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Introduction

The importance of the lactation of the sow in pig production is often neglected (Hartmann & Holmes, 1989) since the milk in itself is not the product that the farmer sells. However, sow milk is very important for the supply of nutrients to piglets that will later ensure a profitable meat product. The production and composition of colostrum and milk is essential for the piglets' ability to survive and grow, both during lactation and after weaning (Devillers *et al.*, 2007; Kim & Wu, 2009; Cabrera *et al.*, 2010). A high intake of colostrum is an important factor for piglet survival during the first days of the nursing period (Rooke & Bland, 2002; Farmer & Quesnel, 2009; Theil *et al.*, 2010; Quesnel, 2011). In a trial made by Devillers *et al.* (2007) 82% of the piglets that did not have sufficient colostrum intake died within three days after birth. A newborn piglet lacks a fully developed immune system since they are born immature and since they have never been exposed to antigens (Rooke & Bland, 2002). The structure of the pig placenta does not allow immunoglobulins to pass over from the sow to the fetus (Varley, 1995; Rooke & Bland, 2002). Therefore the newborn piglet depends on colostrum to ingest immunoglobulins. The ingestion is needed in order to be able to obtain passive immunity. A piglet that does not ingest colostrum will consequently not only be more sensitive to infections, but also to starvation and hypothermia. Piglet mortality pre weaning is an important factor in the economical loss in the pig industry (Rooke & Bland, 2002). Jensen & Recén (1989) showed in trials with Swedish Landrace pigs that the length of the nursing period in a semi-natural environment was on average 17.2 weeks. In North America the nursing period was shortened in the 90's from about 21 days to 12-14 days (Cabrera *et al.*, 2010). In most European countries the nursing period is four weeks but in Sweden the nursing period is normally five weeks (Sveriges Grisföretagare, 2009). The aim of this review was to investigate the literature concerning sow colostrum and milk to highlight its importance in pig production.

Literature review

Formation of colostrum and milk

Mammogenesis occurs during prepuberty, puberty and gestation and continues during lactation as long as the teats are suckled (Farmer *et al.*, 2004; Ji *et al.*, 2005; Ji *et al.*, 2006). If the teats are not suckled, involution will occur. This involution is especially rapid if the teats are not suckled during the first seven to ten days of lactation (Kim *et al.*, 2001). Mammogenesis is slow during the first two thirds of gestation and more rapid during the last third (Ji *et al.*, 2006) and is important for the formation of colostrum and milk. According to Ji *et al.* (2006) and Kim & Wu (2009) gilts and primiparous sows with underdeveloped mammary tissue and with a low feed intake fail to obtain sufficient milk production. They need additional nutrients to support mammogenesis, especially due to immaturity at first mating or insemination.

The porcine mammary gland starts to produce colostrum before parturition and this production continues until up to 48 hours after the onset of lactation (Klobasa *et al.*, 1987). As the mammary gland continues to produce, colostrum is gradually replaced by mature milk. This event occurs from around 24 to 36 hours after parturition (Rooke & Bland, 2002). The production of colostrum and milk in sows is performed in the same way as in dairy cows and other mammals. Nutrients from the blood are synthesized by the epithelial cells in the alveoli into milk components and transported into the alveolar lumen where milk is produced. The porcine mammary gland, however, does not contain any cisterns why milk is only stored in the alveoli and milk ducts (Hartmann & Holmes, 1989). As long as the teats are suckled the mammary gland continues to produce milk until weaning, which occurs after around 17 weeks in semi-natural environments (Jensen & Recén, 1989).

