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Maximising piglet survival

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Introduction

Peri-natal mortality still plagues the swine industry despite improving knowledge on neonatal physiology, nutrition, health and management. Currently, across Europe one out of five to six piglets born (i.e. 17 to 20%) does not survive from the onset of farrowing until weaning at 3-4 weeks of age. In France, this means that 6.5 10^6 piglets are lost each year. It is clear that these losses have a serious economic impact while being unacceptable for ethical reasons.

Piglet mortality comprises stillbirths and live-born piglets that die before weaning. Most stillborn piglets die during farrowing as a result of asphyxiation or soon after birth as they have been weakened by the birth process. Overlying is often reported as a major terminal cause of pre-weaning mortality, with this ultimate cause being probably the final act in a chain of events. In fact, the underlying causes are not fully understood.

In this paper, after a brief survey of the extent of peri-natal mortality, we provide new insights on the importance of colostrum for the piglet's survival. Emphasis is given to the nutritional and immunological roles of colostrum and to insufficient consumption of colostrum as a major underlying cause of post-natal mortality.

1-Peri-natal mortality.

In major pig producing countries, total piglet mortality is in the range of 17-20% and is even higher in litters from high prolific sows. In France for example (Figure 1), during the past decade the increase in total number of piglets born per litter from 11.8 to 13.7 has resulted in an increase in total mortality from 17.8 % to 21.1%. Of the total losses, approximately 40 % are classified as stillbirths. Therefore, reducing both stillbirths and post-natal deaths are of equal importance.

1-1 Stillborn piglets. Stillbirths are usually classified as either pre-partum or intra-partum deaths. Of total stillbirths, 70 to 90% are intra-partum deaths as a result of asphyxiation due to damage or rupture of the umbilical cord and (or) to premature detachment of the placenta. Because stillbirths are often misdiagnosed and hence overestimated, supervision of farrowing and provision assistance to the weak piglets have proven to be efficient to reduce stillbirths. According Holyoake et al. (1995) and White et al. (1996) attending of farrowing results in a reduction of stillbirths from 0.6-0.7 to 0.2-0.3 per litter. Similarly, Le Cozler et al. (2002) reported a marked increase in the proportion of litters without stillbirth.

1-2 Mortality of live-born piglets. Many surveys have been carried out to examine causes of death of live-born piglets. However, while the major terminal causes (including crushing by the sow) are well-known, underlying mechanisms are less well understood (for a review, see by Edwards. 2002). Most (55-65%) losses occur in the first 2-3 d after birth. There is an increasing evidence that failure to achieve a regular and adequate intake of colostrum is likely to be both a direct and an underlying cause of the majority of deaths

(Dyck and Swiestra, 1987; de Passillé and Rushen, 1989; Weary et al., 1996, Tuschscherer et al., 2000; Edwards, 2002). A recent study by Damm et al. (2005) reported that 72% of live-born piglets that died had not consumed colostrum. Reports by Le Dividich et al. (2005a) and Devillers (2005) also indicated that, with the exception of some piglets where crushing was the primary cause of death, piglets dying in early life gained several times less weight and therefore had consumed much less colostrum and hence less energy and immunoglobulins than survivors during the first 24 h after birth (Table 1). It is assumed that piglets consuming less colostrum would be less vigorous and less able to compete for productive teats, and hence more prone to die by undernutrition and (or) hypothermia. The acquisition of sufficient passive immunity is unlikely to be a major factor underlying these early production losses. This is substantiated by the facts that (i) piglet mortality recorded in a specific pathogen free herd did not differ from that recorded in production herds (Cariolet et al., 2004) and (ii), piglets born later in the birth order have less immune protection, but are not at a higher risk of dying (Le Dividich et al., 2004). However, Hendrix et al. (1978), Blecha and Kelley (1981), Klobasa et al. (1981) reported that low IgG concentrations in blood serum soon after birth are associated with subsequent mortality and morbidity. However these observations may simply reflect an inadequate colostrum (energy) intake. However, piglets which die (both stillbirths and those alive at birth dying before weaning) have in common to be usually lighter at birth than the survivors. According to Leon and Madec (1992) stillbirths are 21% lighter than piglets born alive. Similarly, during the suckling period, mortality among low birth-weight piglets accounts for 40 to 60% of total pre-weaning deaths. Selection for high litter size has resulted in a decrease in absolute mean birth-weight amounting to 35-45 g for every extra pig born, and has generated a higher proportion of low birth-weight piglets. For example, the increase in litter size from 11 to 16 increases the proportion of light piglets (< 1.0 kg) from 9 to 23% (Quiniou et al., 2002).

