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Piglet Survival in Early Lactation: A Review

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Abstract: Piglet death during the perinatal and lactation period is one of the more easily identified causes of reduced production efficiency in swine herds. Pre-weaning mortality rates vary between 12 and 25%. The present review analyses factors related with non-infectious pre-weaning mortality. Among the maternal factors, farrowing and intra-uterine asphyxia, behaviour and maternal ability are discussed. Piglet factors include newborn vigour, teat seeking ability, acidosis, hypothermia and hypoglucemia. Even though there had been technological changes and improvements in husbandry, housing designs and preventive measures, piglet mortality in lactation remains a major economical and welfare problem. The major causes of pre-weaning mortality are those associated with basic husbandry skills, starvation and crushing by the sow. One potential alternative to reduce neonatal mortality in pigs is the monitoring of foetal stress during birth, it is also important to consider the physiological, behavioural and biochemical changes that take place during early lactation which subsequently affect the vitality, maturity and development of neonatal pigs. A mortality rate of say 8% of piglets born alive is possible and should be the target, getting more knowledge of factors influencing piglet non-infectious mortality within the first three days may help improve piglet welfare.

Key words: Pigs, piglet survival, neonate viability, pre-weaning mortality, crushing

INTRODUCTION

Offspring mortality is invariably high in the first few days after birth, reflecting the problems of transition from the totally protected intra-uterine life to an unpredictable extra-uterine existence. In addition to the danger from various environmental hazards, the access of the neonate to milk will be limited by the mother and competition with littermates.

Piglet death during the perinatal and lactation period is one of the more easily identified causes of reduced production efficiency in swine herds (Mota, 1997), it has also been identified as an important welfare issue (Fraser, 1990). Piglet mortality within the first three days of life is still a problem in intensive swine farms (Spicer *et al.*,1986). Mortality rates vary between 10 and 20%(Tucscherer *et al.*,2000) depending on the housing system. In an earlier study with data obtained over 5 years on 761 farrowings of sows, (Grissom *et al.*, 1990) obtained an overall pre-weaning death loss ranging from 12.2 to 24.2% and it was higher in pen than in crate systems. Mortality of live born piglets in farrowing crates for the United Kingdom national herd ranges between 11.7 (MLC, 1996) to 12.2% (Pic, 1996). In pens which allow the animal to turn only, mortality figures range between 8.7% (Fraser *et al.*, 1988) and 15.4% (Lou and Hurnik, 1996). Moreover, Friendship *et al.* (1986) found that the pre-weaning mortality was positively correlated to the number of farrowing crates per room. In slightly larger individual pens mortality figures range between 11.5% (Schmid, 1991) and 14.5% (BØe, 1991) piglet mortality in group systems has been recorded between 12 and 25% (Algers, 1991; Arey, 1995) outdoor farrowing systems, in which the sows are not confined, appear to have levels of pre-weaning mortality comparable to those in farrowing crates, 10.8 and 11.3% for outdoors and indoors, respectively (MLC, 1998). But we have to be careful with this figures, the use of crates may have been confounded with other management differences, especially before crates came into nearly universal use (Fraser, 1990).

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According to Svendsen and Bengtsson (1986) and Tyler *et al*. (1990) between 10 and 35% of the newborn piglets may die within the first three weeks of age. Moreover, over 50% of the deaths occur during the first three days after birth (Dyck and Swierstra, 1987) with crushing accounting for 70 to 80% of the deaths (English and Morrison, 1984). Most of the etiology factors are due to interactions between the piglet and its environment (Kelley, 1982; Le Dividich and Herpin, 1994) also low immunocompetence at birth may play a role increasing susceptibility to pathogens leading to death in lactation (Xu *et al*., 2000). Sows have epitheliochorial placenta which does not allow maternal antibodies to cross, therefore piglets are not provided with passive immunity and are prone to get sick or die. Thus, the immune system of the newborn piglet is anatomically and functionally immature, making survival depending on colostrum maternal antibody passive transfer (Bleacha *et al*., 1983; Odle *et al*., 1996) Neonate piglets are very vulnerable because of their small size, limited body reserves and poor immunity status, leaving them prone to crushing and starvation (Edwards and Furniss, 1988).

