Porcine neonates failing vitality score: physio-metabolic profile and latency to the first teat contact

M.E. Trujillo-Ortega[1], D. Mota-Rojas[2], O. Juárez[2], D. Villanueva-García[3], P. Roldan-Santiago[2], M. Becerril-Herrera[4], R. Hernández-González[5], P. Mora-Medina[1], M. Alonso-Spilsbury[2], A.M. Rosales[2], R. Martínez-Rodríguez[1], R. Ramírez-Necoechea[2]

[1]National Autonomous University of Mexico (UNAM), FMVZ, CEIEPP and FESC, Mexico City and State of Mexico, Mexico
[2]Department of Animal Production and Agriculture, Stress Physiology and Farm Animal Welfare, Metropolitan Autonomous University, Campus Xochimilco (UAM-X), Mexico D.F., Mexico
[3]Division of Neonatology, Mexican Children's Hospital "Federico Gomez", Mexico D.F., Mexico
[4]EIAH- Benemerita Autonomous University of Puebla, Teziutlán, Puebla, Mexico
[5]Department of Experimental Research and Animal Resources, National Institute of Medical Sciences and Nutrition "Salvador Zubirán", Mexico D.F., Mexico

ABSTRACT: The objective of this study was to compare the metabolic and electrolytic profile as well as the morphological appearance of the umbilical cord and newly born piglets' weight that failed the vitality test scale compared to those who passed. Newborn piglets were divided into three groups according to the vitality with a modified Apgar score at birth: Group 1, failing with a score < 5 (G_1: *n* = 218), Group 2 had a score of 6 to 7 (G_2: *n* = 439) and Group 3 had scores > 8 (G_3: *n* = 464). Results showed significant differences among groups ($P < 0.05$) in the physio-metabolic pH, PCO_2, PO_2, Na^+, Ca^{2+}, glucose, lactate and bicarbonate values. Regarding weight, temperature and latency to connect the maternal teat, there were also significant differences ($P < 0.05$) among groups; it took 23.38 min for G_3 while neonatal piglets from G_1 took 30 min longer ($P < 0.05$) to make the first teat contact. The neonates from the latter group had a higher percentage (75.68%) of broken umbilical cords, with higher birth weight (+200 g, $P < 0.05$), showed higher than normal blood glucose concentrations, and had lower body temperature at birth (–0.7°C, $P < 0.05$) and PO_2 in comparison with the other groups of neonates that passed the vitality score. A novel point of this study is the profile characterization of piglets that failed and passed the vitality score; we expect that the data provided may be applicable as reference values of metabolic and electrolyte blood profiles in newborn piglets according to their vitality. In conclusion, this study demonstrates that low vitality newborn piglets had clearly undergone through perinatal asphyxia. Potential indicators increasing this condition are: high birth weight, low body temperature, vitality score ≤ 5, and the presence of the broken umbilical cord at birth.

Keywords: piglet; welfare; haemodynamics; acidosis; asphyxia; neonate; Apgar score

Clinical studies by Mota-Rojas et al. (2007) carried out on commercial pig farms showed that out of 1000 newly born piglets between 150 and 200 animals experienced apnoea after birth and it was related to perinatal asphyxia longer than 30 s, affecting the vitality in a negative way and delaying the latency of connecting to the dam's teat, which represents an economic impact for the producer. In another study where 11 324 farrowings were analysed from 5000 breeding Mexican pig farms, Mota-Rojas and Ramírez (1996) concluded that the cost of each newborn was approximately 16 USD, which multiplied by the number of stillbirths per year (28 430) represented an annual approximated loss of 445 000 USD. Therefore it is important to have the resources that allow quick and efficient evaluations of the physiological state of newborn piglets. The number of piglets born alive is an indicator of the economic benefits of a farm (Houška et al., 2010).