From the above, it is clear that a low birth-weight and an insufficient colostrum intake are major causes of mortality during the early suckling period when most losses occur. Moreover, the effects are likely synergistic. Therefore, two major questions arise (i) to what extent is saving these light piglets of interest and (ii) what the issue of colostrum in piglet survival?

2-The question of piglets of low birth-weight.

"Small" is an arbitrary term. It is applied to newborns weighing 75-80% of the mean birth-weight of the litter, on the basis that these pigs have a greater risk to die before weaning (Rydhmer, 1992; Leon and Madec, 1992; Herpin et al., 1996; Bidanel, Personal communication). A small piglet should be define within his birth litter. However, it is difficult to define a threshold for birth-weight below which the piglet could be considered as being small because birth-weight is dependent on genotype, parity and litter size.

2-1 Is the difference between a small and a large piglet only a difference in weight?

Small pigs have less body energy reserves, are more susceptible to cold (Le Dividich et al., 1991) and therefore, are more prone to experience deep hypothermia and (or) to be overlain by the sow. They take longer to achieve their first sucking (Hoy et al., 1994), and within the litter, are less able to compete for maternal resources than their heavier littermates. Consequently, the smaller piglets consume less colostrum (Fraser and Rushen, 1992) resulting in a reduced supply of energy necessary to sustain a high metabolic rate, and a reduced acquisition of protective immunoglobulin (Ig). Further, several studies have shown a decreased number of muscle fibres in small piglets as a consequence of a smaller secondary fibre population (Handel and Stickland, 1987; Dwyer and Stickland, 1991; Kühn et al., 2002; Gondret et al., 2005- 06). The total fibre number is fixed at birth and it is largely accepted that difference in the amount of nutrients transferred from the mother to her foetuses is a major cause of intra-litter variation in total fibre number (Dwyer et al., 1994). Number of muscle fibre is a major determinant of muscle mass, and because there seems to be a physiological limit for fibres hypertrophy (Hegarty and Allen, 1978), small piglets have a reduced growth potential and do not have the capacity to fully catch up to heavier counterparts.

2-2. Performance, carcass and muscle fibre characteristics of small piglets

When surviving the neonatal period (birth to 3d.of age) small piglets perform less than their heavier littermates. Differences in growth are the most pronounced during the early life. For example, during the suckling period, piglets weighing less than 1.0 kg at birth grow 21% less than their counterparts weighing 1.4-1.6 kg at birth (Quiniou et al., 2004, Le Cozler et al., 2004). However, during the fattening period (from 25 kg to slaughter) difference is reduced to 6-10% (Quiniou et al., 2004, Gondret et al., 2005, 2006). Overall, from birth to slaughter, compared with heavier littermates (1.4-1.6 kg) small piglets (< 1.0 kg) require 10 to 23 additional days to reach the commercial slaughter weight (Powell and Aberle, 1980; Hegarty and Allen, 1978; Caugant and Guéblez, 1993; Quiniou et al., 2004; Le Cozler et al., 2004; Gondret et al., 2005-2006). Most reports indicate marginal effects of birth-weight on feed conversion and carcass lean meat content. However, when really full-fed, piglets that are light at birth (1.05 kg) are found to be fatter than their heavier littermates (1.89 kg) (Gondret et al., 2006). There is also some difference in muscle fibre structure but, as to what extent this had effects on meat quality requires clarification. Finally, on the basis of existing data on the ability of the piglet to survive and to convert feed into weight gain and lean meat, and on the profitability of saving small piglets (Gourmelen and Le Moan, 2005), it is suggested that a birth-weight of ≈ 0.85-0.90 kg represents a limit below which saving of piglets from modern genotypes is questionable.

3- **Why colostrum is so important for the piglet's survival?**

As most farm animals, the pig is born with low energy reserves and without immune protection. The two major roles of colostrum are therefore to provide the piglet with energy for heat production and metabolism and, with passive immunity which helps to prevent infections.

3-1 Energy role of colostrum.

