RESEARCH REPORT
ANIMAL SCIENCE

Title: An Integrated approach to improve while herd pig survivability- #19-152 IndPPA

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Industry Summary: Pre-weaning survival in US herds ranges from 80-90% with the majority of the death loss occurring in the first three days after birth from crushing from the dam. Risk factors for mortality are low body weight, inability to regulate body temperature after birth, and low colostrum intake. The swine industry has adopted several management practices to aid in these areas, such as drying piglets at birth or split suckling. However, in commercial settings, few have shown improvements in colostrum intake or survival to weaning. An additional management practice has been to induce sows to farrow to allow for labor to be present at the time of farrowing to assist sows during farrowing as well as assist piglets in nursing. However, questions have remained about whether inducing sows negatively impacts the piglet by increasing the likelihood of hypoxia or oxygen deprivation during the birthing process. The purpose of the studies in this project were to evaluate the impacts of farrowing induction on piglet blood parameters, colostrum intake and survival as well as evaluate heat lamp management to increase piglet body temperature after birth. These studies found that farrowing induction did not negatively impact the farrowing process or fetal blood oxygenation at birth. Piglets born later in the birth order did have increased signs of hypoxic stress in the blood, but this was seen in naturally farrowing and induced sows. Piglets placed at the udder, regardless of where the heat lamp is located within the farrowing rate, nursed sooner after birth and had increased body temperatures at 30min after birth. However, this did not increase colostrum intake or survival in these piglets. In both studies performed, body weight and colostrum intake were the main drivers of mortality. Therefore, additional work looking at novel methods to increase colostrum intake and increase birth weight in piglets should be investigated.

Keywords: preweaning mortality, survival, farrowing temperature, colostrum

Scientific Abstract:

Objective 1 (Farrowing induction): Historically, sows have been induced to farrow using prostaglandin followed by an injection of oxytocin 24 hours later. Benefits of induction can include decreased rate of stillbirths, dystocia, and postnatal mortality along with increasing the likelihood of farrowings being attended. Several studies have indicated that oxytocin administration may negatively impact fetal oxygen supply during parturition, potentially from umbilical cords breaking prior to birth, resulting in increased preweaning mortality. Therefore, the objective of this study was to determine if various induction protocols impact umbilical cord breakage and fetal blood parameters at birth. Fifty-eight primiparous and multiparous sows were assigned to one of three treatments: no induction (NO; n= 24), or 2 cc prostaglandin administered on d114 of gestation followed by either 1 cc of oxytocin 24 hours later (OXY24; n=13) or 0.5 cc of oxytocin at 6 and 12 hours after prostaglandin (OXY6; n=21). Details of the farrowing process were recorded, and umbilical cord blood was collected from piglets at birth and evaluated on an iSTAT machine using an Abbott EC8+ test cartridge. There were no differences in total born, number born alive, stillborns, mummies, or assistance needed during farrowing. Induced sows were more likely to farrow by d115 compared to naturally farrowing sows (P=0.02). Sows in the OXY24 treatment tended to have longer farrowings when compared to both NO and OXY6 (4.8 vs 3.6 vs 3.9 hours; P=0.09). Colostrum from OXY6 sows tended to have a greater amount of lactose present than NO and OXY24 (P=0.05). Colostrum from sows with longer gestation lengths had higher percent fat (P=0.03). Piglets born from NO sows had higher base excess, total carbon dioxide, and glucose which suggests that these piglets had prolonged moments of asphyxiation (P<0.01). OXY24 piglets had the lowest blood pH which is indicative of hypoxic birthing conditions (P<0.01). Preweaning mortality was driven largely by a low birth weight coupled with low colostrum intake (P=0.03). All piglets regardless of treatment, displayed signs of stress during farrowing. Induction did not influence preweaning mortality but has the potential to decrease the incidence by increasing attended farrowings.

