Effects of drying and providing supplemental oxygen to piglets at birth on rectal temperature over the first 24 h after birth[1]

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ABSTRACT: Neonatal piglets can experience both a decrease in body temperature and hypoxia, increasing risks for pre-weaning mortality. This research evaluated the effects of drying and providing supplemental oxygen to newborn piglets on rectal temperature (RT) over the first 24 h after birth. The study used a CRD with three Intervention Treatments (IT; applied at birth): Control (no intervention), Drying (dried using a desiccant), Oxygen [dried using a desiccant and placed in a chamber (at 40% oxygen concentration) for 20 min]. A total of 42 litters (485 piglets) were randomly allotted to treatments at the start of farrowing. At birth, each piglet was given a numbered ear tag, weighed, and the treatment was applied; RT was measured at 0, 20, 30, 45, 60, 120, and 1440 min after birth. Blood was collected from one piglet from each birth weight quartile within each litter at 24 h after birth to measure plasma immunocrit concentration. There was no effect ($P > 0.05$) of IT on piglet RT at 0 or 1440 min after birth. Between 20 and 60 min after birth, piglet RT was lower ($P \leq 0.05$) for the Control than the Drying treatment, with the Oxygen treatment being intermediate and different ($P \leq 0.05$) from the other two IT. The effect of piglet birth weight on responses to IT were evaluated by classifying piglets into Birth Weight Categories (BWC): Light (<1.0 kg), Medium (1.0 to 1.5 kg), or Heavy (>1.5 kg). There were IT by BWC interactions ($P \leq 0.05$) for piglet RT at all measurement times between 20 and 120 min after birth. Relative to the Control, the effects of the Drying and Oxygen treatments on RT were greater ($P \leq 0.05$) for Light than heavier piglets. Plasma immunocrit concentrations tended ($P = 0.07$) to be greater for piglets on the Control treatment compared to the other two IT and were lower ($P \leq 0.05$) for Light than Heavy piglets, with Medium piglets being intermediate and different ($P \leq 0.05$) to the other BWC. In conclusion, drying piglets at birth reduced the extent and duration of RT decline in piglets in the early postnatal period compared to undried piglets, especially for those of low birth weight. However, the combination of drying and placing piglets in an oxygen-rich environment provided no additional benefit over drying alone.

INTRODUCTION

Newborn piglets are cold susceptible. They have limited body surface insulation, being born with very little body fat and a sparse hair coat. They are born wet, and energy is required to evaporate amniotic fluid from the body surface, which reduces body temperature (Curtis, 1970). In addition, piglets have low body energy reserves at birth and do not possess brown fat that is found in some species, limiting the capacity for thermoregulatory heat production (Curtis, 1970; Trayhurn et al., 1989). As a result, the lower critical temperature (below which the piglet has to produce extra heat to maintain body temperature) is relatively high, around 35 °C (Mount, 1959). Largely due to greater body size, the thermal comfort zone of the sow is considerably lower than that of the piglet. At temperatures above the upper threshold of this zone sows become heat stressed, with negative effects on the farrowing process (Muns et al., 2016) and, ultimately, on feed intake and milk production (Black et al., 1993). As a compromise between sow and piglet thermal requirements, farrowing rooms are typically maintained at temperatures around 22 °C on the day of farrowing (PIC, 2018). This is considerably below piglet lower critical temperature, leading to substantial heat loss from the body surface (mainly via convection and radiation, as well as evaporation).

In the absence of any mitigating intervention to reduce heat loss, all piglets experience some degree of hypothermia under typical farrowing room conditions (Pedersen et al., 2011). Hypothermic piglets generally have decreased mobility and vigor, limiting the ability to compete with littermates for access to teats during suckling, resulting in reduced colostrum intake (Le Dividich and Noblet, 1981). This reduces the energy available to the piglet for thermoregulation and can lower immune status. Higher piglet rectal temperature in the early postnatal period has been favorably associated with time to first suckling and colostrum intake (Kammersgaard et al., 2011; Vallet et al., 2015). Piglets which do not ingest sufficient colostrum are more susceptible to disease (Devillers et al., 2011). Therefore, hypothermia predisposes piglets to mortality, either directly or from secondary causes such as starvation, crushing, and disease (Devillers et al., 2011). Low birth weight piglets are at greater risk of postnatal hypothermia (Herpin et al., 2002) as they have a higher body surface area to body volume ratio than heavier littermates and, therefore, have a relatively greater potential for heat loss (Vande Pol et al., 2020a,b, 2021). In addition, they have lower body energy stores to use for heat production (Herpin et al., 2002).