Colostrum is the first secretion of the mammary gland. Its composition has been recently reviewed by Xu (2003). Briefly, it is characterised by a rapid change to that of milk in the course of 24-36 h transition period. Compared with milk, colostrum contains more dry matter, protein, bioactive components and less fat and lactose. However its gross energy (GE) remains practically constant over the first 24 h post-partum. Colostrum is remarkably well utilised by the piglet. Compared with milk, its metabolizability, i.e., the ratio metabolisable energy (ME) / GE is lower (0.93 vs 0.98), while both have a ratio of N retained / N intake of 0.88-0.91 (Le Dividich et al., Unpublished data). Compared with mature milk, colostrum contributes to the maturation of the developing intestine (for a review, see Xu et al., 2002) and specifically stimulates muscle protein synthesis (Burrin et al., 1992), with the synthesis being mostly restricted to the myofibrillar protein compartment (Fiorotto et al., 2000). This may contribute to muscle maturation since at birth skeletal muscle contains very few myofibrils (Herpin et al., 2002).

3-1-1 Contribution of colostrum to meet the energy requirement of the new-born pig. As any animal, the neonatal pig needs energy to meet its requirements for maintenance, including thermoregulation and physical activity, and growth. In practice, Le Dividich et al. (2005a) calculated that the minimum net energy required for survival of a 1.0 kg-piglet may be in the range of 900 to 1000 kJ during the first postnatal day. This energy requirement is met by body energy reserves and colostrum since the first suckling usually occurs on average 20 min after birth. However, available energy derived from body reserves is low, amounting to about 420 kJ / kg birth-weight (Mellor and Cockburn, 1986), which barely meets the energy required for maintenance during the first day of life (Figure 2), thus emphasising the importance of colostrum as a source of energy. Le Dividich et al. (2005a) and Devillers (2004) estimated that the piglet must consume approximately 160 g colostrum / kg birth-weight to survive.

3-1-2 Colostrum production of the sow and consumption of the piglet. Both colostrum production and consumption result from a close interaction between the sow and her litter because both are dependent on the sow's ability to produce colostrum, and on that of the piglets to reach and extract colostrum from the udder. Litter or individual piglet weight gain from birth to 24 hours after birth is a very good marker of colostrum produced by the sow or consumed by the piglet (Devillers et al., 2004, Le Dividich et al., 1997). The ratio of conversion of colostrum into weight gain ranges between 2.3 and 2.5.

The main characteristic of colostrum production by the sow is its very high variability. In a study involving 51 sows, litter weight gain during the first 24 hours after birth averaged 1087 g with a coefficient of variation of 67% (Le Dividich et al., 2005a). Thompson and Fraser (1988) found similar results and suggested that there were large differences between sows in the early availability of colostrum and milk. A similar variability has been reported in ewes.

Litter size is a major factor influencing sow milk production. In contrast, litter weight gain (or colostrum production of the sow) is only marginally dependent on litter size (Figure 3). Similarly, Milligan et al. (2000), found no difference in piglet growth during the first 3 days postpartum between litters of 9 and 12 piglets. Consequently, weight gain available per piglet during the first 24 hours after birth decreases by 19 g (i.e, approximately 45 g colostrum) for each additional piglet born (Le Dividich et al., 2004). It is suggested that the sow itself is the main factor accounting for variability in colostrum production. However, very less is known on factors controlling colostrum production by the sow.

Colostrum intake in the piglet is initially very high, representing up to 5 to 7 % of birth weight in the first two postnatal hours (Fraser and Rushen, 1992), and decreases gradually thereafter. When an unrestricted supply of colostrum is available, consumption amounts to 450 g / kg birth-weight (Le Dividich et al., 1997), suggesting that the ingestive capacity of the pig is very high at birth. In sow-reared piglets, colostrum consumption over the first 24 h after birth ranges from 210 to 280 g / kg birth-weight (Le Dividich and Noblet, 1981; Milon et al., 1983, Bland et al., 2003, Devillers et al., 2005). Within-litter, main factors influencing colostrum consumption are birth-weight, birth order and litter size. Body weight gain between birth and 24 h of age increases by 18 g (≈ 43 g colostrum) per 100 g increase in birth-weight (Le Dividich et al., 2005a). This, and the fact that 60 to 80 % of sows produce enough colostrum to feed adequately a litter of 12-13 piglets (Devillers, 2004; Le Dividich et al., 2005a), illustrate the importance of litter homogeneity. Surprisingly, birth order has no effect on colostrum consumption during the first 24 h after birth (Devillers et al., 2005; Le Dividich et al., 2005a). Other factors including cold exposure (Le Dividich and Noblet, 1981) and splayed limbs at birth (Devillers et al., 2005) markedly decrease colostrum consumption, while birth hypoxia results in both an increase in the interval between birth and first suckling and a decrease in colostrum consumption (Herpin et al., 1996).