The transitional period during expulsion from the uterus to the birth of a newborn is of utmost importance since many adaptation problems may be detected, such as thermoregulation alterations and breathing difficulties (Odehnalová et al., 2008). The understanding of normal transitional physiological changes of the newborn piglets is important for evaluating their vitality (Sanchez et al., 2009; Maniau et al., 2010). The vitality of the neonatal piglets is described as the capacity to develop and survive, recovering from any imbalance caused by stress in the birth process. Vitality of the neonatal piglet depends on various factors (see review by Alonso-Spilsbury et al., 2007) influenced by the mother, the piglet and the environment.

The Apgar scoring system is an easy and reliable method for routine assessment of both human and animal neonates, in terms of viability and short-term survival prognosis (Alonso-Spilsbury et al., 2005; Castagnetti et al., 2007, 2010; Veronesi et al., 2009; González-Lozano et al., 2009; Orozco-Gregorio et al., 2010). However, its use is not widespread in veterinary medicine. In addition, behavioural traits such as time until first upright standing and latency to first udder contact are indicators of pig vitality (Leenhouwers et al., 2001; González-Lozano et al., 2010). Randall (1971) demonstrated effects of viability scoring at birth on the time to reach the udder and colostrum intake; low viability scores were directly correlated with low birth weights and hypercapnia. Similarly, Zaleski and Hacker (1993) showed that viability score was highly correlated with pH and PCO_2 and De Roth and Downie (1976) studies found a strong relation between birth weight and viability scores.

Another indicator of piglet vitality is the umbilical cord (UC) pathology. Morphologic aspects of the UC such as adherence and rupture have usually been studied and retrospectively correlated with the perinatal outcome in piglets (Mota-Rojas et al., 2002, 2005a,b,c; Castro-Nájera et al., 2006).

Although breathlessness and hypothermia usually represent less severe neonatal welfare insults than do hunger, sickness and pain (Mellor and Stafford, 2004), measurements of blood gases and estimates of non-invasive physiological variables of the newborn piglets still provide crucial information on oxygen delivery, important for subsequent survival. Reference values of serum electrolytes in healthy piglets during the first 48 h of life (Wehrend et al., 2003) and acid-base balance in piglets at birth (van Dijk et al., 2006) were described elsewhere. Also, there are references for blood biochemistry for survivors and piglets that died during the first 10 days of life (Tuchscherer et al., 2000). However, information on the metabolic and electrolyte state of the neonates that failed the vitality scale test at birth is scarce (Herpin et al., 1996; Casellas et al., 2004). Thus, the objective of this study was to thoroughly compare metabolic and electrolytic blood profiles as well as the morphological appearance of the umbilical cord and ability to contact the dam teat in piglets with different vitality scores at birth.

MATERIAL AND METHODS

Animals, facilities and management

This is a retrospective study, evaluating data from all neonates that were expulsed (1121 newborn piglets) from 100 hybrid Yorkshire × Landrace sows from 1st to 5th parities, as part of a more comprehensive larger project dealing with asphyxia of newly born piglets (Trujillo-Ortega et al., 2007). The experiment was carried out on a commercial pig farm with intensive production, located in central Mexico. During the experiment, all sows remained in farrowing crates, following the guidelines established by the Mexican Official Standard (NOM-062-ZOO, 1999). Sows were fed twice daily with a commercial lactation diet. Dams and their litters had ad libitum access to water.

Sows were moved from the gestation area (housed in stalls) to the farrowing unit with individual crates one week before the expected farrowing date. As a standard procedure on the farm, prostaglandins were used to synchronize farrowings. The farrowing unit had electronic ventilation systems and was lit with both natural and electric light set at 39.8 candelas, room temperature averaged 26°C with a relative humidity of 60%.