One method of reducing heat loss immediately after birth is through limiting the evaporation of amniotic fluid by drying piglets at birth. In this regard, Vande Pol et al. (2020a,b) showed that drying piglets with a desiccant reduced piglet temperature decline in the early postnatal period compared to an undried control, and that this effect was greatest for low birth weight piglets. In addition to reducing hypothermia in neonatal piglets, Vasdal et al. (2011) showed that drying piglets at birth also reduced the time to first suckling which could result in increased colostrum intake (Declerck et al., 2017). However, Christison et al. (1997) reported no effect of drying or warming of piglets at birth on time to first suckling. In addition, Vande Pol et al. (2021) reported no effect of drying piglets at birth on serum immunocrit concentration, which is an indirect measurement of colostrum intake (Vallet et al., 2015). Further study is required to establish the impact of drying and warming of piglets at birth on piglet immunocrit levels.

Another potential cause for piglet morbidity and mortality in the early postnatal period is hypoxia. This can be relatively severe if during farrowing the time from umbilical cord rupture to piglet expulsion is extended (Trujillo-Ortega

et al., 2007). One potential intervention to reduce the negative effects of hypoxia is to administer oxygen to piglets immediately after birth. There has been limited research on the effect of this approach on postnatal changes in piglet rectal temperatures, and results of previous studies have been contradictory. Herpin et al. (2001) found a positive effect of oxygen administration at birth on both body temperature of all piglets, and on pre-weaning mortality of low birth weight piglets. In contrast, Willard (2020) found that drying piglets at birth followed by administration of oxygen immediately after birth resulted in lower rectal temperatures than the application of drying alone. Given these contradictory results, further research is necessary to determine the impact of oxygenation on postnatal changes in piglet body temperature. Therefore, the objective of this study was to determine the effects of drying and oxygen supplementation of piglets at birth on rectal temperatures over the first 24 h after birth under typical commercial production conditions.

MATERIALS AND METHODS

This study was conducted in the farrowing facilities of a commercial breed-to-wean farm of The Maschhoffs, LLC, located near Crawfordsville, IN, during the months of September to November. The experimental protocol was approved by the University of Illinois Institutional Animal Care and Use Committee prior to the initiation of the research.

Animals, Experimental Design, Treatments, and Allotment

A total of 42 litters (485 piglets) were used. Sows were from 15 commercial dam lines of Yorkshire and Landrace origin and had been mated to commercial sire lines. The experiment compared three Intervention Treatments (applied at birth): Control (no drying or supplemental oxygen); Drying (piglets were completely dried by repeatedly coating with a commercial cellulose-based desiccant); Oxygen [piglets were dried as in the Drying treatment and placed in an enclosed chamber (at 40% oxygen concentration) for 20 min. Litters were randomly allotted to treatment at the start of farrowing after the birth of the first piglet, with the restriction that sow genotype and parity were balanced across treatments.

Housing and Management

Each sow was housed in an individual farrowing crate, located in the center of a farrowing pen; the flooring was of either woven metal or perforated plastic. Flooring type was balanced across treatments. Crate dimensions were 0.6 m wide by 2.0 m long, giving a floor space within the crate of 1.2 m²; pen dimensions were 1.5 m wide by 2.1 m long, giving a total pen floor space of 3.2 m². Crates were equipped with a sow-operated feed dispenser attached to a feed trough and a nipple-type water drinker for the sow. An infrared heat lamp was suspended in the center of the floor area over an insulated rubber mat located on one side of the farrowing pen. Farrowing room air temperature was maintained using heaters, evaporative cooling cells, and fan ventilation as needed; room thermostats were set at 22.5 °C throughout the study period.

