7. Transition feeding of sows

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Abstract

The transition period from late gestation to early lactation is rather short, but it is nonetheless of major importance for the productivity of high-prolific sows. The transition period, here defined as the last 10 d of gestation and the first 10 d of lactation, encompasses substantial changes for the sow. More specifically, fetal growth, mammary growth, colostrum production and sow maintenance require substantial amounts of nutrients during late gestation. After parturition, nutrients are mainly required for milk synthesis and sow maintenance, but the regressing uterus supplies considerable amounts of amino acids to the blood. The physiology of the sow ensures that nutrient transfer to the offspring is not being compromised and that nutrients are preferentially being allocated to uterine tissues before parturition and to the udder after parturition. During the transition period, the sow becomes catabolic due to the high priority of milk production and to current feeding practices. Indeed, feed is changed from a gestation to a lactation diet for most sows and the feed supply typically goes from a restricted supply to an *ad libitum* allowance. In addition, transition sows are often exposed to shifts in housing, and in Europe, this shift is now associated with a change from loose group housing to individual housing. Around parturition, colostrum is being secreted and milk synthesis is initiated in the mammary glands. After the onset of lactation, milk composition changes, especially during the first few days of lactation, and milk yield increases throughout the transition period and becomes the most important determinant of nutrient requirements. Thus, nutrient requirements of transition sows are affected by many intrinsic factors and these requirements change rapidly, yet, sow feeding practices do not acknowledge these changes. Development of new feeding strategies specifically adapted for the transition sow is likely of importance to match the rapid changes in nutrient requirements.

Keywords: colostrum synthesis, mammary secreta, nutrient requirement, periparturient sow, protein

7.1 Introduction

In the past, it was common to feed sows with one diet throughout gestation and lactation, and this may still be the prevalent feeding practice in some countries where protein sources are rather cheap and livestock density low. However, most sows nowadays are fed a diet low in energy and protein throughout most of (or during the entire) gestation, and are shifted to a lactation diet high in energy and protein at some point during the

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transition period. The transition period, here defined as the last 10 d of gestation and the first 10 d of lactation, encompasses substantial changes for the sow.

Sows entering the transition period are subjected to quite different feeding regimens. Indeed, farmers, advisers and feed specialists have developed various feeding regimens merely based on trial and error rather than on scientific knowledge. Ideally, the feeding of sows during the transition period should be adapted to each individual while considering the physiological stage (i.e. day of gestation or day of lactation), live weight and level of productivity (e.g. milk yield) in order to meet the requirements for nutrients. In practice, however, feeding sows seems to focus much more on minimization of manpower and elimination of possible mistakes than maximizing sow productivity and, in most countries, sow feeding pays no attention to factors such as parity or live weight of sows, reproductive stage and productivity level.

The nutrient requirements of energy, protein and essential amino acids change rapidly during transition. However, on most farms the feeding system is only capable of supplying a single diet to each pen, and therefore the shift from a gestation diet to a lactation diet most often coincides with transfer of the sow to the farrowing unit shortly before parturition. The nutrient contents of gestation and lactation diets therefore need to compromise between what is optimal for fetal growth, mammary growth, colostrum production, milk production, sow maintenance and sow body gain/body mobilisation. This chapter will focus on the discrepancy between the simplicity of practical sow feeding and the complexity of sow physiology and on the rapid changes in nutrients required to ensure optimal sow performance. This chapter will reveal which traits are important to consider when feeding transition sows, it will give an overview on how hyperprolific sows are fed today and how they should be fed optimally based on calculated requirements of energy, lysine and nitrogen using a factorial approach.

7.2 The importance of the transition period

In spite of its short duration, the transition period is very important, mainly because the number of weaned piglets is a major determining factor for the productivity of sows and most losses of piglets occur in the first 3 d after parturition (Rootwelt *et al.*, 2013). During the transition period important biological events take place, and many physiological processes related with reproductive output are markedly altered. Many of these traits are (or may potentially be) affected by sow nutrition. In the following paragraphs, the most important traits are described along with the known or expected impact of feeding.

7.2.1 Neonatal piglet mortality and neonatal energy supply

Neonatal piglet mortality includes both the losses of piglets before and during the farrowing process (stillborn piglets) and mortality of liveborn piglets. Both losses are complex issues because multiple factors are involved in their underlying causes. Stillborn piglets are associated at least partly with the farrowing process (Oliviero *et al.*, 2010). On the other hand, the major loss of liveborn piglets occurs during the first 3 d postpartum (Rootwelt *et al.*, 2013) and neonatal mortality can, to a great extent, be explained by insufficient energy supply (Quesnel *et al.*, 2012, Theil *et al.*, 2014a), although piglet health and lack of immunity may also play a role (Pedersen *et al.*, 2010). Immediately after birth, the newborn piglets rely upon oxidation of glycogen from the liver and muscle depots and oxidation of nutrients from ingested colostrum as sources of energy. Shortly after the colostrum period ends milk starts to be produced in copious amounts (Hartmann *et al.*, 1984a) and this occurs during the 2nd d of lactation. However, the time from birth of the 1st born piglet to onset of lactation varies between sows from 23 to 39 h (Vadmand *et al.*, unpublished data). This difference in the timing of the onset of milk yield has a tremendous consequence for the neonatal piglets because the energy intake drops when sow colostrum becomes scarcely available after 15 h postpartum (Theil *et al.*, 2014a), and at the same time the piglets are extremely vulnerable to dying of hunger (Baxter *et al.*, 2013; Quesnel *et al.*, 2012). Jean and Chiang (1999) reported that piglets weighing less than 1,100 g at birth had a survival rate of 48% until d 3 when sows were supplemented with 10% soybean oil, whereas the survival increased to 80% and 98% if sows were supplemented with 10% coconut oil and medium chain fatty acids, respectively. Neonatal piglet mortality is a complex issue which is covered in details in Chapter 11 (Edwards and Baxter, 2015). This chapter will focus solely on the underlying biological traits of neonatal pig mortality and describe how sow nutrition may affect these. The underlying biological traits include fetal growth, litter size, glycogen depots, growth of placenta and uterine tissues, mammary growth, farrowing process, colostrum synthesis, time of onset of lactation, milk synthesis, production-related diseases, sow heat production, physiological adaptations, body condition, and body mobilization. Many of these traits are covered in more details elsewhere in this book but will be dealt here only as they relate to sow nutrition during the transition period.