Variables

To avoid interference with the vitality criteria, no aid was given to newborn piglets at the time of farrowing and during the vitality evaluation. The neonates were evaluated at birth using Randall's (Randall, 1971) adaptation of the Apgar score for human neonates, described by Zaleski and Hacker (1993) and modified by Mota-Rojas et al. (2005c), measuring the following variables within one minute after birth: heart rate (beats per min): < 120 (bradycardia), between 121 and 160 (normal), and > 161 (tachycardia); latency to breathing (min), the interval between birth and the first breath: > 1 min, between 16 s and 1 min, and < 15 s; colour of the skin on the snout: pale, pink or cyanotic; latency to standing, measured as the interval between birth and the first time the neonate stands on all four legs. This was classified as > 5 min, between 1 and 5 min, and < 1 min and the skin stain with meconium as severe, mild, or absent (Mota-Rojas et al., 2006). Each variable was scored from 0 (the least favourable) to 2 (the most favourable) and a global score ranging from 1 to 10 was obtained for each neonatal piglet. A scoring of less than 6 indicated failure to pass the vitality scale test.

Heart rate was measured with a stethoscope. The first breath was considered when a movement was observed in the thoracic area accompanied by exhalation of air. The time it took each piglet to stand up was measured with a chronometer until the newborn was able to stand on all four feet. In addition to the scale, the latency to the first mammary contact was recorded through individual piglet observation from continuous video recording. This latency was the interval between birth and the moment when the newborn first made a contact with the dam's teat, independently if there was milk consumption or not. The time registered for this variable began from the moment the newborn was relocated close to the mother's vulva, immediately after taking the first blood sample. All the piglets were monitored for blood values and vitality score, and were individually identified with numbers on their backs.

The inclusion criteria to form the groups were taken exclusively from the vitality score, independently of the physio-metabolic profile, birth order and gender. Animals were classified into three groups: Group 1 (G_1: n = 218) made up of neonates that failed the vitality scale test with a rating of ≤ 5; Group 2 (G_2: n = 439) included those with a score between 6 and 7 points, and Group 3 (G_3: n = 464) those newborn piglets with a vitality score ≥ 8 points; all vitality measurements were done within the first minute of life.

The blood samples of the neonates were taken immediately after birth, prior to the onset of regular respiratory movements. Sampling was performed by retro-orbital bleeding with a 100 µl microcapillary tube in the medial canthus of the eye at a 30°–45° angle towards the back of the eye and inserting the needle into the venous suborbital sinus, according to the technique used by Zaleski and Hacker (1993) and Orozco-Gregorio et al. (2008). The pH, partial pressure of carbon dioxide ($PaCO_2$/mmHg) and oxygen (PaO_2/mmHg), electrolytes [Na^+, K^+ and Ca^{2+} (mEq/l)], glucose and lactate (mg/dl), HCO_3 (mmol/l) levels and haematocrit (%) were analysed simultaneously using a third generation gas analyser (GEM Premier 3000, Instrumentation Laboratory Co., Lexington, USA and Instrumentation Laboratory SpA, Milano, Italy).

Body temperature was recorded within the first and on the fifth minute after expulsion and was registered instantly (1 s) with a tympanic membrane thermometer (ThermoScan Braun GmbH, Kronberg, Germany). The tympanic temperature was used as it correlates with the cerebral temperature significantly better than the colonic temperature, and has been useful as non-invasive measurement in experiments involving survival after hypoxia/ischemia (Haaland et al., 1996a).

The umbilical cords were evaluated at birth and classified as attached (normal) or broken according to the criteria from Mota-Rojas et al. (2002). Having assessed the vitality and gross morphology of the umbilical cord, piglets were individually weighed using a digital scale (Salter Weight-Tronix Ltd., West Bromwich, UK).

The experiment received ethical approval by the Research Institutional Animal Care and Use Committee (IACUC), at the Faculty of Veterinary Medicine and Zootechnics at UNAM in Mexico City. To shorten the handling duration, the sampling occurred simultaneously whenever possible, e.g. by measuring heart rate and ear temperature at the same time. At the end, all procedures were carried out within 5 min.