Management in the farrowing facility was according to farm protocols. Sows that had not farrowed by d 116 of gestation were induced to farrow on the following d using Lutalyse (1 injection of 1 mL given at 0600 h; Zoetis; Parsippany, NJ); the identity of each sow induced and date of induction were recorded. The farrowing process was monitored continuously by the investigators; if the interval between the births of piglets exceeded 60 min, the investigator checked the birth canal for obstructions, and assisted the farrowing process as needed.

Procedures and Measurements

Sow rectal temperature was measured at the start and end of the farrowing process; sow parity and litter size were recorded. At birth, piglets were given a uniquely numbered ear tag for identification, and the assigned treatment was applied. Piglet rectal temperature was measured at birth and at 20, 30, 45, 60, 120, and 1440 min after birth. After the Intervention Treatments were applied, piglets were returned to the farrowing pen (immediately for the Control and Drying treatments, after 20 min in the oxygen chamber for the Oxygen treatment), being placed at the udder of the sow. Piglets were weighed within 12 h of birth using a Brecknell LPS-15 bench scale (Avery Weigh-Tronix; Fairmont, MN; with a resolution of 0.005 kg). Scales were calibrated daily prior to use with a standard test weight. An enclosed plastic box (dimensions 43.2 cm × 81.3 cm × 31.1 cm; Contico; Saint Louis, MO) was modified to create the chamber used for the Oxygen treatment. Modifications included

installing tubing to deliver the oxygen, an oxygen sensor, heating pad, a thermometer, and viewing windows (clear plastic ports on the top of the chamber for observing piglets). A 50:50 oxygen:nitrogen mixture was dispensed into the chamber, with the rate being adjusted as necessary to maintain an oxygen concentration of around 40% throughout the time that piglets were in the chamber. Oxygen concentrations in the chamber were monitored continuously using an oxygen sensor (CM-0161 TR250Z 95% Oxygen Sensor, CO_2Meter, Ormond Beach, FL).

Piglet and sow rectal temperatures were measured, at a depth of 2.5 and 10 cm (Soerensen and Pedersen, 2015), respectively, using a HSTC-TT-K-24S-36 thermocouple attached via a SMPW-K-M connector to a dual input K/J digital thermometer (HH801A; Omega; Stamford, CT; with a resolution of 0.1 °C). Thermocouples were calibrated each week during the study period by taking measurements in a temperature-controlled chamber (Model CL134, Omega Engineering Inc., Norwalk, CT) that was set at reference temperatures that encompassed the expected range (i.e., 30, 32, 34, 36, 38, and 40 °C). A regression equation was developed between measured and reference temperatures for each thermocouple and was used to adjust all rectal temperature measurements taken during the following week of the study with that thermocouple. This approach was used to adjust for the variation in temperature measurements between thermocouples and changes in thermocouple accuracy over time. The floor surface temperature in each farrowing pen was measured at three locations [behind and at both sides of the sow (one of these measurements being under the heat lamp)] at the beginning and end of the farrowing process using a digital infrared thermometer (TOOGOO GM320 LCD digital infrared thermometer gun; Shenzhen IMC Digital Technology Co.; Shenzhen, China; with a resolution of 0.1 °C).

Blood samples to measure serum immunoglobulin immunocrit concentrations were obtained at 24 h after birth from a sub-sample of four piglets from each litter (one piglet randomly selected from each birth weight quartile of each litter). A 2 mL blood sample was collected from the abdominal vein of each piglet into plain glass tubes, placed immediately on ice, and subsequently centrifuged (for 30 min at 3000 × g). Serum was obtained and stored at −20 °C prior to analysis for immunoglobulin immunocrit concentration as previously validated and described by Vallet et al. (2013).