Yield of colostrum and milk

It is not possible to regularly milk the sow in the same manner as can be done with dairy cows. This is due to the fact that the porcine mammary gland does not contain cisterns for storage of milk, secreted by the epithelial cells of the alveoli. Due to the lack of cisterns milk removal, from the alveoli and milk ducts, can only be performed after inducing the milk ejection reflex. Stimulation by the piglets, for at least one minute, is necessary to induce the milk ejection reflex in order to obtain a release of oxytocin and milk ejection (Fraser, 1980; Hartmann & Holmes, 1989). Besides this the sow nurses her piglets around 20 times per day for several weeks after parturition and the duration of milk flow is only ten to 20 seconds (Fraser, 1980; Hartmann & Holmes, 1989). The yield of sow colostrum and milk is therefore difficult to measure. However, there are several methods used to estimate yield in sows. The first method is called weigh – suckle – weigh (WSW). This method is performed by weighing the piglets before and after they nurse in order to measure the weight difference. The increase in weight should correspond to the intake of milk. However, this method can cause stress, as the piglets must be separated from their mother, which can lead to a decreased milk intake. Another aspect is that defecation, urination, metabolic processes and salivation must be considered, since the piglet also looses weight due to these factors. The second method is called the isotope dilution technique. This method aims to measure the rate of total water turnover in the piglets. The difficulty of this method is that it must be ensured that the piglets does not eat or drink anything other than sow milk (Pettigrew *et al.*, 1985; Theil *et al.*, 2002). According to Theil *et al.* (2002) the WSW method resulted in 12.7 % lower milk yield than the dilution method, which indicates that WSW underestimates the sows' milk yield. A third method is based on weight gain of piglets. The piglets are weighed at birth and again at another age, for example 24 h after birth (to estimate colostrum yield) or three weeks after birth (to estimate milk yield). A feed conversion ratio is thereafter used in order to recalculate the weight gain into milk yield (Devillers *et al*, 2004; Devillers *et al.*, 2007; Bergsma *et al.*, 2008; Aguinaga *et al.*, 2011).

Colostrum yield varies a lot between sows (Farmer & Quesnel, 2009; Quesnel, 2011). In a study performed on Landrace x Large White sows the average colostrum yield was 3.67 ± 0.14 kg during the first 24 hours after parturition, ranging from 1.91 kg to 5.31 kg (Devillers *et al.*, 2007). The colostrum yield is not affected by litter size but can be affected by parity number, the weight of the sow at parturition, the time of farrowing, sow health, sow nutrition and by the genotype of the sow (Klobasa *et al.*, 1987; Le Dividich *et al.*, 2005; Devillers *et al.*, 2007; Farmer & Quesnel, 2009). The mean piglet birth weight and litter weight variation is also related to colostrum yield. Piglets with a higher birth weight are more efficient in the prestimulation of the udder and thus, a heavier litter results in increased colostrum yield (Devillers *et al.*, 2007).

Sows of Danish Landrace x Yorkshire had, in a trial by Theil *et al.* (2002), where the WSW-method was used, an average milk yield of 8.65 ± 0.81 kg/day, ranging from 4.60 kg/day to 9.60 kg/day. However, when the Isotope dilution technique was used in the same trial, the average yield was 9.91 ± 0.69 kg/day throughout lactation. In another trial by Aguinaga *et al.* (2011) the Iberian sow had an average yield of 5.18 ± 0.16 kg daily between day zero and 34 after parturition. This indicates that there may be differences in milk yield between breeds, but these differences could also be due to differences in experimental techniques. The porcine mammary gland is limited in size and only contains between 20-30 g of milk at its maximum, even during peak lactation (Kim *et al*., 1999). The milk yield is, in contrary to colostrum yield, affected by litter size (Auldist *et al*., 1998). The Iberian sow reaches peak lactation on day 12 after parturition and the yield will thereafter decrease (Aguinaga *et al*., 2011). The results of Aguinaga *et al*. (2011) correspond to results from Theil *et al*. (2002) where experiments were performed on Danish Landrace x Yorkshire sows. These results showed that milk intake of piglets was higher in week two and three than in week one of lactation.

Composition of colostrum and milk

Colostrum varies a lot in composition between individuals (Le Dividich *et al.*, 2005; Quesnel, 2011). Results from trials by Aguinaga *et al.* (2011), performed on Iberian sows, and Klobasa *et al.* (1987), performed on German Landrace, are shown in Table 1. These results correspond to the results reviewed by Le Dividich *et al.* (2005). The composition of sow milk from the same trials is shown in Table 2. The total output of milk nutrients changes throughout lactation (Aguinaga *et al.*, 2011) even though the general composition can be considered constant (Theil *et al.*, 2002).