Objective 2 (Supplemental Heat Management): Heat lamps are extensively used as a heat source for newborn piglets in the swine industry. The assistance to piglets to reach the udder is variable between operations. The objective of this study was to evaluate the effect of the location of the heat lamp (HL) and piglets (PL) at birth on the piglet's suckling behavior, body temperature, growth, and survival. A total of 1053 piglets from 87 litters were used for this study. Litters were blocked by parity and randomly assigned to one of the four treatments in a 2x2 factorial design, combining the HL and PL at birth. The four treatments were: HLU/PU, HL situated in the sow's udder, and piglets placed at the sow's udder; HLB/PU, HL at the sow's back and piglets atthe udder; HLU/PV, HL at the udder and piglets placed at the sow's vulva; and HLB/PV, HL at the sow's back and piglets at the vulva. After birth, each piglet was weighed and rectal temperature taken. Body temperature was recorded at 30 min, 1h, and 2 h. The time from birth to first approach to the udder and first suckle were recorded. Body weight was recorded at 24h, and weekly until weaning. Piglet mortality and reasoning for death was recorded through weaning. Data was analyzed as a complete factorial with 4 treatments in addition to the effects of HL and PL evaluated separately using PROC MIXED and GLIMMIX in SAS. HLB/PV piglets tended to be colder at 30 min after birth (P=0.097) than the other treatments. When the individual effect of PL was analyzed, piglets placed at the sow's vulva had lower temperatures at 30 min (P=0.019) than piglets at the udder. The time taken to reach the udder and for the first suckle were greater (P < 0.001 and P=0.019, respectively) in piglets placed at the vulva. Mortality, colostrum intake, body temperature after 30min, and growth through weaning were not affected by treatment.

Introduction:

Objective 1: Genetic selection for highly prolific sows and increased total born has consequently resulted in longer farrowing duration and higher occurrences of low birth weight piglets which negatively impacts preweaning survival through decreased colostrum intake (Le Dividich, 1999; Devillers et al., 2011; Kirkden et al., 2013; Gourley et al., 2020). Longer farrowing duration increases the risk of hypoxia in piglets born later in the litter because a risk of umbilical occlusion or breaking of the cord (Randall, 1972b, a; English and Wilkinson, 1982; Alonso-Spilsbury et al., 2005). Hypoxic events during farrowing can lead to low viability of the piglet which impairs suckling ability and decreases the chance **of** surviving until weaning (English and Wilkinson, 1982; Herpin et al., 1996; Kammersgaard et al., 2011; Gourley et al., 2020). One common farrowing induction method is to administer prostaglandin followed by an injection of oxytocin 24 hours later. Benefits of induction with prostaglandin and oxytocin include decreased rate of stillbirths, dystocia, decreased farrowing duration, and postnatal mortality along with the possibility of increasing the chance of farrowings being attended (Straw et al., 2008; Nguyen et al., 2011).

A greater number of sows farrowed during the work day when given oxytocin 6 or 24 hours after prostaglandin when compared to sows who only received prostaglandin which improved the predictability the start of farrowing (Alexopoulos et al., 1998; Kirkwood and Aherne, 1998). It has also been shown that it is not necessary to wait 24 hours to administer oxytocin, but rather to give it in multiple, low dosages to achieve a decrease in stillbirths and postnatal mortality (Clark and Bilkei, 2002). While several studies have indicated that oxytocin administration during the farrowing process may negatively impact fetal oxygen supply at parturition (Mota-Rojas et al., 2002; Ward et al., 2019), none have evaluated inducing farrowing on fetal oxygenation. Therefore, objective 1 of this study was to compare the impacts of various induction protocols on umbilical cord breakage, fetal blood parameters at birth, colostrum intake, and preweaning mortality.

Objective 2: The farrowing barn has to provide the thermal environment for both the piglet and the sow to successfully farrow the piglets and for the piglets to thrive and survive after birth. Unfortunately, these two temperatures are quite different where the piglet's ideal environmental temperature after birth is in the ~90F and the sow is <75F. In order to create these two environments the barn temperatures are typically set for the sow's comfort and supplemental heating is added in the form of heat lamps or heated pads for the piglets' comfort. Piglets' rectal temperature at 24hr of age has been correlated to colostrum intake and survival to weaning (Devillers et al., 2011, Muns et al., 2016). Many studies have compared various types of supplemental heat sources (lamps vs mats vs water beds, etc) and while it is evident that supplemental heat increases survival (Morrison et al., 1983), the type of heat supplement does not seem to vary in their ability to warm the piglets and help them grow and survive to weaning (Lane et al., 2020, Stinn and Xin 2014, Zhu et al., 2020). Therefore objective 2 of this study was to evaluate the impacts of heat lamp placement within the farrowing crate and management of the piglet after birth on colostrum intake, growth, and survival to weaning.