Statistical Analysis

The experiment used a completely randomized design, with litter as the experimental unit and piglet as a subsample of the litter. The PROC UNIVARIATE procedure of SAS v. 9.4 (SAS Inst. Inc., Cary, NC) was used to verify normality and residual variance homogeneity. All variables conformed to normality and homogeneity assumptions and were analyzed using mixed models (PROC MIXED of SAS v. 9.4; SAS Inst. Inc., Cary, NC). The model used for the analysis of sow parameters and litter measurements accounted for the fixed effect of Intervention Treatment. The model used for analysis of treatment differences in piglet birth weight and serum immunoglobulin immunocrit concentration also accounted for the random effect of litter.

Effects of Intervention Treatment on piglet rectal temperatures at the various measurement times after birth were analyzed using a repeated measures analysis, with the model accounting for the fixed effects of Intervention Treatment, measurement time, and the interaction, and the random effect of litter. A repeated-measures statement was included in the model with measurement time as the REPEATED term and piglet within litter as the SUBJECT term.

An analysis was carried out to determine if the response to Intervention Treatment differed according to piglet birth weight. Piglets were classified into Birth Weight Categories (BWC): Light (<1.0 kg; 0.81 ± 0.167 kg), Medium (1.0 to 1.5 kg; 1.29 ± 0.135 kg), or Heavy (>1.5 kg; 1.73 ± 0.156 kg). The maximum weight for the Light category (i.e., 1.0 kg) represented the birth weight below which pre-weaning mortality increases substantially (Zotti et al., 2017). The minimum weight for the Heavy category (i.e., 1.5 kg) represented the weight above which pre-weaning mortality is relatively unaffected by birth weight (Zotti et al., 2017). Piglet rectal temperature data at each measurement time were analyzed using a statistical model that accounted for the fixed effects of BWC, Intervention Treatment, and the interaction, and the random effect of litter.

For all analyses, when the fixed effects were a significant source of model variation, least-squares means were separated using pairwise t-tests with the PDIFF option of SAS; differences were considered significant at $P \le 0.05$. All P-values were adjusted using a Tukey's adjustment for multiple comparisons.

RESULTS AND DISCUSSION

Sow parity and temperatures, farrowing pen temperatures, and conditions in the oxygen chamber are summarized by Intervention Treatment in Table 1. There were no differences ($P > 0.05$) observed between Intervention Treatments for any of these measurements. In general, the sows used in the study and the temperature conditions in the farrowing facilities were typical of U.S. commercial production. Sow temperatures before and after farrowing were between 38.6 °C and 39.3 °C, which is normal for farrowing sows (Littledike et al., 1979). Temperatures under the heat lamps (between 35.2°C and 36.8°C) were close to the target temperature (35 °C), which was similar to the critical temperature of newborn piglets (Mount, 1959). Farrowing pen temperatures away from the heat lamp ranged between 24.7 °C and 26.7 °C (Table 1) which was higher than the set point for the farrowing rooms (22.5 °C). This was most likely due to relatively high outdoor temperatures that occurred during the period when this study was conducted. In addition, temperatures were generally higher at the end than at the start of farrowing (Table 1), which reflects the increase in outdoor ambient temperature during the measurement period from start of farrowing to 2 h after birth of the last piglet. The temperature in the oxygen chamber was targeted to be similar to that in the farrowing pens away from the heat lamp. This temperature averaged 24.4 ± 4.40 °C over the study period, which was comparable to the temperatures in the farrowing pen at the start of farrowing. Oxygen concentration in the oxygen chamber averaged 40.4% (Table 1), which was close to the target (40%).

Least-squares means for the average number of piglets born alive per litter and piglet birth weight are presented by Intervention Treatment in Table 2. Litter sizes and birth weights were similar ($P > 0.05$) for the three Intervention Treatments (Table 2). The number of piglets born alive (10.7 to 12.2 per litter) was lower than values reported for U.S. herds at the time that this study was conducted (i.e., 13.2 piglets per litter; PigChamp, 2018). Piglet birth weights were similar to those reported in recent studies (Feldspausch et al., 2019; Vande Pol et al., 2020a,b, 2021).