Statistical analysis

A completely randomized design was used. Continuous data were summarized as mean ± standard deviation and were compared among the three groups by means of the ANOVA test under the GLM (General Linear Models) procedure of

Table 1. Mean ± standard deviation (SD) of blood critical values from newborn piglets classified according to the vitality score

Blood trait	Vitality score		
	G_1 (0–5) (*n* = 218)	G_2 (6–7) (*n* = 439)	G_3 (8–10) (*n* = 464)
pH*	7.1 ± 0.6^c	7.2 ± 0.6^b	7.3 ± 0.5Ş
PCO_2 (mmHg)	86.6 ± 23.3^a	53.7 ± 12.8^b	46.4 ± 10.6^c
PO_2 (mmHg)	21.7 ± 10.5^c	26.2 ± 6.8^b	27.9 ± 7.3^a
Na^+ (mmol/l)	134.0 ± 3.5^b	134.8 ± 3.5^{ab}	135.7 ± 3.8^a
K^+ (mmoI/l)	6.8 ± 0.6^a	6.6 ± 0.6^a	6.7 ± 4.3^a
Ca^{2+} (mmol/l)	1.8 ± 0.2^a	1.6 ± 0.1^b	1.5 ± 0.1^c
Glucose (mg/dl)	83.5 ± 38.9^a	63.3 ± 15.3^b	67.1 ± 15.8^b
Lactate (mg/dl)	90.0 ± 21.2^a	44.3 ± 17.7^b	36.1 ± 15.1^c
HCO_3^- (mmol/l)	18.9 ± 1.9^c	21.3 ± 2.3^b	23.0 ± 2.9^a
Hematocrit (%)	32.6 ± 4.3^a	32.5 ± 4.4^a	31.1 ± 4.6^a

Within a row, means with different letters (a, b, c) differ (ANOVA, $P < 0.05$)
*Kruskal-Wallis test, expressed as a mean and standard deviation

the SAS statistical programme (2004). The multiple comparisons of means were performed using Tukey's test. In addition, the Kruskal-Wallis test was run for variables without normal distribution like the pH of the umbilical cord and a Chi-square test was performed to compare UC morphology among groups.

RESULTS

Metabolic profile

There were significant statistical differences ($P < 0.05$) among groups (G_1, G_2 and G_3) catalogued according to their vitality score in the blood variables pH, PCO_2, PO_2, HCO_3^-, glucose and lactate. There were also significant differences among groups in plasma electrolytes Na^+ and Ca^{2+}, ($P < 0.05$). We found no differences among groups for K^+ concentrations ($P > 0.05$) and for the haematocrit percentages ($P > 0.05$) (Table 1).

Umbilical cord gross morphology

G_3 showed a large significant difference ($P < 0.0001$), with a higher percentage of normal intact umbilical cords compared to that of G_1. There was also a significant difference regarding broken UC ($P < 0.0001$) between groups, G_1 (failing) showed a two-fold higher incidence compared to G_2 (Table 2).

Table 2. Condition of the umbilical cord (number and percentage) of newborn piglets classified according to the vitality score

Umbilical cord condition	Vitality score			*P*-value
	G_1 (0–5) (*n* = 218)	G_2 (6–7) (*n* = 439)	G_3 (8–10) (*n* = 464)	
	n (%)			
Adhered (normal)	53 (24.31)	358 (81.54)	420 (90.5)	0.0001
Broken (abnormal)	165 (75.68)	81 (18.45)	44 (9.48)	0.0001

Kruskal-Wallis test

Table 3. Mean ± standard deviation (SD) of weight, sex, body temperature and latency to first teat contact from newborn piglets classified according to the vitality score