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Materials & Methods:

Objective 1: Farrowing Induction

Animals

Sows

All procedures involving animals were reviewed and approved by the Institutional Animal Care and Use Committee (PACUC #1902001856). Confirmed pregnant sows were moved into farrowing crates on d 112 of gestation at the Animal Sciences Research and Education swine facility at Purdue University. On d 114 of gestation 58 sows were blocked by parity (gilt-parity 1, and parity 2+) and assigned one of three treatments: no induction (NO; n= 24), 2 cc prostaglandin (Lutalyse ®, Zoetis Inc., Parsippany-Troy Hills, NJ) administered on d 114 of gestation followed by 1 cc of oxytocin 24 hours later (OXY24; n=13), or 2 cc prostaglandin administered on d 114 of gestation followed by 0.5 cc of oxytocin at 6 and 12 hours after prostaglandin (OXY6; n=21). Administration of prostaglandin was performed at 10:00 a.m. intramuscularly in the neck of each sow using an 18-gauge, 40 mm needle. Oxytocin was administered subcutaneously in the crease between the vulva and ham using a 20-gauge, 12 mm needle. Data collected included induction-to-farrowing interval, farrowing duration, farrowing assistance, time of birth for each piglet, umbilical cord breakage, number of piglets born alive, stillborns, mummies, and whether feed was present in the feeder at farrowing. Umbilical cords were classified as broken if the piglet's cord was no longer attached to the mother at birth.

Colostrum Composition

Within 12 hours of the birth of the first piglet, a 50 ml colostrum sample was collected by milking the front, middle, and back teats and stored in -80ºC until further analysis for total fat, protein, and lactose. Prior to analysis, all samples were thawed at 4 ºC overnight in a continuous rotator, in order to homogenize samples. Fat percentage was measured in triplicate by loading sample in a non-heparinized capillary tube and centrifuged at 12,000 x g for 10 min. Length of the fat layer on the top and the total sample length were measured using a caliper (Pittsburgh Automotive, Camarillo, CA). Fat percentage was calculated as the ratio between fat length and total sample length, multiplied by 100. Protein concentration was determined by diluting homogenized colostrum with phosphate buffered saline (1:100). Ten microliters of colostrum were mixed with 250uL of Bradford reagent (Pierce Coomassie Plus Assay Kit, Thermo Fisher Scientific, Waltham, MA). Color development in samples and standard curve (bovine serum albumin, 0.025 to 2 mg/mL range) was measured with a spectrophotometer (Sparks 10M multimode microplate reader, Tecan, Männedorf, Switzerland). Lactose was extracted from 200 µL of skimmed colostrum by adding 800 µL acetonitrile. Extracts were centrifuged at 3,220 × g at room temperature for 10 min to remove precipitated proteins. Before injecting samples, they were diluted 1:5 with acetonitrile and spiked with 1,000ng of D-lactose-13C (Sigma-Aldrich, St. Louis, MO). Liquid chromatography was performed using Intrada Amino Acid 3µm, 2 x 150mm column (Imtrakt USA, Portland, OR) connected to an Agilent 6470 QQQ LC-MS/MS system (Agilent, Santa Clara, CA). Acetonitrile with 0.3% of formic acid and acetonitrile with 100mM Ammonium formate solution (20:80 v/v) were used as mobile phases.

Sow and Piglet Blood Parameters

Blood samples were collected from the ear veins of sows at the time of birth of the first piglet, sixth piglet, and end of farrowing and evaluated for glucose and hemoglobin levels using an AimStrip® *Plus* blood glucose monitor (Germaine Laboratories, Inc., San Antonio, TX) and the HemoCue® Hb 201+ Hemoglobin Analyzer (HemoCue America, Brea, CA). End of farrowing was characterized by placental membranes expelled from the sow. Sows were provided manual assistance if the birthing interval between piglets exceeded 30 minutes. All farrowings were attended 24 hours a day until all sows farrowed.