The present review analyses factors related with non-infectious pre-weaning mortality. Among the maternal factors, farrowing, behaviour and maternal ability are discussed. Piglet factors include newborn vigour, teat seeking ability, acidosis, hypothermia and hypoglucemia.

MATERNAL FACTORS

Farrowing and intra-uterine asphyxia: Events associated with farrowing are intricately interrelated with the postnatal performance of piglets. Asphyxiation during parturition is a common event in many animal species (Svendsen and Bengtsson, 1986). Piglets are particularly susceptible to intra-partum anoxia despite the fact that they are relatively mature at the time of birth. Some studies have shown that at the time of birth piglets are quite immature when compared with puppies, kittens and bunnies (Stanton and Carroll, 1974). Pigs are a polytocous species so piglets born at the end of the litter are likely to suffer asphyxiation to a greater degree because of the cumulative effects of successive uterine contractions. These uterine contractions reduce oxygenation to the unborn piglets and increase the risk of umbilical occlusion, damage, or rupture of the cord as well as premature placenta detachment (Randell, 1972 and English and Wilkinsion, 1982). Therefore, placental insufficiency plays a major role in the aetiology of perinatal mortality and morbidity (Svendsen and Bille, 1981). In fact, rupture of the cord lowers placental blood pressure, causes a partial collapse of the chorionic villi and thus facilitates placental detachment (Perry, 1954).

Metabolic acidosis and hypoxia are sequela to asphyxia and can cause profound health effects in postnatal performance due to an abnormal suckling, a reduced absorption of colostrum and inadequate passive transfer of neonatal immunity. Acidosis also causes hypothermia, increases mortality and reduces survival in neonates (Alonso-Splishbury *et al*., 2005). Indeed, increased acidemia and hypercapnia are associated with reduced viability (Randall, 1971).

One of the first deleterious effects of intrauterine hypoxia is the expulsion of meconium into the amniotic sac leading to meconium staining of the skin and in severe cases, meconium aspiration into the lungs (Mota-Rojas *et al*., 2006). Hypoxia *in utero* has been shown to increase intestinal peristalsis and relaxation of the anal sphincter causing the expulsion of meconium into the amniotic fluid, gasping by foetuses and subsequent inhalation of amniotic fluid contaminated with meconium (Stanton and Carroll, 1974; Curits, 1974). Pigs suffering from lack of oxygen during birth are often born covered in meconium (Spicer *et al*., 1990).

Baby pig survival may be enhanced through the reduction of the extent and (or) consequences of birth asphyxia. This means that in modern housing conditions and with an always increasing number of piglets born per litter, management practices such as

- Induction, supervision and control of duration of farrowing
- Assistance to weak piglets and piglets that are particularly at risk, *i.e*., later born piglets, lower weight piglets and piglets born posteriorly, in establishing respiration
- Provision of an early intake of colostrum through tube feeding or help to reach the udder
- Provision of an adequate ambient temperature in the farrowing crate through progressive shift of heating lamps from the back to the side of the sow, should help to save more piglets (Herpin and Dividich, 1995).

Behaviour: From descriptive ethological studies of domestic pigs in naturalistic environments, according to Jensen (1986) the main elements of maternal behaviour relevant to neonate survival would appear to be: The selection of the birth site and behaviours involved in nest building, farrowing, including the acceptance of the offspring, suckling and defense of the nest and/or the litter.

Pre-farrowing nesting behaviour may provide the development of maternal behaviour in nulliparous sows

(Cronin and Van Amerongen, 1991). Sows farrowing in outdoor conditions have the opportunity to build nests prior to parturition; nests favour mother-offspring bonds(Cronin and Van Amerongen, 1991; Stolba and Wood-Gush, 1989) and provide physical and thermal protection for the litter (Jensen, 1989) and elaborate nest approach and lying down behaviours reduce the risk pf crushing (Baxter, 1984). A number of studies have indicated that the performance of these behaviours can improve parturition and piglet survival (Herskin *et al*., 1998).

The sow recognizes general characteristics of the litter but does not develop bonds with each individual piglet. Unlike the sow, piglets are able to discriminate their home environment very reliably 12 to 24 h after birth, they can also distinguish maternal odours from alien ones and respond preferentially to their mother´s grunts by 36 h of age.