7.2.2 Fetal growth, piglet birth weight and litter size

Fetal growth increases exponentially throughout gestation and is predominant during the last 10 d before parturition. Indeed, almost one third of fetal weight gain occurs during this short period (Noblet *et al.*, 1985). Fetal growth (and the resulting birth weight) is important for piglet survival and growth performance both during the suckling period and after weaning (Akdag *et al.*, 2009; Cabrera *et al.*, 2012). In terms of sow nutrition, the high fetal growth rate increases the protein and amino acid requirements in late gestation. Normally, nutrients are prioritized for the offspring (Theil *et al.*, 2012) and if maternal feed supply is inadequate, or if feed composition is not optimal for the late-pregnant sow, the body pools of fat and protein will be mobilized to ensure growth of fetuses and other reproductive tissues. In line with that, increased feed intake or increased energy supply to sows in late gestation has normally no or only a marginal effect on piglet birth weight (Campos *et al.*, 2012). However, L-carnitine seems to be able to stimulate fetal growth during gestation and its mode of action is believed to be through increased placental growth leading to greater nutrient transfer to the piglets (Eder, 2009). The recent genetic improvement of litter size giving rise to our modern hyperprolific sow lines (Baxter *et al.*, 2013; Pedersen *et al.*, 2010) has increased the maternal investment of nutrients allocated to fetal growth and growth of other reproductive tissues (Andersen *et al.*, 2011), even though the increased litter size may have reduced the mean piglet birth weight. From a nutritional point of view, the actual litter size should ideally be taken into account to allow a more optimal nutrient supply to the sow during the transition period. However, from a practical point of view this is not possible because the litter size is unknown prior to parturition. After parturition, litters are typically equalized on d 1 or 2 of lactation, thereby correcting the variation for this biological trait.

7.2.3 Glycogen depots in newborn piglets

Newborn piglets are highly vulnerable to dying from insufficient energy supply (Theil *et al.*, 2014a). During the colostrum period, neonatal piglets oxidize substantial amounts of glycogen from the liver and muscles (Pastorelli *et al.*, 2009; Theil *et al.*, 2011) in order to cope with the low ambient temperature in the extra-uterine environment and with their very large heat loss due to a high surface to volume ratio of the body. Glycogen is retained in fetuses during late gestation (not only during the last 10 d) and the main purpose of these depots is indeed to supply neonatal piglets with energy. Genetic selection for increased piglet survival seems to have increased glycogen retention in liver and muscle tissues during fetal life (Leenhouwers *et al.*, 2002). Glycogen retained in a litter of 17 newborn piglets totals roughly 1 kg (Theil *et al.*, 2011), and this amount is roughly equivalent to the starch content of 2 kg of standard sow gestation feed. Since glycogen depots are built-up during the last 2 to 4 wk prior to parturition (Père, 2003) and sow gestation diets are very rich in starch, the glycogen depots in newborn piglets may not need to be considered from a quantitative nutritional point of view. However, from a welfare and economical point of view, it is indeed of interest to study whether the glycogen depots can be improved by altered sow nutrition. Seerley *et al.* (1974) reported a greater concentration of glycogen in the liver of newborn piglets when sows were fed additional energy from cornstarch beginning on d 109 of gestation. According to Jean and Chiang (1999), hepatic glycogen content of piglets 4 h after birth was greater if their dam was fed either 10% medium chain fatty acids or 10% coconut oil from d 84 of gestation until farrowing, as compared with sows fed soybean oil. However, Boyd *et al.* (1978) reported no beneficial effect on liver glycogen concentration in newborn piglets when sows were fed additional energy from either cornstarch or tallow from d 100 of gestation until farrowing. Likewise, Newcomb *et al.* (1991) found no effects of feeding sows with starch, soybean oil, or medium-chain triglycerides for the last 14 d of gestation on hepatic glycogen of newborn piglets.

7.2.4 Placenta, uterus, fluids and membranes

The placenta and uterus also grow in an exponential fashion in late pregnancy, hence, the retention of nutrients is high during the last 10 d of gestation. In Contrast, the volume of amniotic fluid peaks around d 80 of gestation (Noblet *et al.*, 1985) and membranes grow quite slowly so these traits require negligible amounts of nutrients during late gestation. The amount of energy required for growth of the placenta and uterus (lean growth) is also rather low and may be neglected, but the amounts of amino acids required for their lean growth are substantial (Noblet *et al.*, 1985). During the farrowing process, placenta, fluids and membranes are expelled from the sow and, consequently, nutrients retained in these reproductive tissues are lost from the sow body. The uterus, in contrast, regresses during the first week after farrowing, which causes release of nutrients that may be utilized for milk production. The amount of energy supplied from the regressing uterus to the sow circulation is of minor importance and can be neglected, but substantial amounts of protein and essential amino acids are released to the blood and should ideally be accounted for when feeding transition sows. It is not known whether sow feeding affects growth and regression of placental and uterine tissues, but it is likely that the nutritional impact is rather low because these traits are associated with offspring survival, which is highly prioritized.