Least-squares means for the effect of Intervention Treatment on piglet rectal temperatures over the first 24 h after birth are presented in Table 2. There was no effect ($P > 0.05$) of Intervention Treatment on piglet rectal temperatures at birth, which was expected, as this measurement was taken before the treatments were applied. Birth temperatures were generally within the range

Table 1. Summary of sow parity and rectal temperatures, farrowing pen temperatures, and conditions in the oxygen chamber during the study, presented for each Intervention Treatment

Item	Intervention Treatment[1]			SEM	*P*-value
	Control	Drying	Oxygen		
Number of sows	14	14	14	-	-
Sow parity[2]	3.6	3.5	2.9	0.80	0.80
Sow rectal temperature, °C					
Before farrowing	38.64	38.57	38.59	0.129	0.94
After farrowing	39.08	39.11	39.34	0.132	0.33
24 h after farrowing	39.15	39.44	39.06	0.148	0.17
Farrowing pen temperature, °C					
Before farrowing					
Under heat lamp	35.94	36.83	35.23	0.893	0.44
Side of pen opposite heat lamp	25.30	24.96	24.84	0.565	0.84
Behind sow	25.43	24.86	24.73	0.575	0.66
After farrowing					
Under heat lamp	36.64	35.78	35.73	0.530	0.41
Side of pen opposite heat lamp	26.11	25.72	26.68	0.625	0.56
Behind sow	25.46	25.89	26.12	0.632	0.77
Conditions in the oxygen chamber					
Oxygen concentration, %	-	-	40.4 (2.83)[3]	-	-
Temperature, °C	-	-	24.4 (4.40)[3]	-	-

[1]Control = piglets were not dried or given supplemental oxygen; Drying = piglets were dried at birth by coating with a desiccant; Oxygen = piglets were dried at birth by coating with a desiccant, then placed in a chamber at 40% oxygen concentration for 20 min.

[2]Parity = total number of litters including the one used in the study.

[3]Mean (standard deviation).

Table 2. Least-squares means for average number of piglets born alive per litter and piglet birth weight and the effect of Intervention Treatment on the rectal temperature of piglets over the first 24 h after birth

	Intervention Treatment[1]			SEM	*P*-value
	Control	Drying	Oxygen		
Number of litters	14	14	14	-	-
Number of piglets born alive					
Total	150	164	171	-	-
Average per litter	10.70	11.70	12.20	0.84	0.45
Piglet birth weight (born alive), kg	1.44	1.45	1.41	0.027	0.60
Piglet rectal temperature, °C					
Time after birth, min					
0	38.76	38.81	38.83	0.038	0.78
20	36.05[c]	37.58[a]	37.20[b]	0.038	<0.0001
30	35.82[c]	37.90[a]	37.29[b]	0.038	<0.0001
45	36.10[c]	38.22[a]	37.72[b]	0.038	<0.0001
60	36.55[c]	38.0[a]	38.10[b]	0.038	<0.0001
120	37.90[b]	38.0[a]	38.70[a]	0.039	<0.0001
1440	39.00	39.00	38.79	0.040	0.30

[a–c]Within a row, means with differing superscripts differ at $P \leq 0.05$.

[1]Control = piglets were not dried or given supplemental oxygen; Drying = piglets were dried at birth by coating with a desiccant; Oxygen = piglets were dried at birth by coating with a desiccant, then placed in a chamber at 40% oxygen concentration for 20 min.

of those reported in previous research (Pomeroy, 1953; Kammersgaard et al., 2011; Vande Pol et al., 2020a,b, 2021). The decline in rectal temperature after birth for piglets on the Control treatment was extensive, with the minimum temperature (at 30 min) being 2.9 °C lower than at birth (Table 2). Other studies have also found that the minimum temperature of untreated piglets occurred at 30 min after birth (Xiong et al., 2018; Vande Pol et al., 2020a,b, 2021). In addition, in the current study, the decline in rectal temperature between birth and 30 min after birth for the Control treatment was within the range reported by others of 2.5 °C (Vande Pol et al., 2021) to 5.1 °C (Xiong et al., 2018). Subsequent to 30 min after birth, the rectal temperature of piglets on the Control treatment increased and by 1440 min after birth approached the level observed at birth, which is in agreement with other studies (McGinnis et al., 1981; Xiong et al., 2018; Vande Pol et al., 2020a,b, 2021).