Table 1. The composition of sow colostrum according to two different trials

	GE (MJ/kg)	**DM (%)**	**CP (%)**	**Whey protein (% of CP)**	**Fat (%)**	**Lactose (%)**	**Ash (%)**
Aguinaga *et al.*, 2011	5.77	22.6	15.8		3.76	2.34	0.635
Klobasa *et al.*, 1987		24.0	11.2	10.5	5.00	3.20	

Table 2. The composition of sow milk according to two different trials. The milk yield was measured until day 34 (Aguinaga *et al.*, 2011) and 42 (Klobasa *et al.*, 1987) of lactation

	GE (MJ/kg)	**DM (%)**	**CP (%)**	**Whey protein (% of CP)**	**Fat (%)**	**Lactose (%)**	**Ash (%)**
Aguinaga *et al.*, 2011	4.63	17.9	5.34		5.85	5.69	1.04
Klobasa *et al.*, 1987		18.0	5.70	3.00	6.50	5.80	

Colostrum has a higher DM, a higher content of CP and a higher content of whey protein than milk, but lower levels of lactose, fat and caseins (Klobasa *et al.*, 1987; Le Dividich *et al.*, 2005). The high DM and protein content in colostrum is due to the presence of immunoglobulins, such as immunoglobulin G (IgG), immunoglobulin A (IgA) and immunoglobulin M (IgM), and albumins (Klobasa *et al.*, 1987). However, immunoglobulins are also present in milk but in lower concentrations. In colostrum IgG accounts for most of the protein content whereas in milk IgA is more common (Klobasa *et al.*, 1987; Rooke & Bland 2002). There is a positive correlation between yield and protein content in colostrum. There is also a positive correlation between yield and IgG content in colostrum. This means that when the yield increases the protein content and IgG content also increases (Devillers *et al.*, 2007). Protein is an important factor in colostrum as well as in milk. Especially arginine deficiency in milk is a limiting factor for piglet growth (Kim & Wu, 2009). The sow prioritizes protein content in colostrum and milk if the protein content in the feed is scarce, by metabolizing body reserves, which indicates that protein is extremely important to the piglets (King *et al.*, 1996). The amount of essential amino acids in sow milk is 1.2 g/day at day five of lactation and 7.0 g/day at day 21 (Kim *et al.*, 1999). The fat in colostrum and milk mostly consists of long chain fatty acids (Le Dividich *et al.*, 2005) and can be affected by the composition of the feed during gestation and lactation (Seerley *et al.*, 1978a; Seerley *et al.*, 1978b; Pettigrew, 1981; Coffey *et al.*, 1987; Rooke *et al.*, 2001; Farmer & Quesnel, 2009; Laws *et al.*, 2009). The lactose content in colostrum is lower than in milk and nearly doubles during the first 14 days of lactation. Since lactose is osmotic and drives water into the alveoli, this affects the milk yield. Milk yield is therefore higher than colostrum yield (Klobasa *et al.*, 1987; Hartmann & Holmes, 1989).

The effects of yield and composition on piglet health and growth
Piglets start suckling within 20-30 minutes after birth (Le Dividich *et al*., 2005). Several factors, such as birth weight, birth order and litter size, affects the colostrum intake (Le Dividich *et al*., 2005; Devillers *et al*., 2007). Piglets with a higher birth weight are more competitive at the udder and can therefore ingest a higher amount of colostrum than piglets with a lower birth weight (Le Dividich *et al*., 2005). Due to their high birth weight, size and motility these piglets are able to defend their selected teat (Hartsock & Graves, 1976; Rooke & Bland, 2002). The piglets that are born first will have an advantage against piglets that are born later and will therefore often choose teats that tend to have a higher milk production. The cause of this is however unclear as it could either be due to that these teats have a higher blood flow or due to the fact that viable piglets, that can affect the production, choose them for some other reason. The heavier piglets will therefore drink some of the colostrum meant for other littermates why the intake varies within litter, especially if the duration of the parturition is extended (Hartsock & Graves, 1976; Le Dividich & Noblet, 1981; Rooke & Bland, 2002). In a trial by Hemsworth *et al*. (1976) it was observed that each piglet suckled on average seven teats during the first four hours after birth. Larger litters result in greater competition between piglets in the struggle to reach the udder. Individual piglets from larger litters therefore have less availability to colostrum and milk. The average piglet birth weight and litter size is negatively correlated. Thus, if the litter size increases the individual piglet birth weight decreases and vice versa. For every extra piglet in the litter the average individual birth weight of the piglets will decrease with 25 g (Devillers *et al*., 2007). According to Le Dividich *et al*. (2005) the available colostrum per piglet decreases with an average of 22-42 g/day if the litter increases with one piglet. Due to successful breeding programs the litters have become larger (Johnson *et al*., 1999). Unfortunately this has also lead to higher mortality of the piglets due to the decrease in availability of colostrum and milk (Hartsock & Graves, 1976; Johnson *et al*., 1999). Piglet mortality is, as mentioned, a great loss to the pig industry (Rooke & Bland, 2002). Cabrera *et al*. (2010) showed that the longer the nursing period is, the better the piglets perform. In this study performance was defined as average daily weight gain, fat depth and viability (including mortality and illness).