At the time of birth of each piglet (NO, n=118; OXY, n=105; OXY6, n=79), umbilical cord blood was collected and immediately placed in a Microtainer® Lithium Heparin/PST™ Gel 600 ul tube (Becton, Dickinson and Company, Franklin Lakes, NJ) and inverted to prevent clotting. Blood samples were analyzed with the iSTAT® portable clinical analyzer using the EC8+ cartridge (Abbott, Priceton, NJ) for Sodium (Na), Potassium (K), Ionized Calcium (iCa), Glucose (Glu), Hematocrit (Hct), Hemoglobin (Hgb), pH, Partial Pressure of Carbon Dioxide (pCO_2), Partial Pressure of Oxygen (pO_2), Base Excess (BE), Bicarbonate (HCO3), Total Carbon Dioxide (tCO_2), and Oxygen Satruation (sO_2). Piglets were dried using bath towels and allowed to nurse normally. Piglets were weighed at birth and 24 hours after to calculate colostrum intake using the equation previously described (Devillers et al., 2011). The equation uses the change in body weight between birth and 24 hours coupled with the number of potential minutes a piglet has to suckle colostrum as a quantitative measure of colostrum intake. Crossfostering within treatment was performed after 24 h to standardize lactation litter sizes. Piglets were weighed again at weaning to calculate average daily gain from birth to weaning and pre-weaning mortality was recorded for each litter.

Statistical Analysis

Analysis of farrowing variables from the sow was performed using the MIXED procedure of SAS 9.4 (SAS Inst. Inc., Cary, NC) with treatment and parity as main effects. Binomial variables were analyzed using the GLIMMIX procedure. Sow blood glucose and hemoglobin were evaluated using the MIXED procedure for repeated measures with treatment and parity as fixed effects and whether the sow ate prior to farrowing as a covariate in the model. The MIXED procedure of SAS 9.4 was also used to evaluate piglet blood parameters using treatment, parity, and birth order as main effects and sow as a random effect. Birth order classes were created to evaluate birth order as a main effect: birth order class 1 (piglet 1-5); birth order class 2 (piglet 6-10); birth order class 3 (piglets born after the 10^{th} piglet). Parity classes were also created as follows: parity class 1 (gilts and parity 1) and parity class 2 (parity 2+). For colostrum quality analysis, the MIXED procedure of SAS was used with treatment as a fixed effect and gestation length as a covariate. A Tukey's means comparison was used to determine differences among means for piglet data and colostrum quality. Significance was defined as $P<0.05$ and values of $0.05 \leq P \leq 0.10$ were considered tendencies.

Objective 2: Heat Lamp Management

. A total of 1053 piglets from 87 litters born between January and July, 2021 at Purdue University were used for this study. Litters were blocked by parity and randomly assigned to one of the four treatments in a 2x2 factorial design, combining the heat lamp (HL) placement (udder (U) or back of sow (B)) and piglet location (PL) in the farrowing crate (vulva (V) or udder (U) at birth. The four treatments were: HLU/PU, HL situated in the sow's udder, and piglets placed at the sow's udder; HLB/PU, HL at the sow's back and piglets atthe udder; HLU/PV, HL at the udder and piglets placed at the sow's vulva; and HLB/PV, HL at the sow's back and piglets at the vulva. After birth, each piglet was weighed and rectal temperature taken. Body temperature was recorded at 30 min, 1h, and 2 h. The time from birth to first approach to the udder and first suckle were recorded. Body weight was recorded at 24h, and weekly until weaning. Piglet mortality and reasoning for death was recorded through weaning. Data was analyzed as a complete factorial with 4 treatments in addition to the effects of HL and PL evaluated separately using PROC MIXED and GLIMMIX in SAS.