3-2 Immunological role of colostrum

The most important constituents of colostrum are the immunoglobulins (Ig) which provide passive immune protection both after absorption of intact immunoglobulins prior to “gut closure” and at the gut mucosa level throughout lactation. Colostrum also contains leukocytes which are absorbed by the new-born and produce a measurable immune activity (Tuboly et al., 1988; Williams, 1993) and numerous soluble factors with antimicrobial and / or immunomodulating activity.

Colostrum is characterised by a high concentration of immunoglobulin IgG, while IgA predominates in milk (Klobasa et al. 1987). Thus colostrum is a source of circulating antibody for the new-born, while milk provides local antibody protection for the intestinal mucosa. Concentrations of IgG in colostrum are initially high but drop rapidly during the first 24h of secretion (Figure 4). This initial concentration of IgG in colostrum varies widely, even between sows on the same unit (Bland and Rooke, 1998; Le Dividich et al., 2004). Vaccination, parity, season, genotype and section of the udder are also reported to influence colostrum Ig concentrations (Inoue et al.,1980; Klobasa et al., 1985, Bland and Rooke 1998; Wagstrom et al., 2000) but not always (Klobasa and Butler, 1987). Feeding mannan oligosaccharides as Bio-Mos® to sows during late gestation improve levels of Ig of colostrum (Quinn et al., 2001; Newman and Newman, 2001). Nevertheless, variation in colostrum Ig concentration is dominated by sow to sow variation.

3-2-1 Transfer of maternal Ig to the new-born piglet. The neonatal intestinal epithelium is capable of absorption of macromolecules, such as Ig, prior to gut closure. Delivery of intact immunoglobulins to the small intestine is facilitated by the presence of trypsin and chymotrypsin inhibitors in colostrum (Zhou et al., 2003). Absorption of Ig occurs by endocytosis and subsequent transfer across the basolateral membrane of the enterocyte to the circulation. Gut closure corresponds to the cessation of transfer of IgG to the circulation of the piglet. It takes place as early as 24h of age in suckling pigs and colostrum intake which specifically stimulates the functional maturation of the gastrointestinal tract (Xu et al., 2002) is the main factor that induces gut closure. It is relevant to notice that colostrum intake in amounts insufficient to maintain piglet body weight have a marked effect on gut closure suggesting that small quantities of colostrum are sufficient to initiate closure (Le Dividich et al., 2005b).

3-2-2 Major factors influencing the acquisition of passive immunity. The acquisition of passive immunity is closely dependent on both the amount of colostrum consumed and on its IgG content. Absorption of IgG is saturated by increasing amounts of colostrum intake. Recently, Le Dividich et al. (2005b) fed piglets different amounts of colostrum in hourly feeds over the first 27 h of life. Plasma IgG concentrations reached a plateau in the first 20 h of suckling. A key observation was that IgG concentrations obtained at the plateau was dependent on the amount of ingested colostrum, averaging 11, 18 and 26 mg /ml in piglets fed 140, 210, and 280 and 350 g colostrum / kg birth weight, respectively. Piglets late in the birth order having access to colostrum of lower IgG concentration have a reduced plasma IgG concentrations (de Passillé et al., 1988; Bland et al., 2003; Klobasa et al., 2004; Le Dividich et al., 2004) (Figure 5). Increasing the vitamin A and E content of the diet of the sow has been shown to influence the IgG status of the piglet in several studies (Rooke and Bland, 2002)

3-2-3 The acquisition of a high passive immunity influences favourably the development of the active immunity. According to Klobasa et al. (1981) there is a negative relationship between development of active immunity and the acquisition of passive immunity. Recent observations (Damm et al., 2002; Rooke et al., 2003; Le Dividich et al., 2004), however, compared the concentrations of plasma IgG at 7 and 28 days of age in sow suckled piglets and found positive relationships between plasma IgG concentration at or before 7 days of age (when there is little de novo IgG synthesis) and 28 days of age. These more recent observations suggest that there is a positive link between colostrum intake and development of immunity in the piglet.