7.2.5 Mammary growth

Substantial mammary growth occurs in the last third of gestation, but 10 d before parturition mammary development is still quite small. The pattern of growth rate of mammary glands during late gestation is not known in details, but without doubt the growth rate is accelerated during the last 10 d of gestation based on visual evaluation of udder development of late gestating sows. The mammary glands continue to grow until approximately d 10 of lactation (Kim *et al.*, 1999a), but their growth rate after parturition is slower than before parturition (Noblet *et al.*, 1985) and this impacts the nutrient requirements. Moreover, if mammary glands for some reasons are not suckled after parturition, these glands will regress during the first week after parturition (Kim *et al.*, 2001; Theil *et al.*, 2006) and, consequently, substantial amounts of amino acids and minor amounts of energy will be recirculated to the blood. In modern high-prolific sows, however, the number of non-suckled mammary glands is low due to the large number of suckling piglets and mobilization of amino acids from regressing mammary glands can be overlooked. From a productivity point of view, it would indeed be interesting to know whether mammary gland growth can be enhanced by nutritional means. This aspect is covered in Chapter 4 (Farmer and Hurley, 2015), but it is evident that there is a lack of information on the impact of feeding during the transition period on mammary development in sows.

7.2.6 Farrowing process: duration, birth intervals, stillbirth rate and piglet vitality

Optimal sow feeding to reduce farrowing length, stillbirth rate or to improve piglet vitality at birth has not received a lot of scientific attention. Expectedly, feeding during the last few days before parturition is important for the farrowing process and, therefore, altered nutrition may be a way of increasing sow productivity, for instance via a reduction in stillbirth rate. Data from 5 Danish studies carried out at Research Centre Foulum from 2007 to 2013 revealed that the mean duration of 126 farrowings was 343±15 min (Vadmand *et al.*, unpublished data). On an individual basis, the farrowing length varied from 87 to 935 min, which means that the fastest sow spent only 1.5 h farrowing, whereas the slowest one spent 15.5 h. All sows gave birth to more than 10 piglets and on average 16.1 piglets were born alive while 1.1 piglets per litter were stillborn. Farrowing length was not associated with the total number of piglets born, but it was greater for sows with stillborn piglets (Figure 7.1). However, it is not clear whether the presence of

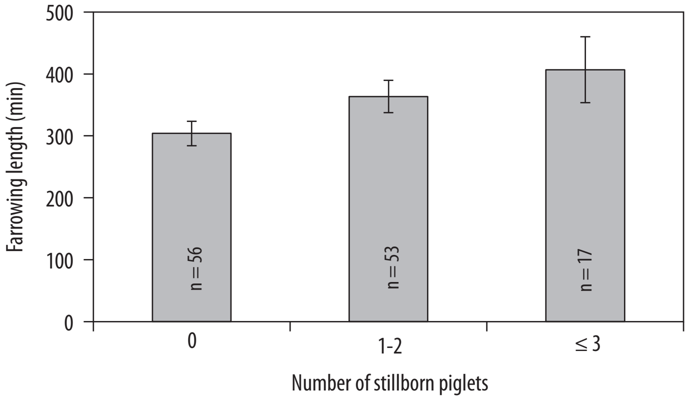

Figure 7.1. Farrowing length of sows giving birth to 0, 1-2 or 3 or more stillborn piglets.

stillborn piglets increases farrowing length or whether a prolonged farrowing increases the frequency of stillborn piglets. The birth interval in the above-mentioned study was on average 20±1 min, but on an individual basis the fastest sow gave birth to a piglet every 7^{th} min, whereas the slowest sow gave birth to a piglet every 52^{nd} min.

Feeding may play a role for the farrowing process in several ways. Inclusion of fiber in the diet prior to parturition may alleviate constipation, which could otherwise act as a physical barrier when fetuses are expelled through the birth canal. The impact of feeding strategies on peripartum constipation is covered in Chapter 10 (Peltoniemi and Oliviero, 2015). Oliviero *et al.* (2010) found that a low constipation index was associated with shorter farrowings. Another beneficial effect of dietary fiber is a greater and prolonged uptake of energy from the gastrointestinal tract (Serena *et al.*, 2009). Indeed, sows fed substantial amounts of fiber absorb energy from the gastrointestinal tract even 24 h after the last meal, and this may be of particular importance for sows during farrowing because their feed intake may be lowered prior to and during farrowing. Excessive obesity at parturition is also associated with prolonged farrowing (Oliviero *et al.*, 2010) and this indicates that the nutritional status of the sow in the transition period may play a role for the farrowing process. Supply of dietary minerals may also be of importance, and calcium is indeed known to be essential for muscle contraction. Proper calcium status for sows at parturition may be required for proper contractions of muscles surrounding the uterus, which are responsible for transporting fetuses forward and expelling them through the birth canal. Reduction of the stillbirth rate by means of optimal zinc supply during late gestation has recently been shown by Vallet *et al.* (2014), although the mode of action of Zinc is currently unknown. Complications during the farrowing process may lead to an increased rate of stillbirths and reduction of stillbirth rate by nutritional means definitely deserves further attention. Coffey *et al.* (1987) reported that addition of 10% fat to the diet of late pregnant sows reduced the rate of stillbirths, but it should be emphasized that their conclusion was based on only 8 sows per dietary treatment, which is a very low number when studying stillbirth rate. Another positive effect of sow nutrition around parturition could potentially be enhanced piglet vitality, although that is more likely to improve survival of liveborn piglets rather than reducing stillbirth rate (Baxter *et al.*, 2008).