Results: Objective 1: Farrowing induction

Effect of Induction on the Farrowing Process and Sow blood parameters

There were no differences among treatments in the time from induction to farrowing, total born, number born alive, stillborns, mummies, or assistance needed during farrowing (Table 1). OXY24 animals tended to have longer farrowings (P=0.096). Interestingly, sows that were parity 2+ required more assistance than parities 0-1 (23.8% vs 6.5 %, respectively, P<0.001).

Although treatment did not have an effect on percentage of sows who farrowed during the work day or within 36 hours of induction, sows were more likely to farrow by d 115 who were induced compared to naturally farrowing sows (Table 1).

Sow blood hemoglobin remained constant throughout farrowing regardless of treatment (Table 2). Younger parities had higher levels of hemoglobin on average than older parities (Table 2). Blood glucose levels were not affected by treatment, however, older parity sows had a greater increase in glucose levels at the end of farrowing than younger sows (P=0.035).

Induction and preweaning mortality

Induction did not influence preweaning mortality, colostrum intake, or average daily gain (ADG) from birth to weaning (Table 3). On average, piglets born from OXY24 sows had a lighter birth weights on average (Table 3). Preweaning mortality was largely driven by birth weight and consequently colostrum intake (P<0.001) with survivability increasing with higher birth weights and colostrum intake (Table 4). Animals born between 0-1 kg consumed 214.7 g of colostrum on average which is just above the recommended minimum of 200 g (Devillers et al., 2011). These animals also had the highest rate of preweaning mortality with 49% of these animals dying before weaning (Table 4). Birth order did not influence preweaning mortality in the present study. Although not significant, it is interesting to note that piglets born from sows who farrowed over 4 hours had a numerical increase in preweaning mortality (22% vs 15%; P=0.363) and consumed about 15 g less of colostrum on average (P=0.208). Average daily gain from birth to weaning was influenced by colostrum intake and birth weight where lighter pigs consumed less colostrum and therefore gained less (P<0.001). It was also observed that animals who died prior to weaning lost weight on average compared to piglets that survived (0.235 vs -0.014; P<0.001). Induction did not influence fat or protein content in colostrum, but OXY6 tended to have a greater amount of lactose present when compared to NO and OXY24 (Table 5). There was also a tendency for an interaction between treatment and gestation length for percent lactose (Table 5). Gestation length influenced percent fat with the higher fat content being associated with a longer gestation length (Table 5).

Induction and its effects on piglet blood parameters at birth

Piglets born from sows who were in the OXY6 treatment group had the same blood potassium (K) level as OXY24, the same blood glucose (Glu) as NO, intermediate base excess (BE), and intermediate pH. Piglets from OXY24 mothers had the lowest pH, BE, and Glu coupled with the highest amount of partial pressure of oxygen (Table 6). Piglets from older parity mothers showed greater amounts of Glu in the blood as well as BE, total Carbon Dioxide (tCO_2), and lower oxygen saturation (sO2).

Piglets born latest in the litter had the highest blood glucose levels (Table 6). Interestingly, piglets born earlier in the litter had a higher BE and total carbon dioxide (tCO_2) than those born later (P=0.009). Piglets born from greater parity sows who farrowed naturally had higher BE, tCO_2, pCO_2, and glucose (Table 7). Piglets from older parity, OXY6 sows showed an increase in Hgb and Hct.

Objective 2: Heat lamp management

HLB/PV piglets tended to be colder at 30 min after birth (P=0.097) than the other treatments. When the individual effect of PL was analyzed, piglets placed at the sow's vulva had lower temperatures at 30 min (P=0.019) than piglets at the udder. The time taken to reach the udder and for the first suckle were greater ($P < 0.001$ and P=0.019, respectively) in piglets placed at the vulva. Mortality, colostrum intake, body temperature after 30min, and growth through weaning were not affected by treatment.

Implications: Placing the piglets close to the udder after birth can minimize decrease in piglet temperature after birth and decrease the time from birth to suckling. However, additional measures are needed to improve colostrum intake in newborn piglets.