3-2-4 Is there an optimum level for passive immunity? Coalson and Lecce (1973) postulate that piglets "can acquire from the dam's colostrum more than adequate passive antibody in the first hour of nursing" corresponding to ≈ 15-17 mg IgG / ml serum. On this basis one may calculate that piglets consuming approximately 70 g / kg BW of the first colostrum would acquire sufficient passive immune protection. However, this amount of colostrum is largely insufficient to meet the energy requirement for survival. Therefore, as postulated by Tyler et al. (1990), the consumption of colostrum in adequate amount to provide appropriate immunity to the piglet is not necessarily sufficient to guarantee its survival. From this, it is tempting to speculate that the level of passive immunity is not a determinant of survival. However, inadequate transfer of maternal antibodies to the new-born piglet may increase susceptibility to infections in the latter part of lactation and after weaning (Varley et al., 1986), while low humoral immunity at weaning may influence post-weaning performance (Edwards and Rooke, 1999). Therefore, the energy and immunological roles of colostrum are of equal importance for the survival and the development of the piglet.

4. Conclusion: the need for research.

During the past decades, considerable amount of scientific papers has been produced in an attempt to reduce mortality of piglets. These have been mainly directed towards (i) provision of an adequate thermal environment to the litter based on the thermoregulatory ability of piglets and (or) providing the weak piglets with an energy source because of the high energy requirement during the first days of life, (ii) management practices to reduce competition among siblings, and (iii) studies of the behaviour of the sow (a component of the maternal quality of the sow) and her litter around parturition. Despite these efforts, piglet survival has not been substantially improved. However, during this period, the pig sector has been constantly on the move and breeding companies have been successful in developing more prolific genotypes with the ensuing increased proportion of high litter sizes and of piglets of low birth weight. We have underlined that an early and high intake of colostrum (energy) is a major determinant of survival during the early suckling period, whereas the acquisition of a high level of passive immunity is desirable as it may influence the development of active immunity and the health and performance of the piglets during the late suckling period and after weaning. However, to what extent the ability of the high prolific sow to produce colostrum has been increased proportionally is not known. Therefore, we suggest that factors initiating and controlling colostrum production of the sow, and the delayed effects of passive immunisation on the health and growth, previously neglected areas, warrant future research. Further, providing equal opportunity for each littermate to survive and to thrive can be defined as the maternal quality of the sow. On this basis, aside the nursing behaviour of the sow, her ability to produce a quality colostrum and the ability of each piglet to acquire sufficient colostrum are important factors. The homogeneity of the litter has a genetic component (Knol et al., 2002, Uby et al., 2003). Works on ewes (Pattison and Thomas, 2004) suggest that the ability of the ewe to produce colostrum has some genetic component. Whether the ability of the sow to produce colostrum has also a genetic component is not known. No doubt that selection of sow on her maternal quality taken as a whole and hence on her ability to produce both colostrum and a more homogeneous litter, offers a new and exciting field of research.

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Summary

Maximising piglet survival *by J Le Dividich (INRA, UMR SENAH, 35590, St-Gilles, Fr), Y Le Cozler and D. Causeur (Agrocampus, 65 route de St-Brieuc, 35000 Rennes, Fr)*

The nutritional and immunological importance of colostrum for the survival and development of neonatal pig are reviewed. The pig is born with low body energy stores and devoid of immune protection. Colostrum provides the piglet with both energy and maternal antibodies. Its gross composition is very variable in fat and protein. Colostrum is very digestible and both colostral energy and N are retained with a very high efficiency. Colostrum production by the sow assessed from the weight gain of the litter from birth to 24h of age is very variable (from 1900 to 5300g). There is no clear effect of litter size and parity suggesting that colostrum production is a characteristic of the sow. Within the litter, colostrum consumption of the piglet varies widely. It is independent of birth order, but positively and negatively related to birth weight and litter size, respectively. Other factors, including cold stress, premature birth and birth hypoxia on colostrum consumption, are also examined.