Trait	Vitality score		
	G_1 (0–5) (*n* = 218)	G_2 (6–7) (*n* = 439)	G_3 (8–10) (*n* = 464)
Weight (g)*	1590.9 ± 229.9[a]	1472.4 ± 207.3[b]	1393.9 ± 218.2[c]
Body temperature at birth (°C)*	37.0 ± 0.4[c]	37.5 ± 0.6[b]	37.7 ± 0.7[a]
Body temperature at 5 min (°C)*	36.6 ± 1.1[a]	35.7 ± 1.3[a]	36.4 ± 1.2[a]
Latency to teat contact (min)*	54.4 ± 8.9[a]	29.2 ± 10.9[b]	23.3 ± 8.1[c]
Males†	131 (60.09%)	193 (43.96%)	197 (42.45%)
Females†	87 (39.90%)	246 (56.03%)	267 (57.54%)

Within a row, means with different letters (a, b, c) differ (*ANOVA, $P < 0.05$)
†Kruskal-Wallis test, $P = 0.05$

Weight, temperature, latency to connect the teat and gender

The weight of neonates that failed the vitality score in G_1 was higher by 197 g ($P < 0.05$) compared to the weight of newborn piglets in G_3 with high vitality scores (Table 3). Body temperature immediately after birth between the neonates in G_1 versus G_3 was by 0.7°C lower ($P < 0.05$). However, there were no differences among groups ($P > 0.05$) in body temperature at 5 min.

As expected and in agreement with Trujillo-Ortega et al. (2007), the high vitality score group (G_3) had the shortest time to contact the udder, whereas the group of newborn piglets that failed the vitality score (G_1) took 30 min longer ($P < 0.05$) to make the teat contact. For the vitality performance regarding gender in the failed viability neonates, 60% of the piglets were males, whereas the larger corresponding percentage of newborn piglets that reached passing qualifications was for the females.

DISCUSSION

Vitality: umbilical cord and asphyxia

A physio-metabolic profile suggested for the neonates from the study is depicted in Figure 1. The integrity of the umbilical cord and assessment of acid-base balance at birth correlated with neonatal survival and birth asphyxia (Zaleski and Hacker, 1993; Herpin et al., 1996; Mota-Rojas et al., 2005c; Van Dijk et al., 2006, 2008a,b). We found significant differences among groups regarding the umbilical cord condition and the vitality score. Pigs with a score of ≤ 5 had a greater incidence of broken umbilical cords, in concordance with earlier studies from Zaleski and Hacker (1993).

Increased levels of plasma lactate in the failed scored vitality group confirm that this neonates suffered early tissue hypoxia (Ježková and Smrčková, 1990; Haaland et al., 1996b; Herpin et al., 1996). Recently, Harris et al. (2008) showed that piglet capacity to tolerate asphyxia depends on each individual, since there is a large variation in the cardiovascular response and cortisol concentrations allowing them to survive birth asphyxia. The incidence and the degree of birth asphyxia experienced in newborn piglets during birth are highly variable and rather unpredictable. Furthermore, Herpin et al. (1996) found a broad range of acid-base values at birth in different members of the same litter. Newly born piglets that failed the vitality scale in our study showed a blood rise in PCO_2 and lactic acid, with a low PO_2, in accordance with previous studies (Herpin et al., 1996; Orozco-Gregorio et al., 2007; Trujillo-Ortega et al., 2007). A reduction of oxygen supply through the umbilical cord leads to increased PCO_2 causing respiratory acidosis resulting in a higher risk of intrapartum anoxia and prenatal mortality (Mota-Rojas et al., 2005a,b,c). The neonatal piglets with a score of ≤ 5 on the vitality scale clearly suffered a degree of asphyxia during birth (Mota-Rojas et al., 2011).