Piglets obtain passive immunity via immunoglobulins in colostrum, where IgG is predominant, by ingestion via the gastrointestinal tract until they have their own active immune system. The immune system is considered active when the piglet itself can produce antibodies against antigens. Immunoglobulins can pass from the gastrointestinal tract into the blood until gut closure, an event that occurs from between 24-36 hours after birth. Immunoglobulins are also present in milk, where IgA is predominant. However, after gut closure the purpose is rather to aid the immune system (Rooke & Bland, 2002). The immunoglobulins are however specific to the antigens that the sow has been exposed to, why they cannot protect the piglet from new antigens (Rooke & Bland 2002; Stalder *et al*., 2004). The age of the sow has thus an impact on the immune competence of her piglets (Cabrera *et al*., 2010).

The average daily intake of milk of Iberian piglets was 863 g/day in a trial with a five-week lactation (Aguinaga *et al*., 2011). The piglets in this trial grew on average 168 ± 3 g/day during the first 34 days of lactation. The average daily weight gain of piglets of Danish Landrace x Yorkshire, were in another trial 166 g week one, 211 g week two and 204 g week three (Theil *et al*., 2002). During the last week of lactation milk conversion rations are quite low which means that the piglets gain less from milk in the end of lactation (Aguinaga *et al*., 2011).

Factors affecting milk production

Colostrogenesis, colostrum yield and colostrum composition is affected by the genotype of the sow (Farmer & Quesnel, 2009). This is also true for milk. According to Bergsma *et al*. (2008) the heritability for milk yield of sows could be compared to the heritability for milk yield of dairy cattle, which according to Veerkamp (1998) is estimated to 0.32. Modern sows are more productive than earlier. Increased productivity means, among other things, that the litters are larger. Larger litters are due to successful breeding. However, this also puts pressure on the sow, since she must supply her piglets with sufficient nutrition for their survival and growth. Larger litters therefore increase the risk of more severe negative energy balance during lactation (Bergsma *et al*., 2008). Increasing the amount of feed can cure negative energy balance. However, this might not be that simple since some sows fail to eat as much as they would need to, in order to support their high milk production. It has been suggested that the solution to this problem is to increase the lactation efficiency genetically. This could for example mean that the mobilizability of body tissues could be increased (Bergsma *et al*., 2008). Bergsma *et al*. (2008) therefore arguments that lactation efficiency should be included in breeding programs for sows.

Different feeding strategies can affect the yield and composition of colostrum and milk (Elliot *et al*., 1971; Seerley *et al*., 1978a; Seerley *et al*., 1978b; Pettigrew, 1981; Coffey *et al*., 1987; Revell *et al*., 1998; Rooke *et al*., 2001; Farmer & Quesnel, 2009; Laws *et al*., 2009). Fat content in colostrum and milk is the easiest parameter to affect by the feed (Farmer & Quesnel, 2009). Other factors such as sow management and health can affect yield and composition. Colostrogenesis, colostrum yield and composition can, for example, be affected by parity number and the endocrine status of the sow (Farmer & Quesnel, 2009).

Conclusions

Research clearly shows the importance of sow colostrum and milk, for survival, growth, development and immune status of piglets. Survival and growth of piglets is the main purpose of pig production and it is affected by both milk yield and milk composition. Sow feed intake affects the composition and yield of colostrum and milk. However, other factors such as genetics, management and welfare can also have an impact. Successful breeding has led to a large increase in the number of born piglets per litter, which is beneficial for the farmer. A side effect, on the other hand, has been an increase in the piglet mortality, especially when the nursing period is shortened. Due to this a lot of research has been done in order to minimize piglet mortality and thus increase the profitability of the farmer. However, it was beyond the scope of this review to cover all the literature concerning this research. To focus on the piglet is important since the piglet is the purpose of the production. However, increased knowledge about the sow and sow lactation would most likely add to the overall understanding of piglet survival and growth.

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