Primiparous sows may show aggressive behaviour at parturition against their own litter, resulting in the wounding or death of piglets (van der Steen, 1988). The major behavioural pathways leading to piglet deaths are considered to be malnutrition through unsuccessful behaviour and crushing of piglets by the sow (Fraser, 1990).

Crushing: Farrowing crates were introduced to reduce piglet crushing. However, crates do not completely solve the problem, mortality rates of pigs in farrowing crates are estimated to be between 4.8% (Svendsen and Bengtsson, 1982) and 18% (English *et al*., 1977). Even at the modest rate of 5%, crushing costs swine producers in the United States more than $695 million annually (estimated from USDA, 1998). Deaths associated with overlay represent a significant cause of neonatal mortality, especially considering that about 70% of the crushing mortality involves healthy, potentially viable piglets (Spicer *et al*., 1986). In a survey of 7,866 litters Kunz and Ernst (1987) found that crushing was the cause of death in 47.4% of all losses of live born piglets.

Crushing involves two distinct behavioural sequences: posterior crushing (beneath the sow´s hind quarters) and ventral crushing (beneath the udder and rib cage). The farrowing crate was originally introduced to make it easier to manage sows, to allow higher stocking densities and to reduce piglet mortality. However, farrowing crates are designed to prevent posterior but not ventral crushing (Fraser, 1990). In farrowing systems which do not confine the sow, the number of piglets which are overlaid or crushed tends to be higher compared with farrowing crates (Arey, 1997). According to Baxter (1989), the smaller the farrowing pen becomes, the greater the proportion of space occupied by the sow and perhaps the greater the chance of traumatic injury to the piglet by the sow. Findings from Marchant *et al*. (2000) agree with this, in a pen system deaths due to crushing accounted for nearly 70% of live born deaths. However, the incidence of crushing in pens varies greatly from study to study (Cronin and Smith, 1992; Blackshaw *et al*., 1994) According to English *et al*. (1977), crushing of piglets by the sow after birth accounted for almost 18% of deaths before weaning.

Many studies have examined the rate of pig crushing, trying with varying success to use different farrowing pen designs or dimensions (Grissom *et al*., 1990; Marchant *et al*., 2000; Friend *et al*., 1998; Alonso-Spilsbury,1994 Cronin *et al*., 1996), maximizing the opportunity of the sow and piglets to form a strong maternal bond and ensure adequate nourishment of the piglets. The major reason these studies have not been successful in decreasing crushing is because, regardless of housing type, pigs are attracted to their dam's udder immediately after birth and for the next three days. Following the initial 3 days, pigs are often seen using a heat lamp instead of the sow's udder. This change of preference for lying area may help pigs avoid death due to crushing, because most of the crushing occurs in the first few days of life (Svendsen and Bille, 1981). Indeed, according to Marchant *et al.* (2001) piglets are most vulnerable to crushing during the first 24h of life, when they are spending much of their time near the udder and have relatively poor mobility. Moreover, studies in outdoor farrowing huts have shown that crushing occurs at evening and night, during the first 12h of farrowing and involve changes between lying, sitting and standing positions, as well as between udder and side lying (Vieuille *et al*.,2003). Friendship *et al*. (1986) pointed out that large rooms are often noisier which might disturb the nursing sow, thereby increasing the likelihood of her crushing her piglets as she would get up and down more frequently.

Attraction to the udder is most likely dependent on odour. Pigs have a highly developed sense of smell within 12 h after birth (Morrow-Tesch and McGlone, 1990). When a sow farrows, the majority of the pigs move directly toward the udder and very few venture the long way around the back. Sows remain recumbent during parturition, which allows the young to follow the surface of her body until they reach the ventrum. Rhode Parfet and Gonyou (1990) found that pigs were attracted to the odour of sow's milk. However, several factors are likely responsible for orientation; Welch and Baxter (1986) found that pigs were attracted to the tactile and thermal properties of a sow's udder. The mother´s hair pattern also assists the neonate as piglets consistently move with the direction of hair growth.

The use of heat lamps and pads to draw pigs away from the sow has been an effective method in increasing pig health and welfare. The added attraction of the odour and comfort should make this management technique even more effective. Widespread application of a perfected model should help to decrease pig crushing. If a simulated udder can be developed that is highly attractive to pigs and is able to keep pigs in a safe area, then sow welfare could be enhanced by allowing sows to farrow in pens that provide them the opportunity to turn around (Lay *et al*., 1991).