Vitality: body temperature and blood gases

One of the consequences of apnoea is hypoxia. The neonatal piglets with a vitality of ≤ 5 had two

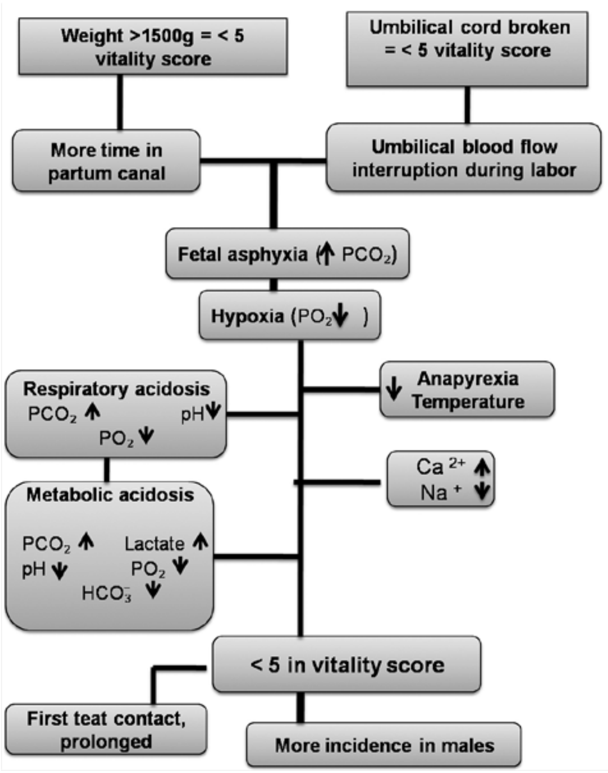

Figure 1. Physio-metabolic performance of porcine neonates with < 5 in the vitality score

notable characteristics – low body temperature and PO_2 within one min after birth. Both traits are related since hypoxia elicits an array of compensatory responses, among them is anapyrexia, the regulated drop of body temperature, which is a very efficient way to prevent cellular damage caused by hypoxia (Steiner et al., 2002). The general importance of anapyrexia resides in the fact that it reduces the consumption of oxygen and increases the affinity of haemoglobin to oxygen (Bicego et al., 2002; Steiner et al., 2002). Variations in temperature tend to affect the entire organism (Odehnalová et al., 2008); the neonate piglets that obtained a low vitality score showed hypercapnia, results in agreement with previous work by Randall (1971) and Herpin et al. (1996); whereas more recently, Groenendaal et al. (2009) indicated that hypothermia affects PCO_2 diminishing this gas concentration at low temperatures.

Vitality: acid-base imbalance and electrolyte profile

A novel point of this study is the blood profile characterization of piglets that either failed or passed the vitality score; the data provided may be applicable as a reference for electrolyte performance in newborn piglets depending on the score, since we know the limited capacity of the neonatal kidney to retain and excrete sodium (Aggarwal et al., 2001).

As expected, pH values were lower for the low viability group compared with the medium and high viability groups, results are in accordance with studies of Herpin et al. (1996). Differences in the Ca^{2+} levels of neonatal piglets are probably due to changes in pH, affecting Ca^{2+} transport proteins. In other words, the more acid the plasma, the fewer binding sites with negative charge are available for setting the calcium to plasma proteins, hence the concentrations of Ca^{2+} ions were elevated in neonatal piglets with failed scores on the vitality scale.

Vitality: energy performance

Herpin et al. (1996) observed an increasing glucose concentration ($P < 0.01$) with blood PCO_2 in piglets with a low vitality score compared to the higher scored ones; similarly, the results from this study indicate that piglets that failed the vitality scale test showed higher than normal glucose concentrations compared to those piglets that passed. Higher blood glucose concentrations were reported in stillborn and weak born piglets (Svendsen et al., 1986) and highly asphyxiated piglets (Herpin et al., 1996), whereas in newborn pigs with low birth weight the utilization of glucose as an energy source is more intensive (Kabalin et al., 2008). The larger difference in blood glucose concentration in the failed score group is most probably due to the effects of catecholamines and stimulation of liver glycogenolysis (Herpin et al., 1996), caused by the stress of neonates during birth, indicating adaptation problems to extra-uterine life (Tuchscherer et al., 2000).