7.2.7 Colostrum synthesis

Sows start to synthesize colostrum prior to parturition, although it is not known exactly when this occurs. The first known colostrum component (β-lactoglobulin) was detected in sow plasma around d 80 of gestation (Dodd *et al.*, 1994), whereas α-lactalbumin (a part of the enzyme complex that catalyses lactose synthesis) increases in sow plasma during the last week of gestation. In line with that, Hartmann *et al.* (1984b) reported that the lactose content of sow plasma increased considerably starting 4 d before parturition, and these studies indicate that colostral lactose is produced mainly during these last days of gestation. In contrast, it is not known when colostral fat is produced or when immunoglobulins and growth factors are being synthesized. From a nutritional point of view, the production of lactose and the amount of energy secreted via colostrum are not a major maternal investment, but in terms of protein and amino acids, colostrum production is clearly a major investment. It was recently found that colostrum yield is on average 30% higher than previously reported (Theil *et al.*, 2014b) and, consequently, the maternal investment in terms of protein and amino acids is even greater than previously believed. The colostrum yield of sows was reported to be on average 5.9±0.1 kg (n=126 sows), but on an individual basis it ranged from 2.7 to 8.5 kg (Theil *et al.*, 2014b; Vadmand *et al.*, unpublished data). It is currently believed that the majority of colostrogenesis occurs during the last 7 to 10 d of gestation (Theil *et al.*, 2014a). However, colostrum may potentially also be produced after the onset of farrowing when colostrum is removed by the piglets. Sow nutrition in late gestation affects the colostrum yield of sows, and further details on the impact of feed composition on colostrum yield can be found in Chapter 8 (Quesnel *et al.*, 2015) and in a recent review (Theil *et al.*, 2014a). It is important to stress that colostrum production does not seem to have a great impact on the energy requirement by the sow because it is produced over many days, whereas the impact of colostrum yield on maternal protein and amino acid balances (discussed later) is much larger. Besides the amount of colostrum produced, colostrum quality may also be of importance for the piglets, and hence sow productivity, because the total transfer of nutrients and bioactive components via colostrum is determined both by the volume and the composition of colostrum. Colostrum contains lactose and fat which are important for supplying energy to the neonate. In addition, colostrum is very rich in proteins mainly due to high concentrations of immunoglobulins, but growth factors are also present (Hurley and Theil, 2011). For a more detailed description of colostrum composition please see Chapter 9 (Hurley, 2015). Sow nutrition may increase the concentration of fat or potentially change the concentrations of immunoglobulins and growth factors, whereas it is not likely that sow nutrition may alter the lactose concentration because lactose draws water into the alveolar lumen via osmosis. The impact of sow nutrition on colostrum quantity has been described in details in Chapter 8 (Quesnel *et al.*, 2015). From a nutritional point of view, the yield of colostrum is more important than its composition because colostrum yield may vary 3-fold between individual sows whereas colostral protein concentration varies to a much lesser extent (Theil *et al.*, 2014b; Vadmand *et al.*, unpublished data).

7.2.8 Time of the onset of lactation

During the first 48 h after parturition, the amount of mammary secreta (colostrum and milk) changes considerably. During the initial 12 to 15 h after birth of the 1st piglet colostrum is abundantly available, but subsequently the amount of secreted colostrum drops (Krogh *et al.*, 2012; Krogh *et al.*, unpublished data). The amount of mammary secreta is then low until the onset of copious milk production, which on average occurs 33 to 34 h after birth of the 1st piglet (Krogh *et al.*, 2012). It is unclear why colostrum becomes scarcely available after 15 h, but it is likely linked to a drop in oxytocin concentration in sow plasma when farrowing ceases. Interestingly, we have found that onset of lactation may happen as early as 23 h postpartum in some sows or as late as 39 h in other sows. Currently, we can only speculate on what causes this variation among sows. We have tested whether time for onset of lactation may be linked to feed composition or feed intake of sows in the transition period, body weight or backfat thickness of sows at parturition, farrowing length or litter size during the colostrum period, but none of these characteristics could explain the individual differences observed (Vadmand *et al.*, unpublished data). Thus, the reason for the difference in the timing of lactation onset between sows remains to be elucidated. It may be linked to when the litter establishes a teat preference and, in a concerted action, successfully massages the udder and induces milk letdown. Interestingly though, an early onset of lactation was associated with higher milk yields in weeks 1, 2, 3 and 4 of lactation (Vadmand *et al.*, unpublished data). The onset of lactation has a great impact on sow physiology because the energy and protein balances drop abruptly once milk production is initiated (Hansen *et al.*, 2012b, 2014).

7.2.9 Milk synthesis

Milk production is a major investment for the lactating sow, and at peak lactation half the amounts of nitrogen (52%) and energy (50%) from the feed are transferred to the piglets via milk (Theil *et al.*, 2004). Consequently, synthesis of milk is the reproductive trait which has the greatest impact on the daily sow nutrient requirements. The nutrient requirements for milk synthesis depend on both the yield and composition of milk, and both traits are affected by the stage of lactation (Theil *et al.*, 2002, 2004; Hansen *et al.*, 2012b), however, without doubt milk yield has the greatest impact on the nutrient requirements.

The sow lactation curve was recently described using a mathematical model (Hansen *et al.*, 2012b). The developed mathematical model predicts milk yield based on the litter weight gain and litter size, and with these simple inputs, milk yield can be estimated for each day of lactation. The mathematical model takes into account all published data on milk yield from 1980 to 2012, where sow milk yield has been measured at least twice during the lactation period. The lactation curve is characterized by an increase in milk yield from the onset of lactation (milk yield of approximately 5.7 kg at d 2) to the end of the transition period (d 10 of lactation) when it averages 11-14 kg/d. After the transition period, milk yield peaks at around d 17 to 19, depending on the litter size and litter weight gain (Hansen *et al.*, 2012b), and the best performing sows produce 15 to 17 kg/d. As a consequence of the secretory activity of the mammary glands, the mammary plasma flow increases from approximately 3,500 l/d 10 d before parturition to 6,000 l/d 3 d postpartum and to 9,500 l/d at d 17 of lactation (Krogh *et al.*, unpublished). The various factors affecting sow milk yield are covered in Chapter 8 (Quesnel *et al.*, 2015).

