

Conclusion

In conclusion, this study showed that IRT is a useful tool to assess the thermoregulatory abilities of piglets at birth. The results indicate that neonatal thermoregulation abilities may be influenced by genetic selection for RFI, as suggested by differences in the thermal status of their ear tips. However, these results have to be taken cautiously as the sample size of the experiment was small.

Supplementary materials

Supplementary data to this article can be found online at https://doi.org/10.1016/j.animal.2020.100069.

Ethics approval

This study was conducted in accordance with the French legislation on experimentation and ethics. The French Ministry of Agriculture authorised this experiment on living animals at the INRAE facilities (UE1372 GenESI Génétique, Expérimentation et Systèmes Innovants Complément, INRAE Le Magneraud) with the agreement number for animal housing A-17661 and the agreement number for the protocol APAFiS #13648-2018020417291866 v4.

Data and model availability statement

Data and models are not deposited in a repository. However, codes for statistical analysis can be found in Supplementary File.

Author ORCIDs

Dr. Oceane Schmitt: 0000-0003-4932-3743.
Dr. Laurianne Canario: 0000-0002-0046-381X.
Dr. Laurence Liaubet: 0000-0003-0201-0264.

Author contribution

Oceane Schmitt: Conceptualisation, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Visualisation, Writing – original draft, Writing – review and editing. Sebastien Reigner: Resources. Jean Bailly: Resources. Laure Ravon: Resources. Yvon Billon: Resources. Laure Gress: Resources and Investigation. Lisa Bluy: Resources and Investigation. Laurianne Canario: Resources. Helene Gilbert: Resources and Writing – review and editing.

Agnes Bonnet: Resources, Supervision. Laurence Liaubet: Supervision, Funding acquisition, Investigation, Project administration, Validation, Writing – review and editing.

Declaration of interest

None.

Acknowledgements

The authors are grateful to the Magneraud and GenPhySE teams for their assistance in data collection. Preliminary results of the present study have been published in an abstract form (Schmitt et al., 2018, 2019).

Financial support statement

INRA metaprogram fund GISA (Integrated management of animal health) funded the SuBPig project (Enhancing survival at birth) and the COST-Action CA15134 GroupHouseNet funded the Short-Term Scientific Mission (STSM).

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