Compared to the Control treatment, the Drying treatment resulted in higher ($P \leq 0.05$) rectal temperatures from 20 to 120 min after birth. In addition, the minimum temperature occurred earlier and was higher ($P \leq 0.05$) for the Drying treatment than for the Control (Table 2). These results were generally similar to those observed in previous studies that compared these two treatments (Vande Pol et al., 2020a,b). Most studies have shown that drying reduced the extent of decline in piglet rectal temperature during the first 60 min after birth; however, the magnitude of this effect has varied

between studies. This may be due, in part, to the use of different drying materials and/or the timing of measurement of rectal temperature after birth (Berbigier et al., 1978; McGinnis et al., 1981). However, the relative effectiveness of using a desiccant as the drying agent for reducing postnatal temperature decline has also varied between studies. Vande Pol et al. (2020b) and Cooper et al. (2019) found that the maximum difference in temperature between undried piglets and those dried with a desiccant occurred at 45 min after birth and was 2.2°C and 2.4°C, respectively. These results are similar to those of the current study in which the greatest difference between Control and Drying treatment was 2.1°C, occurring at both 30 and 45 min after birth (Table 2). In contrast, Vande Pol et al. (2020a) found the greatest difference between these two treatments was 1.4°C, which occurred at 60 min after birth. These differences between studies for the effectiveness of drying piglets at birth on moderating subsequent body temperature decline may be due, in part, to differences in study conditions, such as ambient temperature levels in the farrowing facilities (Vande Pol et al., 2021).

The Oxygen treatment resulted in higher ($P \leq 0.05$) rectal temperatures than the Control treatment from 20 to 120 min after birth; however, temperatures for piglets on the Oxygen treatment were lower ($P \leq 0.05$) than for those on the Drying treatment from 20 min (when the piglets were removed from the oxygen chamber) to 60 min after birth (Table 2). These results indicate that the

combination of drying and placing piglets in an oxygen rich chamber was not as effective at reducing the extent of rectal temperature decline in the first 20 min after birth than drying alone. Willard (2020) used the same Oxygen and Drying treatments as the current study and also found that the Oxygen treatment resulted in lower rectal temperatures between 20 and 60 min after birth compared to the Drying treatment. These findings were unexpected and are at variance with the results of the study of Herpin et al. (2001), that undried piglets placed in an oxygen-rich chamber (40% oxygen concentration) for 20 min after birth had increased piglet rectal temperature at 30 min after birth by 0.6°C. Willard (2020) reported that blood oxygen saturation of piglets on the Oxygen treatment increased by 26.7% between birth and 20 min after birth but decreased by 14.2% for piglets not administered oxygen. This would suggest that the Oxygen treatment used in the current study should have been effective at increasing piglet blood oxygen levels.

In the current study, piglet rectal temperatures in the period subsequent to removal from the chamber increased to a similar extent for the Oxygen as for the Drying treatment (i.e., by 0.9°C for both treatments between 20 and 60 min after birth; Table 2). This suggests that the Oxygen treatment had a negative effect on piglet rectal temperature while piglets were in the oxygen chamber but did not influence subsequent temperature recovery. The cause of this effect is not clear; however, Willard (2020) found similar postnatal changes in temperature in piglets exposed to either ambient (approximately 20%) or 40% oxygen concentration in the same type of chamber as used in the current study. This implies that the difference between the Oxygen and Drying treatments observed in the current study may have been due to conditions in the chamber rather than oxygenation *per se.* Temperatures in the oxygen chamber were similar to those in the farrowing pens at the start of the farrowing process (Table 1); however, by the end of farrowing, the temperature in the chamber was between 1.1°C and 2.3°C lower than in the pen (Table 1). In addition, piglets in the oxygen chamber did not have access to a heat lamp or contact with the sow during this period. This could have resulted in the thermal environment experienced by those piglets being less favorable than that for the piglets in the farrowing pen. This could be responsible for the observed differences in piglet rectal temperature between the Oxygen and Drying treatments in the current study and that of Willard (2020). Further

research is needed to understand the effects of environmental conditions in the oxygen chamber on changes in piglet rectal temperature.