Macrochemically, sow milk is composed of lactose, fat, protein, minerals, vitamins and water (Theil *et al.*, 2012). For a more detailed description of milk constituents, see Chapter 9 (Hurley, 2015). Right after the onset of lactation, milk composition changes quite fast, although not as fast as during the colostrum period (Jackson *et al.*, 1995). Studies from Klobasa *et al.* (1987) and Csapo *et al.* (1996) demonstrated that changes in milk composition occur during the transition period, whereas the composition of sow milk is constant after d 10 of lactation. This is in line with the mathematical model developed by Hansen *et al.* (2012b). The increased content of milk fat in the transition period, either in response to stage of lactation or to dietary fat supplementation (Lauridsen and Danielsen, 2004), is coupled with a similar increase in the dry matter fraction. In contrast, the lactose concentration is rather constant at 5 to 6% because lactose draws water into milk. The protein concentration is slightly higher (6.0 to 6.5%) at d 2 to 4 of lactation whereas it is rather constant at 5.5% thereafter (Klobasa *et al.*, 1987). Concomitantly with the drop in milk protein at d 5, the relative concentrations of amino acids change (gram of amino acid per 100 g protein; Csapo *et al.*, 1996). Some amino acids become more abundant after d 5 (glutamic acid, proline, isoleucine, and lysine), some become less abundant (threonine, serine, glycine, alanine, cysteine, valine, methionine, leucine, and phenylalanine) and yet others are constant when expressed relative to milk protein (aspartic acid, tyrosine, histidine, tryptophan, and arginine).

7.2.10 Production-related diseases in the transition period

A healthy sow around the time of parturition is important for the overall sow productivity and piglet performance after birth, but the incidence of diseases seems to increase around parturition (Blaney *et al.*, 2000; Oliviero *et al.*, 2010). The causes for this are unknown, but it may be speculated that the general immunity of the sow is affected, for example, by the loss of immunoglobulins to the colostrum production which makes the sow extra vulnerable to risk factors associated with diseases close to parturition. Diseases related to the farrowing process cover a wide range of disorders and mastitis and the postpartum dysgalactia syndrome [PPDS; defined as inadequate and insufficient colostrum and milk production in sows up to 72 h after birth of the first piglet (Klopfenstein, 2006)] receive most attention because of their major impact on milk production. An overview of sow health and diseases is provided in Chapter 18 (Friendship and O'Sullivan, 2015). Even though the causes for the production- related diseases are diverse and often not well characterized, many factors are involved and sow nutrition is an important aspect. For instance, feeds produced from wheat (and rye) infected with ergot can dramatically reduce the yields of colostrum (Blaney *et al.*, 2000) and sow milk (Kopinski *et al.*, 2008). Providing a daily intake of fiber during the transition period also seems to be important to reduce the risk of constipation at parturition. Indeed, if the fiber intake is reduced, the hindgut fermentation drops, and the amounts of digesta in the hindgut and of feces drop accordingly. The fiber intake is determined by feed intake and fiber content of the sow diet. Typically, fiber intake is reduced in late gestation either because the feed supply is lowered in late gestation or because the fiber content is lowered in lactation diets (which often are fed to late-gestating sows), or due to both reasons. On the contrary, too high a feeding level is a risk factor for developing the post-partum dysgalactia syndrome (Papadopoulos *et al.*, 2010) and it may even increase sow mortality (Abiven *et al.*, 1998). In addition, excessive feed supply for an extended period of time may lead to obese sows, and this is associated with prolonged duration of farrowing (Oliviero *et al.*, 2010). Inclusion of vegetable protein in late gestation diets has been reported to reduce the occurrence of agalactia in sows compared with the inclusion of protein originating from fish meal and meat and bone meal (Göransson, 1990). Likewise, reducing the energy density of the diet (Göransson, 1989b) or reducing the energy supply during the last few days before parturition (Göransson, 1989a) were shown to reduce the incidence of agalactia. In general, sows that experience a farrowing-related disease often respond by reducing the synthesis of colostrum or milk, or both. At present it is not clear why, but part of the explanation may be a significant shift in nutrient prioritization (e.g. amino acids may preferentially be used for producing new immunoglobulins to combat the disease instead of being used for protein synthesis and secreted into colostrum or milk). Another plausible explanation could be an insufficient water intake around farrowing which potentially may reduce milk yield.

7.2.11 Heat production of transition sows

The sow heat production increases during the transition period mainly due to milk production. The amount of energy required for maintenance (ME) is constant per unit of metabolic live weight ($kg^{0.75}$), except at parturition. Indeed, the ME is higher for lactating sows (460 $kJ/kg^{0.75}$) than for late gestating sows (405 $kJ/kg^{0.75}$; NRC 2012). During the last 10 d of gestation, the metabolic live weight of the sow hardly changes even though the fetuses grow rapidly, and consequently the energy required for maintenance is rather constant. For a young sow weighing 200 kg, the ME requirement is 21.5 MJ/d, whereas it is around 29.2 MJ/d for a multiparous sow weighing 300 kg. These data illustrate that the live weight of sows plays a central role for the energy requirement. If a standard sow diet is used, then young sows with a live weight of 200 kg require 1.7 kg of feed to meet their energy requirement for maintenance, whereas older sows with a live weight of 300 kg require 2.2 kg of feed. At parturition, the live weight of sows typically drops by approximately 20 kg due to litter birth and delivery of placenta and uterine fluids, but the associated drop in sow metabolic live weight is almost counteracted by the increase in ME from 405 $kJ/kg^{0.75}$ prior to parturition to 460 $kJ/kg^{0.75}$ after parturition. Thus, the energy required for maintenance can be considered constant throughout the transition period. However, sows produce additional heat, which is associated with reproductive costs and diet-induced thermogenesis (Noblet *et al.*, 1985; Van Milgen *et al.*, 1997). The contribution of the diet-induced thermogenesis to the additional heat loss of sows is not known but in late gestating sows (d 104 of gestation, fed 3.5 kg/d) the total additional heat loss can be estimated as 7.5 MJ/d by subtracting the calculated ME (NRC, 2012) from the observed heat production in late gestation (Theil *et al.*, 2002). Right after parturition, the additional heat loss is likely very low because the sow does not produce large quantities of colostrum or milk. In contrast, from the onset of copious milk production on d 2 onwards, the additional heat loss increases considerably daily. The additional heat loss as it relates with milk synthesis can be estimated as:

$$\text{Additional heat loss, MJ/d} = \frac{\text{energy secreted in milk}}{\text{k}} - \text{energy secreted in milk} \tag{1}$$

where energy secreted in milk is in MJ/d and k is the efficiency of converting metabolizable energy to energy secreted in milk. The k has been reported to be 0.78 in a study where sow milk production was assessed by the deuterated water (DO) dilution technique (Theil *et al.*, 2004). After parturition, the amount of energy secreted increases from approximately 26 MJ on d 2 to 45 MJ on d 10 and, concomitantly, the additional heat production increases from 7.3 to 12.7 MJ/d. The increment in heat production due to milk synthesis from d 2 to d 10 corresponds to the amount of energy present in approximately 0.5 kg of feed. This increase in additional heat is only associated with the extra heat due to milk synthesis and does not include extra costs associated with diet-induced thermogenesis which, expectedly, will increase the amount of feed required.