Meishan sows are known to produce large litters and crush few, if any, pigs. Hohenshell *et al.* (1996) studied the behaviour of Meishan sows to determine how their behaviour immediately after parturition differed from that of modern production sows. Preliminary research on these sows indicates that Meishans´ may be more vigilant and aware of their pigs' location and then they quickly lie down without crushing pigs. Farrowing crates have reduced the selection pressure for beneficial maternal characteristics in sows.

Butorphanol currently is a controlled substance, so other analgesics with similar properties should be investigated. Administration of butorphanol to sows upon the completion of farrowing decreases sow body position changes. Because it is these position changes that crush pigs, pig mortality may be decreased by the administration of butorphanol. Butorphanol may be administered orally, in this way, sows could be treated by mixing the proper dosage in feed or by putting it into the water supply. At this time, many analgesics are not cost-effective, but, if there were a large enough interest, appropriate analgesics could be more affordably marketed. Alternatively, use of more comfortable flooring and (or) an increase in sow body fat may be more practical solutions that would allow sows to lie more comfortably and change position less frequently (Haussmann *et al*., 1999).

Malnourished piglets appear to be more vulnerable to crushing, perhaps because persistent suckling attempts cause them to spend more time near the sow. Prevention of crushing thus requires a reduction in malnutrition, not merely restriction of the sow´s movements, since sows are very reactive to the squeals of piglets and moreover, the occurrence of crushing is significantly related to individual differences in sow behaviour (Wechsler and Hegglin, 1997). According to Hutson *et al.* (1992) variation in sow responsiveness post-partum indicates that the sow is capable of responding to distress calls at any time post-partum, but is most receptive to piglet stimuli within the first 2 days post-partum. On the other hand, trauma has been associated with clinical illness of the piglet (26%), the sow (15%), or both (3%) (Spicer *et al*., 1986).

In a more recent study Andersen *et al.* (2005) found that sows that did not crush any of their piglets showed a more protective mothering style, in terms of more nest building activity, responded sooner on piglet distress calls, initiated more contacts sooner after presentation of distress calls, nosed more on the piglets during posture change, were more restless when the piglets were taken away and were socially more flexible (avoided conflicts to a larger extent) in a grouping situation, than sows that crushed several piglets, thus concluding that crushing as a cause of neonatal death in piglets is therefore highly related to mothering style.

Lactacional failure and starvation: Postmortem examinations have typically identified trauma (usually crushing) and starvation as the two leading causes of piglet deaths (Fraser, 1990). According to this author, crushing and starvation may often serve as alternative end-points of a single process. A piglet that is debilitated by being excluded from teat ownership or by otherwise failing to establish adequate milk intake is likely to be crushed, but if crushing is prevented, the animal may die from malnutrition some time later.

A sow´s milk production in the first days of lactation can vary from excellent to disastrous and many litters of piglets experience mild to severe malnutrition soon after birth. Lactation failure in sows is a world-wide problem. Insufficient milk production by the sows and the consequent malnourishment of the piglets may be directly responsible for between 6 and 17% of all pre-weaning mortality in commercial pig farms. Lactation failures may be due to high environmental temperatures (Barb *et al*., 1991) metabolic disorders and endocrine imbalances in the sow, the presence of bacterial infections like metritis or hypogalactia (Quinlan, 2001) or endotoxins inhibiting prolactin secretion (Smith and Wagner, 1984) and primiparous sows impending suckling by their piglets (Quinlan, 2001). According to Dyck and Swierstra (Dyck and Swierstra, 1987) agalactia is considered a primary cause of starvation when more than 3 piglets from a litter die.

Higher levels of fear of humans had been associated with longer durations of farrowing, larger variation in inter-birth intervals and a higher number of piglets dying without milk in their stomachs, moreover, the duration of farrowing was positively correlated to the number of piglets dying without milk in their stomachs (Janckzak *et al*., 2003).

PIGLET FACTORS

Behaviour: teat order and latency to first suckling: Survival for the newborn pig depends on its ability to stand, move from the birth site to the mammary area of its dam and then to locate and suck from the teats. The behaviour of the piglets during the first 24 h after birth has a major influence on their consumption of colostral immunoglobulins. A number of studies have reported that piglets with low birth weights competed with their larger and heavier littermates for teats during suckling bouts and consequently ingested less colostrum (De Passillé *et al*., 1988; Milligan *et al*., 2002).