Vitality: weight and asphyxia

Another factor that is predisposed to the process of asphyxia is the neonatal weight, in human babies low birth weight is related to poor vitality scores. Similarly, Okere et al. (1997) found that the piglet viability score was highly correlated with piglet weight ($r = 0.66$). However, in this study, piglets with a score of ≤ 5 were the heaviest among groups and showed asphyxia signs. A possible explanation is that heavier piglets had a greater difficulty in travelling down the birth canal, not to forget that these failing neonatal pigs had a greater incidence of broken umbilical cords. These three characteristics – weight, a score of < 5 and broken umbilical cords, constitute a higher level of foetal hypoxia. According to Hoy et al. (1995) neonatal asphyxia delays the first contact with the udder and the first intake of colostrum and is associated with a reduction of rectal temperature at 24 h of life being of the prognostic value for early postnatal vitality.

Vitality: temperature and latency to teat contact

The survival of newborn piglets with low birth weight is reduced because they show poor thermoregulatory abilities and are slow to acquire colostrum (Baxter et al., 2008). Trujillo-Ortega et al. (2007) found a positive correlation between latency to the first teat contact and vitality score. Indeed, Leenhouwers et al. (2001) results showed that the survival chances of small pigs decreased considerably with prolonged first colostrum intake. Surprisingly, as indicated in this study, neonates with a vitality score ≤ 5 weighed more among groups; this indicates that vitality scoring is independent of weight. Contrary to Hoy et al. (1994) and Baxter et al. (2008) results, it took the heavier piglets (G_1) longer to make the first udder contact.

Casellas et al. (2004) observed a positive correlation between viability score and rectal temperature at birth and 60 min after birth, whereas Leenhouwers et al. (2001) reported no correlation between rectal temperature and early postnatal survival. In the present study, neonate piglets with a score ≤ 5 showed lower temperatures immediately after birth, results similar to those reported by Casellas et al. (2004) and Orozco-Gregorio et al. (2008), who found a correlation between low body temperature and lower vitality scores and prolonged time taken to contact the teat, which indicates deterioration of the newborn piglet self-regulation caused by not ingesting colostrum.

Vitality: gender

Gender differences were observed in the different vitality classes, males represented the highest percentage in the failed vitality score group (G_1). The physiological explanation has not been clear up to now, however, regarding rabbit foetuses, Nielsen and Torday (1981) found that while the biochemical indices of lung maturation were the same for full-term males and females, the male foetuses reached the maturity values later than females. Moreover, in human medicine, low Apgar scores are predominantly for boys.

CONCLUSIONS

Traditionally, low birth weight piglets are more prone to have higher rates of pre-weaning mortality. Although we did not measure the mortality rates in this study, our results show that the piglets with a failing score on the vitality scale were the heaviest among groups, it took them 30 min longer to contact the maternal teat, they had a higher percentage of broken umbilical cords, low body temperature (first minute of life), low blood PO_2 and higher than normal blood glucose and lactate levels showing perinatal asphyxia, compared to the other groups of neonates with a passing score on the vitality test; thus this study demonstrates that low vitality piglets had clearly undergone through perinatal asphyxia. Our results confirm that hypoxia and anapyrexia lead to longer latencies to the first teat contact. Critical metabolic and electrolyte blood profiles and latency to the first teat contact according to the vitality scores of piglets at birth are provided as reference values. Gender differences in the vitality score are interesting findings and require further research, as females have significantly higher survival rates than males, despite the higher birth weight in the males.

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Corresponding Author

Prof. Ph D. Daniel Mota-Rojas, Metropolitan Autonomous University (UAM-X), Department of Agriculture and Animal Production, Calzada del Hueso 1100, Colonia Villa Quietud, México D.F., 04960 México
Tel. +52 55 548 375 35, e-mail: dmota100@yahoo.com.mx