7.2.12 Physiological adaptations and role of the liver during transition

The energy and protein balances and the intermediary metabolism of sows change considerably during the transition period (Hansen *et al.*, 2012a; Mosnier *et al.*, 2010; Theil *et al.*, 2002, 2004, 2013). Around parturition, the sows change from an anabolic to a catabolic metabolism and concomitantly the protein balance is lowered considerably (Theil *et al.*, 2002, 2004). Moreover, hepatic metabolism also changes and, for instance, portal blood flow is 2-fold and arterial plasma flow 3-fold greater during lactation than in late gestation (Flummer *et al.*, unpublished data). The liver weight only accounts for 2 to 4% of the sow live weight, but the hepatic oxygen consumption accounts for 40% of the cardiac output during lactation (Kristensen and Wu, 2012). Interestingly, as metabolic activity increases dramatically in the liver during the transition period, indicated by the pronounced increase in hepatic supply of arterial and portal blood, the total heat production of sows changes only moderately from an average of 31 MJ/d 10 d before parturition (Theil *et al.*, 2002) to 37 MJ/d 10 d after parturition (Theil *et al.*, 2004). Milk synthesis requires substantial amounts of energy and nutrients as well as increased metabolic activity in the mammary glands. The 3-fold increase in hepatic arterial blood supply suggests that the liver carries out part of the metabolic burden associated with milk production. Another role of the liver is to maintain glucose homeostasis and at peak lactation the liver uses glycogen depots to buffer the plasma glucose from 4 h after feeding until the next meal (Flummer *et al.*, unpublished). In addition, the liver extracts propionate very efficiently (>95%) when compared with the amount absorbed from the gastrointestinal tract. The liver converts propionate to lactate, which can be used as an energy source in either muscle or mammary tissues (Flummer *et al.*, unpublished data).

A low dietary n-6:n-3 ratio is beneficial both for the inflammatory profile of sows during transition and for the feed intake shortly after parturition (Papadopolous *et al.*, 2009). These last authors further claimed that the dietary n-6:n-3 ratio was associated with a better metabolic adaptation to the altered physiology of the sows around parturition. The metabolic adaptation may involve alterations in hepatic metabolism, as it is known that the dietary n-6:n-3 ratio affects the hepatic gene expression of weaned pigs (Theil and Lauridsen, 2007). The nutrients supplied via the feed during the transition period are, of course, important for the intermediary metabolism of sows. In a recent study, sows were fed low fat and either high or low fiber until 7 d before expected parturition, and were then fed lactation diets throughout the transition period and lactation. Feeding the high fiber diet prior to d -7 lowered the fermentation considerably, as indicated by the plasma contents of fatty acids, and in turn it impaired the piglet performance during the colostral period (Hansen *et al.*, 2012a). In another recent study, it was reported that the colostrum yield of sows was correlated positively with plasma urea (Loisel *et al.*, 2014), and since urea is produced in the liver, this observation suggests that the hepatic metabolism and the oxidation pattern (i.e. oxidation of protein, carbohydrate and fat) affect the productivity of sows during the transition period.

7.2.13 Body condition and body mobilization

Body condition is another important aspect for transition sows. When sows enter the farrowing units their body condition should neither be too high nor too low. If sows are too fat, they will likely experience problems during the farrowing process (Oliviero *et al.*, 2010) and, in addition, the neonatal mortality of piglets from obese sows may be greater (Hansen *et al.*, 2012a). However, a high body condition is favorable for milk persistency, i.e. milk yield at peak lactation (Hansen *et al.*, 2012a). On the contrary, a sow that is too thin is also unwanted because of the likelyhood of shoulder lesions and of a prolonged post-weaning oestrus interval (King and Williams, 1984).

Mobilization of body fat and protein reserves during late gestation were shown to be positively associated with sow colostrum yield (Decaluwé *et al.*, 2014). In support of that, Loisel *et al.* (2013) found that colostrum yield was positively related with plasma urea at parturition (which is indicative of protein oxidation). In addition, Hansen *et al.* (2012a) reported that a negative energy balance during the last days before parturition was beneficial for milk yield on d 7 to d 10 of lactation. This corroborates previous findings where *ad libitum* feeding of sows prior to parturition was detrimental to subsequent milk yield (Danielsen, 2003), however, the underlying mechanisms are not yet understood.

7.3 Feeding practice of modern hyperprolific sows during the transition period

7.3.1 Dietary shift during transition – when?

Sows are typically fed a gestation diet followed by a lactation diet and the dietary shift generally coincides with physical movement of sows from the gestation stalls to the farrowing units. However, the time for shifting the diets differs greatly between farms (Figure 7.2). Some farms shift the diet approximately one week prior to parturition, which makes sense biologically because fetal and mammary growth and colostrum synthesis require substantial amounts of protein and lysine. Other farms have the same intention but due to insufficient space in the farrowing units the physical movement is delayed until a few days before parturition. These farms may experience increased prevalence of postpartum dysgalactia syndrome, although it is not known whether this is associated with altered feeding, stress due to physical movement of sows too close to parturition or