Neonatal survival depends largely on piglets reaching the udder soon after birth, nursing successfully and continuing to do so regularly thereafter. Colostrum is the source of dietary energy which also contains immunoglobulins which can be absorbed intestinally by piglets for up to 36 h after birth, prior to gut closure (De Passillé *et al*., 1988). The speedy acquisition of colostrum by the piglet soon after birth is therefore essential to provide the energy and antibody protection necessary for survival. Thus, the ability of the piglet to seek a teat and suckle soon after birth should enhance the chance of survival.

During lactation, piglets compete in two distinct ways. In the first few days after birth, piglets compete aggressively for access to teats; most piglets will establish "ownership" of a particular teat while others will die or survive by suckling opportunistically (De Passillé *et al*., 1988). These authors conclude that a high level of fidelity is an advantage to piglets because it reduces teat disputes and the chance of missing nursings. Piglets also compete indirectly with their littermates by stimulating and/or draining their teats more effectively and thus receive a larger fraction of hormones and nutrients involved in milk production from their respective teats (Algers *et al*., 1991).

The lack of a teat cisternae makes fights during milk ejection costly. The stability of the teat order is correlated with litter size, milking capacity of the sow and piglet morbidity and mortality. Duration of milk flow in the sow is very short and lasts for only 20 to 30 sec (Fraser, 1980). The piglet needs all 20 sec to consume the 20 to 30 g of milk that is produced in a functional teat (Algers, 1993); A piglet that is consistently late for 1 sec in beginning the fast suckling behaviour will lose 5 to 10% of its daily milk intake (Rushen and Fraser, 1989). Therefore it is quite important to keep lactating sows in quiet farrowing rooms. Particular attention should be given to piglets consuming <40 g, as the data of Coalson and Lecce (Coalson and Lecce, 1973) suggest that such low colostrum intakes may impair immune competence.

Several typical situations can result in a substantial delay between birth and first successful nursing. Bate *et al.* (1985) found that latency from birth to secure a teat and suckle was shorter in females than in males, but was not influenced by body weight. These results suggest that the higher serum testosterone levels of male piglets may have detrimental effect on their teat-seeking ability. However, according to Rhode Parfet and Gonyou (1990) latency to first mammary contact is not influenced by either birth weight or sex, but is affected by position in the birth order, number of pigs born at the time of mammary contact and frequency of position changes by the sow; The effects of birth order are generally negligible except among later born piglets (ninth and greater) with these pigs taking longer to locate the mammary area regardless of floor type (sloped or not). The use of sloped floors in crates tend to increase the latency to first teat contact, probably due to hypoxia since they had longer birth intervals, thus they might have had difficulty in orientation (Rhode Parfet and Gonyou, 1990).

Individual low birth weight: The key issue to sow breeders is to wean a large number of healthy and fast growing piglets. Sow prolificacy has been improved considerably during recent years. As a result the rearing capacity of the sow is often exceeded. The increasing litter size at birth causes a lower average birth weight. A reduction in the piglet birth weight means increased risk of higher pre-weaning mortality rate. According to Hoy *et al*. (1994) investigations with 1,248 newborn piglets in 7 farms showed a high significant influence of birth weight on parameters of early postnatal vitality.

According to Caceres *et al*. (2001) birth weight is inversely related to pre-weaning mortality. Litters of domestic piglets show strong sibling competition, large differences among litter-mates in birth weight and growth and in the absence of human intervention, a high mortality rate (Freser, 1990; Tylor *et al*., 1990). Several studies have concluded that in addition to the known effect of low birth weight, a lack of uniformity in birth weight is itself an important risk factor for piglet survival (Pettigrew *et al*., 1986 ; Caceres *et al*., 2001). The first days after birth are marked by exceptionally large variation between litters in piglet weight gains. Some litters enjoy large, steady gains in the first days after birth, others gain very little and some lose weight for one or more days (Alonso-Spilsbury, 1994).