Because of the epitheliochorial nature of the porcine placenta, the new-born piglet must acquire maternal immunoglobulin G from ingested colostrum for passive immune protection until the immune system of the piglet becomes fully developed. Colostrum IgG concentrations vary widely between individual sows both in initial concentration and in the rate at which concentrations decline during the first 24h of life. The piglet can only absorb IgG intact prior to gut closure, which occurs in the first 24 h of life and is induced by intakes of colostrum which are unable to maintain piglet live-weight. As a result the amounts of IgG absorbed intact by the piglet vary widely.

The effects of colostrum consumption on neonatal survival are discussed. Consumption of colostrum in amounts sufficient to meet the energy requirement of the piglet is a major determinant for survival. Since most neonatal losses occur in the first 2 days of life before acquisition of a large amounts of maternal IgG for immune protection becomes important for survival, then piglet IgG concentration does not correlate well with survival but will be important in later resistance to disease challenge.

It is concluded that colostrum production is a good marker for the maternal quality of the sow. Future research should focus on the ability of the sow to produce more colostrum and on the possible delayed effects of passive immunisation on the health and performance of piglet at weaning and later in life.

Key words: Pig, Mortality, Colostrum, Energy, Immunoglobulin

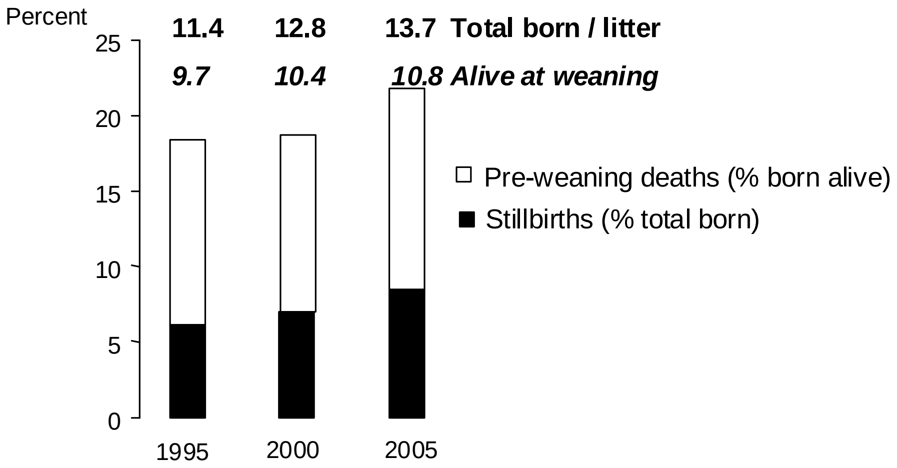

Figure 1. Stillbirths and pre-weaning deaths throughout the past 10 years in France (From ITP database)

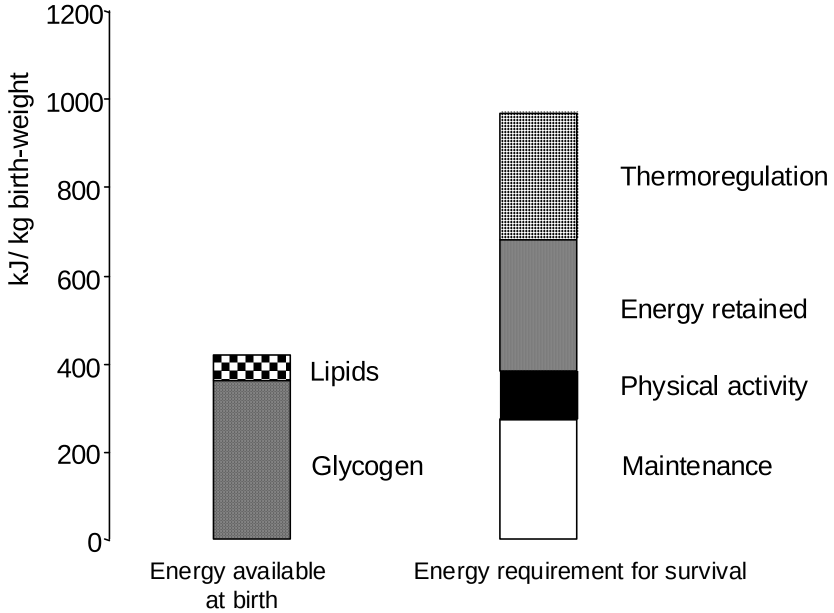

Figure 2 Energy available at birth and energy requirement (birth-24 hours) survival (kJ net energy / kg birth-weight (Le Dividich et al., 2005)