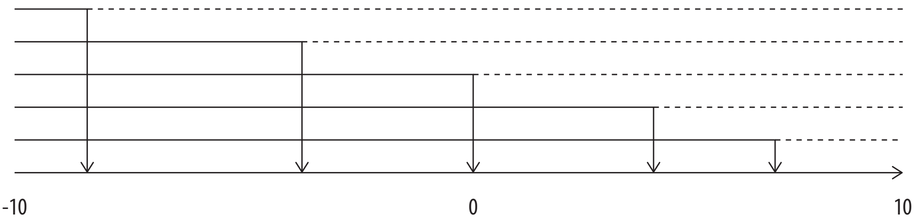

Figure 7.2. Farms use different strategies when changing sow feed from gestation diet (solid line) to lactation diet (dotted line) during the transition period (different strategies are shown by arrows; 0 represents the day of farrowing).

other causes (Papadopoulos *et al.*, 2010). Yet, other farmers choose to shift the diet only at parturition, a few days after or even up to 7 d after parturition. The farms using these latter strategies claim that it is optimal because it reduces the pressure on the sow udder in early lactation when the suckling ability of the piglets is rather low. The time chosen for this dietary shift relies much more on a strong belief than on scientific evidence. Such strong belief also characterizes the choice of the feeding curve used during the transition period (discussed later). As a corollary, some late-gestating sows are fed lactation diets and some early-lactating sows are fed gestation diets. At present, it is not common to feed sows a specific transition diet or to mix gestation and lactation diets in different proportions to match the rapid changes in nutrient requirements, yet this is an avenue which should likely be considered.

7.3.2 Contents of energy, lysine and nitrogen in the diet of transition sows

Dietary energy originates from carbohydrates, protein and fat in sow diets and normally these three nutrient classes account for approximately 87 to 89% of the feed, whereas water and minor amounts of minerals and vitamins accounts for the remaining 11 to 13%. Of the energy-supplying ingredients, carbohydrates are always the most abundant in sow diets, and dietary starch is the most abundant energy source in sow feeds. Normally, starch accounts for more than 50% of the dry matter fraction of sow feeds. On an energy basis (gross energy), carbohydrates (starch and fiber) constitute 76 and 64% of the energy in gestation and lactation diets, respectively. In comparison, protein accounts for 16 and 22% of the energy in gestation and lactation diets, respectively, whereas dietary fat typically accounts for 8 and 14%, respectively. On an ME basis, the dietary energy contents of sow diets from various countries are quite similar (Table 7.1) and range from 11.9 to 13.6 MJ ME/kg in gestation diets, whereas the energy density is often 6 to 10% higher in lactation diets (13.0 to 14.0 MJ ME/kg). The dietary ME content may be reduced by including more ingredients rich in fibre, and this is commonly done when formulating gestation diets. Conversely, the dietary ME content may be increased by including more dietary fat and most lactation diets are actually formulated with 3 to 5% of supplementary fat. However, in general, dietary energy contents vary by less than 20% across both gestation and lactation diets (Table 7.1). A survey carried out during the

Table 7.1. Typical contents of dietary energy, nitrogen and lysine in gestation and lactation diets.

	Gestation diets			Lactation diets		
	Energy, ME (MJ/kg)[1]	Nitrogen, SID (% in diet)[2]	Lysine, SID (% in diet)[3]	Energy, ME (MJ/kg)[1]	Nitrogen, SID (% in diet)[2]	Lysine, SID (% in diet)[3]
Canada	11.9	1.9	0.52	13.4	3.0	1.0
Denmark	13.0	2.2	0.31	14.0	2.9	0.63
Netherlands	12.1	2.2	0.50	13.0	2.8	0.75
France	12.1	2.2	0.50	12.9	2.6	0.89
USA	13.6	2.2	0.58	13.8	3.1	1.0

[1] Metabolizable energy, i.e. gross energy-energy lost in feces, urine and gases.

[2] Standardized ileal digestible (dietary content corrected for apparent ileal digestibility and basal endogenous losses of nitrogen).

[3] Standardized ileal digestible (dietary content corrected for apparent ileal digestibility and basal endogenous losses of lysine).

spring of 2014 revealed that specific transition diets are not presently used in Canada, Denmark, the Netherlands, France or the USA.

The dietary nitrogen content is around 2% in gestation diets and close to 3% in lactation diets (Table 7.1). These values are equivalent to approximately 13 and 18% of the crude protein in gestation and lactation diets, respectively. Dietary nitrogen originates mainly from a protein source, such as soybean meal, and either wheat and barley (Europe) or maize (USA and Canada). Lactation diets are typically formulated with 22 to 25% soybean meal whereas gestation diets contain 15 to 18% soybean meal. In Europe, the nitrogen content of lactation diets is lower than in USA and Canada, likely because pollution with nitrogen from manure is of major public concern.

The dietary content of standard ileal digestible (SID) lysine differs much more than the dietary energy and protein contents. In general, the lysine level in lactation diets is 2-fold higher than that found in gestation diets. Between countries, the dietary SID lysine content varies considerably, and in gestation diets, the content of SID lysine ranges from 0.31 to 0.58% whereas it ranges from 0.63 to 1.0% in lactation diets (Table 7.1). Dietary lysine generally originates from soybean meal and either wheat/barley or maize (such as for dietary nitrogen), but in addition, crystalline lysine is often added to lactation diets to specifically increase the lysine levels.

7.3.3 Feeding curves and sow appetite during transition

Most gestating sows are fed restrictedly throughout gestation, and hence also during the transition period, in order to avoid excessive maternal deposition of muscle and fat tissues which can predispose to farrowing problems and health-related issues such as mastitis, metritis and agalactia around parturition. In late gestation, the feed allowance is typically increased compared with that in early- and mid- gestation and the elevated feeding level is generally introduced 2 to 4 wk before parturition. This practice is applied as a simplistic attempt to match the increased requirements for amino acids due to fetal growth, but it does not take into account that fetal growth rate changes exponentially during this phase (Noblet *et al.*, 1985), and that fetuses retain steadily more nitrogen and lysine. Yet, other farms choose to feed sows the same daily amount throughout the entire gestation period whereas some farms use a high-fiber diet and allow the sows *ad libitum* access to feed in order to keep things manageable. Increasing the dietary fiber level does indeed reduce the mean energy intake within a herd (Danielsen and Vestergaard, 2001), however, *ad libitum* feeding cannot be recommended for gestating sows because it creates huge variations in body condition over time. The various impacts of feeding high fiber diets to sows during gestation are described in details in Chapter 5 (Meunier-Salaün and Bolhuis, 2015).