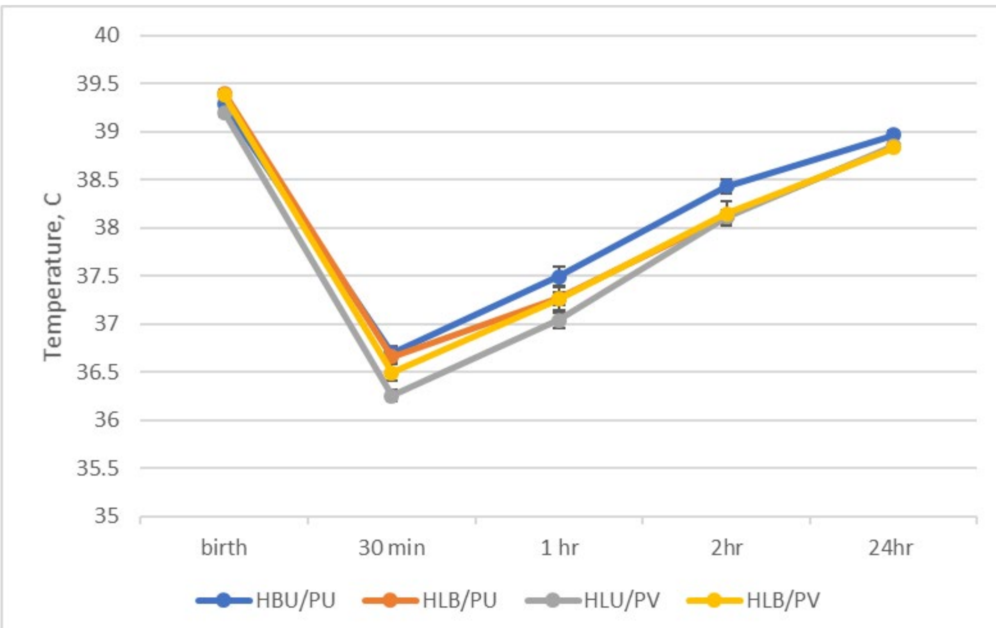

Table 1. Effect of piglet and heat lamp location within the crate and piglet size on body temperature, suckling behavior, colostrum intake, mortality, and growth.

						p-values		
	HLU/PU	HLB/PU	HLU/PV	HLB/PV	SEM	TRT	Lamp Location	Piglet Placement
Colostrum intal	312.2	308.3	311	311.6	5.47	0.932	0.7582	0.6581
Time from birtl	14.7a,x	11.7a,x	23.1b,y	31.2b,y	3.1	<.001	0.6572	<0.0001
Time from birtl	48.4ac, x	36.7a, x	56.8bc, y	53.7ac, y	6.68	0.047	0.12	0.0186
Body weight at	5.5	5.6	5.7	5.5	0.25	0.889	0.5476	0.8852
ADG from birth	221.7	209.1	226.6	221.5	9.98	0.455	0.2564	0.2359
Mortality	0.18	0.23	0.16	0.17	0.04	0.367	0.3815	0.1581

a,b indicate a difference between treatments when all 4 treatments were in the model.

X,y indicate differences in heat piglet placement

Discussion:

Objective 1: Induction does not negatively impact the farrowing process or fetal blood oxygen at birth. Birth weight and colostrum intake were the main drivers of preweaning mortality in this study with ADG from birth to weaning being higher in animals who survived. Although birth order did not impact preweaning mortality or colostrum intake, piglets born later in the litter did show signs of asphyxia, which may impact overall lifetime growth and development of the animal. Both induction protocols and natural farrowings showed at least some signs of asphyxia, but it did not increase preweaning mortality or ADG after birth. Therefore, induction can be used to encourage sows to farrow by day 115 of gestation without negatively impacting piglets.

- Objective 2: Piglets that were placed at the udder approached the udder faster than piglets that were placed at the vulva. Piglets that were placed at the vulva also suckled sooner after birth compared to piglets that were placed at the vulva, regardless of heat lamp location. However, this faster access to milk did not result in increased colostrum intake, average daily gain through lactation or survival to weaning. As might be expected, piglet body weight was the largest driver of colostrum intake, nursing behaviors and survival to weaning. Placing newborn piglets at the udder increases body temperature at 30 minutes after birth and decreases time to first suckle regardless of the location of the heat lamp.