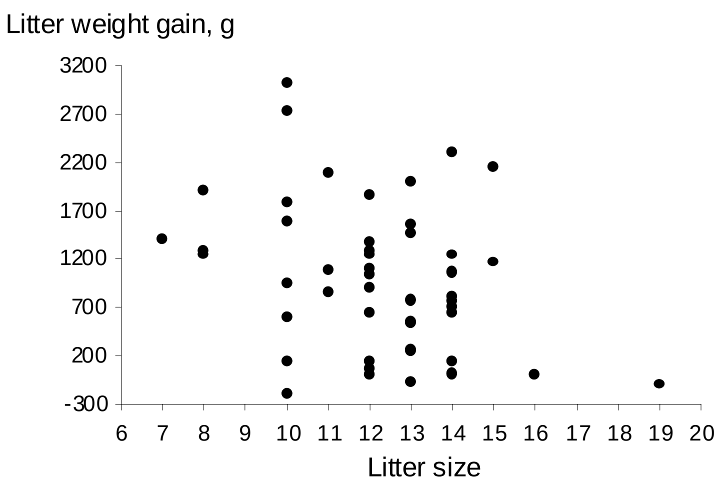

Figure 3. Litter weight gain from birth to 24hours of age in relation to litter size

(From Le Dividich et al., 2005)

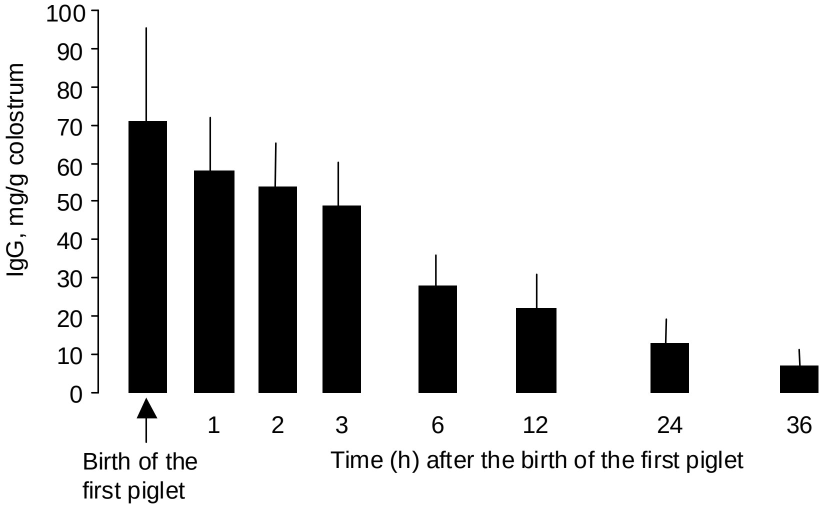

Figure 4. Pattern of IgG concentraion (± sd) of colostrum during the first 36 hours after the first piglet was born (Le Dividich et al., 2004)

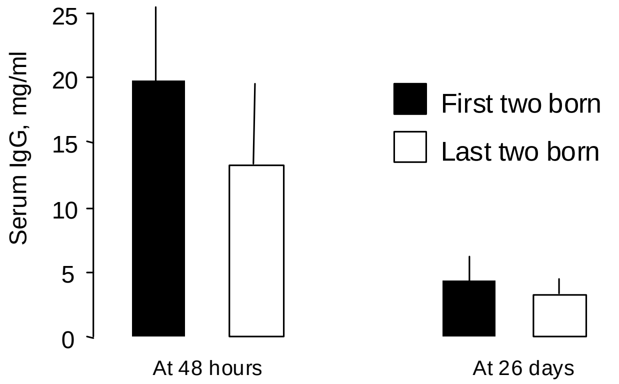

Figure 5. Effects of birth order (first two- *vs* last two born) on serum IgG concentrations in pigs at 48 hours and 26 days of age

Table 1.Some characteristics of piglets surviving to weaning or dying before weaning (data from 35 litters where there was at least one death, mean litter size=13 live born)

	Survivors	Dying
Piglets, n	358	96
Birth weight, g	1484 ±296	1207±387
Birth to 24h weight gain, g	103 ± 104	-29 ± 93
Birth to 24 h gain (g/kg birth-weight)	66 ± 67	-40 ±82
Birth order (quartile)	2.6 ± 1.1	2.3 ±1.1