The degree of variation in birth weight within a litter is due to the differences in placental transfer of nutrients to individual fetuses and restricted nutrient supply is associated with the production of low-birth-weight offspring (Litten *et al*., 2003). According to Marchant *et al*. (2000) only 28% of piglets weighing less than 1.1 kg at birth survived to seven days.

Zajas-Cruz *et al*. (2000) showed that piglets of low average birth weight were not competitive if mixed with larger piglets. Higher mortality rates observed in first parity sows seem to be related to lower piglet birth weight (Lucbert and Gatel, 1988). On the other hand, a high birth weight is considered an advantage to survival, but it has been found that females, although having a lighter birth weight, suckled earlier than males (Bate *et al*., 1985) this finding is consistent with previous report from Bereskin *et al.* (1973) who reported that females lighter birth weight than males, had a better survival rate. Moreover, these latter authors showed a significant decrease in male survival rate with increasing litter size.

It is also worth mentioning that nutritional deficiencies at all stages of growth, both pre- and post-natal, can affect animals´ physical, mental and behavioural development (Barker, 1998). Compromised growth during foetal life as consequence of perturbations in nutrient supply, results in low-birth weight piglets that are at increased risk from morbidity and mortality during early life.

Asphyxia and neonatal vitality: The survival and normal growth rate of a newborn pig, the ultimate indicators of vigour, reflect proper maturation and adaptation. Maturation prepares the newborn animal for the transition from the intrauterine to the extra-uterine environment, whereas adaptation allows the neonate to adjust to the demands of a harsh, extra-uterine environment (Stanton and Carroll, 1974). The vigour at the time of birth among piglets of the same litter varies considerably and this variation is due in part to factors related to the interruption of oxygen flow during birth (Randall, 1971). Differences in piglet vigour are related to a variety of host factors such as genetic background, birth weight, blood iron concentration and various hormonal concentrations (Fraser *et al*., 1995). Some studies revealed a strong positive correlation among birth weight, vigour and postnatal survival rates (England, 1974).

Prolonged or intermittent asphyxia *in utero* and during delivery does not necessarily lead to intra-partum stillbirth; However, such asphyxia weakens piglets and renders them less capable of adaptation to extra-uterine life (Zaleski and Hacker, 1993; Trujillo-Ortega *et al*., 2006). Indeed, live born piglets dying before 3 weeks of age have higher blood lactate levels at birth than those surviving after this age (English and Wilkinson, 1982) and the ability to thermoregulate during an acute cold stress is inversely related to umbilical blood lactate levels (Stanton *et al*., 1973). The relationships between degree of hypoxia at birth and subsequent survival and vitality, however, have not been clearly established (Herpin and Dividich, 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, growth rate and survival over 10 days, these criteria being of prognostic value for early postnatal vitality (Hoy *et al*., 1995). Postnatal vitality is also positively correlated with birth weight, as shown by Hoy *et al.* (1994) but the effect of asphyxia was often as high as and sometimes higher than, the effect of birth weight (Herpin and Le Dividich, 1995).

In addition, intra-partum asphyxia drastically activates the sympathoadrenal system and the liberated catecholamines may elicit several deleterious actions such as damage to brain capillary endothelium and acidosis, possibly associated with the mobilization of carbohydrates stores in anaerobic conditions. Depletion of glycogen stores will also reduce the physiological reserves of the newborn and its ability to withstand prolonged bouts of extra-uterine stress. This may lead to reduced vigour at birth, less aggressive nursing behavior, and, consequently, reduced colostrum intake, thereby enhancing the shortening of energy supply for thermoregulation (Herpin and Le Dividich, 1995).

Piglets that suck infrequently or with little vigour may be less successful in obtaining immunoglobulins (Blecha and Kelly, 1981). The importance for piglet growth and survival of an early and sufficient intake of immunoglobulin has been repeatedly emphasized (De Passillé *et al*., 2003).

Thermoregulation and neonatal viability: The quality of the climatic environment available for the pig from the moment of birth has a very substantial effect on its survival chances. Its lower critical temperature at thus stage is 34°C and if such conditions are not provided, it will use up its very limited energy reserves in an attempt to maintain normal body temperature.