Least-squares means for piglet rectal temperatures for the Intervention Treatment by BWC interaction subclasses are presented in Table 3. There were treatment interactions ($P \leq 0.05$) for all measurement times except at birth and 1440 min after birth. At all other measurement times and for all Intervention Treatments, Light piglets had lower ($P \leq 0.05$) temperatures than the other two BWC, with the exception of the Drying treatment at 120 min, when temperatures for the three BWC were similar ($P > 0.05$). Medium piglets had lower temperatures than Heavy piglets ($P \leq 0.05$) at all times between 10 and 120 min for the Control treatment, but only at 20 min for the Oxygen treatment (Table 3). There were no differences ($P > 0.05$) between Medium and Heavy piglets on the Drying treatment at any measurement time. Previous research has also shown that, in the absence of any intervention, the extent and duration of piglet temperature decline after birth is greater in low birth weight piglets than in heavier littermates (Pattison et al., 1990; Pedersen et al., 2016; Cooper et al., 2019; Vande Pol et al., 2020a,b, 2021).

The Intervention Treatment by BWC interactions were mainly due to the differences between Intervention Treatments varying in magnitude between the three BWC (Table 3). While piglets of all BWC subjected to the Drying and Oxygen treatments had higher ($P \leq 0.05$) temperatures between 20 and 60 min after birth than those of similar weight on the Control treatment (Table 3), this difference was greater for the Light than the heavier BWC. For example, the difference between the Control and Drying treatments at 30 min after birth were 2.6, 2.2, and 1.9°C for Light, Medium, and Heavy piglets, respectively. These results are similar to those of Vande Pol et al. (2020a,b) and Willard (2020). Overall, these results suggest that drying piglets had a relatively greater effect on reducing piglet postnatal temperature decline as birth weight decreased.

Least-squares means for the effect of Intervention Treatment and BWC on serum immunoglobulin immunocrit concentrations are presented in Table 4. There was no interaction ($P > 0.05$) between Intervention Treatment and BWC for this measurement. Immunocrit concentrations tended ($P = 0.07$) to be higher for the Control treatment compared to the Drying and Oxygen treatments. Vande Pol et al. (2021) found that serum immunocrit concentrations were lower

Table 3. Least-squares means for the interaction of Intervention Treatment (IT) and Birth Weight Category (BWC) for the rectal temperature of piglets over the first 24 h after birth

Item.		Intervention Treatment[1]			SEM	P-value
		Control	Drying	Oxygen		BWC × IT Interaction
Number of piglets born alive						
Light		22	17	17	-	-
Medium		49	75	85	-	-
Heavy		79	72	69	-	-
Piglet rectal temperature, °C						
Time after birth, min						
0	BWC[2]				0.044	0.12
	Light	38.62	38.79	38.63	-	-
	Medium	38.79	38.91	38.80	-	-
	Heavy	38.79	38.65	38.93	-	-
20	BWC[2]				0.044	0.01
	Light	34.94^f	36.82^{c,d}	35.90^{d,e}	-	-
	Medium	35.95^d	37.66^{a,b}	37.04^{b,c}	-	-
	Heavy	36.42^{c,e}	37.74^a	37.74^a	-	-
30	BWC[2]				0.044	0.001
	Light	34.60^h	37.21^{c,d,e}	35.87^{f,g}	-	-
	Medium	35.76^g	37.96^{a,b}	37.14^{b,c,d}	-	-
	Heavy	36.21^{e,f}	38.09^a	37.85^{a,b,c}	-	-
45	BWC[2]				0.044	0.01
	Light	34.92^e	37.36^{b,c}	36.31^{c,d}	-	-
	Medium	35.97^d	38.31^a	37.65^{a,b}	-	-
	Heavy	36.52^c	38.42^a	38.17^{a,b}	-	-
60	BWC[2]				0.044	<0.0001
	Light	35.12^e	37.69^{b,c}	36.65^{c,d}	-	-
	Medium	36.44^d	38.54^a	38.07^{a,b}	-	-
	Heavy	37.04^c	38.56^a	38.45^{a,b}	-	-
120	BWC[2]				0.045	0.0002
	Light	37.19^c	38.27^{a,b}	37.47^{b,c}	-	-
	Medium	37.77^b	38.66^a	38.74^a	-	-
	Heavy	38.21^a	38.68^a	38.82^a	-	-
1440	BWC[2]				0.048	0.17
	Light	38.63	38.89	38.17	-	-
	Medium	38.85	39.05	38.79	-	-
	Heavy	39.16	39.02	38.91	-	-