Newborn piglets are poorly insulated, devoid of brown adipose tissue and rely almost exclusively on shivering thermogenesis in the cold (Berthon *et al*., 1994). At birth, they usually experience a sudden 2 to 4°C decrease in body temperature and recovery of a normothermic temperature of 39°C is achieved within the following 24 to 48 h of life in adequate environmental conditions. However, excessive hypothermia due to severe environmental conditions, low body weight or reduced vitality at birth could reduce piglet vigour and colostrum intake and lead, ultimately, to the death of the animal (Herpin and Le Dividich, 1995).

During progressive hypothermia the newborn pig displays adequate metabolic responses as long as its body temperature is above 34°C. Shivering intensity is related to body and skin temperature during moderate hypothermia, this relation being weaker and not significant during deep hypothermia. Metabolic and physiological alterations induced directly or indirectly by body cooling are usually reversible in appropriate environmental conditions (Lossec *et al*., 1998).

Prior to birth, the uterine environment of the sow provides the piglet with a constant and comfortable temperature. At the time of birth, the piglet is suddenly exposed to fluctuant and cold environmental temperatures and survival depends almost exclusively on thermoregulation (Curtis, 1974). It is well known that piglets suffering from asphyxia are particularly prone to hypothermia. One study showed lesser rectal temperatures 1 h after birth in pigs suffering from asphyxia. This deleterious effect of intra-partum hypoxia has also been reported in asphyxiated piglets in which thermoregulation was impaired (Herpin *et al*., 1996; 1998). According to Herpin *et al.* (1996), neonatal asphyxia reduces postnatal vitality by increasing the time required to find the udder and by hampering the ability of the piglet to maintain body temperature during the first 24 h of life. This delayed feeding and hampered thermoregulation results in reduced growth rates and decreased neonatal survival during the first 10 days after birth. However, because asphyxiated piglets exposed to moderate cold at birth show some thermogenic and shivering capabilities, it has been assumed that the effect of thermoregulation on vigour may be indirect. Piglets with reduced vigor have less aggressive suckling behaviour and consequently, a reduced opportunity for colostrum intake (Herpin and Le Dividich, 1998). This reduced intake of milk leads to an inadequate transfer of passive immunity and an increase in neonatal infections (Edwards, 2002).

Unlike the newborns of other domestic species, piglets lack of brown fat and, therefore, lipid storage can not be used as a major metabolic fuel. Piglets, however, mobilize free fatty acids during starvation and cold exposure but their thermoregulation primarily results from shivering (Svendsen and Bengtsson, 1986; Herpin, 1998). It is has been reported that thermogenic response in neonates exposed to lesser temperatures is rapidly triggered and regulated by sympathic stimulation (Curtis and Rogler, 1970). Thermoregulation after birth is also mediated through the effect of catecholamines on the cardiovascular system (Mayfield *et al*., 1986).

The newborn piglet has only a limited capacity for gluconeogenesis, thus unsuckled or starved piglets become hypoglycemic within 15 to 20 hours after birth (Svendsen and Bengtsson, 1986). Such hypoglycaemia causes metabolic disturbances, impairs chemical thermogenesis and triggers a metabolic acidosis in porcine neonates. In this situation, catecholamines play a major role in maintaining normal body temperatures in the newborn (Quisber, 1995) as the body looses heat through four mechanisms (Cunningham, 1997) evaporation, conduction, convection and radiation.

Clinical signs of hypoglycemia are observed when the concentration of the blood glucose decreases to about 2.7 mM (Pettigrew *et al*., 1971). Hypoglycaemia results from the failure of the piglet to maintain blood glucose homeostasis by either endogenous glycogenolysis and gluconeogenesis or an exogenous intake of carbohydrate (lactose) from colostrum.

CONCLUSION

In spite of the technological changes and improvements in husbandry, housing designs and preventive measures, piglet mortality in lactation remains a major economical and welfare problem. The major causes of pre-weaning mortality are those associated with basic husbandry skills and maternal-offspring behaviour. One potential alternative to reduce neonatal mortality in pigs is the monitoring of foetal stress during birth, it is also important to consider the physiological and behavioural changes that take place during parturition and the first three days post-partum which subsequently impact the vitality, maturity and development of neonatal pigs; recording these variables may be useful to identify weak piglets quickly and to establish palliative measures. A mortality rate of say 8% of piglets born alive is possible and should be the target. Negative associations between fear of humans and maternal abilities in sows should be avoided in order to improve piglet welfare.

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