$^{a–h}$For each time after birth, means within the IT × BWC interaction with differing superscripts differ at $P \leq 0.05$.

[1]Control = piglets were not dried or given supplemental oxygen; Drying = piglets were dried at birth by coating with a desiccant; Oxygen = piglets were dried at birth by coating with a desiccant, then placed in a chamber at 40% oxygen concentration for 20 min.

[2]Light = <1.0 kg; Medium = 1.0–1.5 kg; Heavy = >1.5 kg.

Table 4. Least-squares means for the effect of Intervention Treatment and Birth Weight Category on immunoglobulin immunocrit values at 24 h after birth

Item.	Intervention Treatment[1]			SEM	P-value	Birth Weight Category[2]			SEM	P-value
	Control	Drying	Oxygen			Light	Medium	Heavy		
Number of piglets	56	51	51	-	-	11	70	73	-	-
Birth weight, kg	1.50	1.49	1.45	0.044	0.71	0.85^c	1.30^b	1.75^a	0.027	<0.0001
Immunoglobulin immunocrit, %[3]	13.6	12.7	12.0	0.50	0.07	9.3^c	12.4^b	13.8^a	0.63	0.0002

$^{a–c}$Within a row, means with differing superscripts differ at $P \leq 0.05$.

[1]Control = piglets were not dried or given supplemental oxygen; Drying = piglets were dried at birth by coating with a desiccant; Oxygen = piglets were dried at birth by coating with a desiccant, then placed in a chamber at 40% oxygen concentration for 20 min.

[2]Light = <1.0 kg; Medium = 1.0 to 1.5 kg; Heavy = > 1.5 kg.

[3]Blood samples obtained at 24 h after birth on a sub-sample of 4 piglets per litter, one from each birth weight quartile.

for piglets that were dried and warmed compared to those that were untreated. Serum immunocrit concentration early after birth is an index of colostrum intake (Vallet et al., 2015). The results of the current study suggest that both the Drying and Oxygen treatments may reduce colostrum intake, possibly due to a disturbance in sucking behavior, which warrants further research. However, mean immunocrit levels for all treatments were relatively high (Peters et al., 2016), suggesting that piglets on all treatments, on average, received sufficient colostrum.

Immunocrit values were greater ($P \leq 0.05$) for Heavy compared to Light BWC piglets, with Medium piglets having values that were intermediate to and different ($P \leq 0.05$) from the other two BWC (Table 4). This suggests that lighter birth weight piglets consume proportionally less colostrum than heavier littermates. This is in line with other studies that have evaluated the impact of birth weight on immunocrit concentrations (Devillers et al., 2011; Nguyen et al., 2013; Vallet et al., 2013; Le Dividich et al., 2017) and, also, with those that have directly measured colostrum intake (Devillers et al., 2011; Le Dividich et al., 2017). Vande Pol et al. (2021) used the same BWC classifications as in the current study and also found a tendency for serum immunocrit concentrations to increase with piglet birth weight.

In conclusion, the results of the current study confirm that birth weight is an important factor influencing piglet temperatures in the early postnatal period, with lower birth weight piglets experiencing the greatest extent and duration of temperature decline. Drying piglets at birth reduced the extent and duration of the postnatal decline in piglet temperature, particularly for those of low birth weight. However, the combination of drying and placement in an oxygen-rich environment for 20 min after birth reduced the magnitude of this effect, particularly for light piglets. Further research is needed to determine the optimal conditions for oxygen administration and potential effects on piglet pre-weaning mortality.

Conflict of interest statement. The authors declare no real or perceived conflicts of interest.

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