In late gestation, most sows are fed at or above the energy requirement (Figure 7.3). At parturition, sows are typically fed a constant level similar to that used immediately prior to parturition and then, on d 3 postpartum, the feed allowance is increased daily or in a stepwise fashion in order to account for the increased demands of milk production (Hansen *et al.*, 2012b). The appetite of sows seems to be a limiting factor for nutrient intake when the feed supply is increased in early lactation and therefore it is common to feed sows well below their energy requirement. Ideally, feed intake should be increased quite fast to avoid excessive mobilization of body fat and protein, but sow feed intake often drops if the feed allotment is increased too rapidly in early lactation (Hansen, 2012). The recommended feeding level seems to be rather comparable in Canada, Denmark, France, the Netherlands, and the USA. In spite of that, a great variation in feed supply is seen at different farms and the feeding levels applied to transition sows seem to be based merely on current beliefs and practical possibilities rather than on nutrient requirements.

Many farmers attempt to restore the body condition of sows during early- and mid-pregnancy. In contrast, during the transition period, the feeding curves (and even the dietary recommendations) are identical for all sows irrespective of parity, live weight,

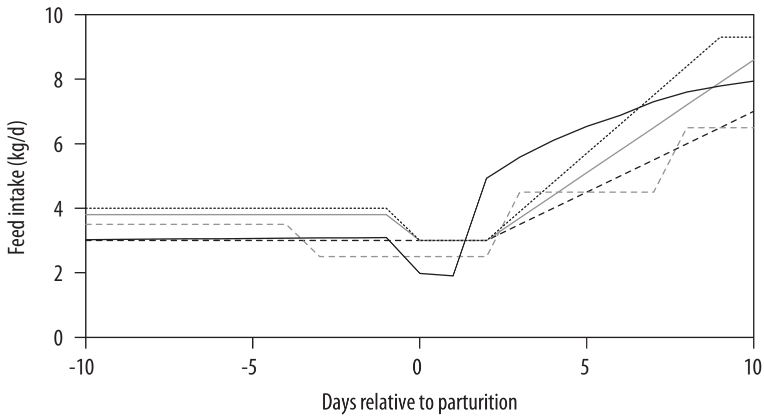

Figure 7.3. Required amount of feed (solid line) and commonly applied feeding curves (dotted and dashed lines) for sows during the transition period.

housing conditions and environmental conditions such as temperature and humidity. An exception is the recommendation in France to feed older sows 0.4 kg/d more than gilts from d 101 of gestation until parturition. And in the Netherlands, it is common to provide gestating sows 0.15 to 0.25 kg/d more during the winter time, although that is not confined to the transition period.

7.4 Recent advances

7.4.1 Nutrient requirements during transition using a factorial approach

The nutrients required during late gestation can be calculated daily using a factorial approach in which separate requirements for sow maintenance, fetal growth, mammary growth, uterine tissues (uterus, placenta, fluids and membranes), colostrum production and heat loss associated with these reproductive traits are summed (Feyera and Theil, 2014; Figure 7.4). From a nutritional point of view, the amount of energy required for reproduction prior to parturition is rather small even in late gestation (12% of intake), whereas the amount of protein required is much higher (41% of intake; Noblet *et al.*, 1985). The requirements and dynamics with respect to weights of sows and weights of their offspring are well described and this can be seen in Chapter 6 (Trottier *et al.*, 2015). For instance, the requirement for metabolizable energy of gestating sows is regarded as being constant per kg of metabolic live weight (405 kJ/kg$^{0.75}$; NRC, 2012), yet, fetal growth is known to follow an exponential growth curve. The dynamic changes of

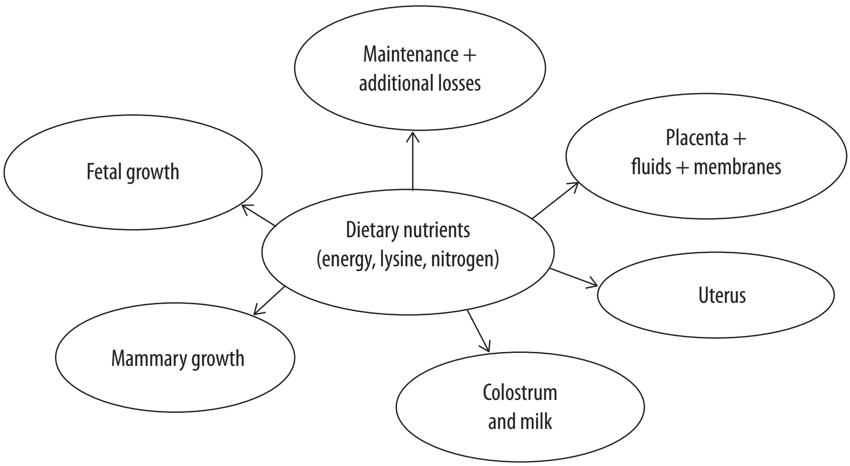

Figure 7.4. Mathematical model describing the nutrient requirements of transition sows. Additional losses refer, for energy, to costs above maintenance associated with reproductive outputs and, for nitrogen, they refer to additional oxidation of proteins due to e.g. amino acid imbalances. Note that after parturition, no nutrients are required for fetal growth, placenta, fluids and membranes, and that the uterus regresses and supplies nutrients to the circulation, which can be used for milk production. The losses in feces are not shown.

uterine tissues are also well characterized (Noblet *et al.*, 1985). However, studies on the nutrient requirements for colostrum production are lacking and it is presently unknown when colostrum is actually being produced and at which rate (Theil *et al.*, 2014b). For simplicity it is assumed that colostrum is being synthesized uniformly during the last 10 d of gestation. Also, the growth rate, and hence nutrient requirements, for mammary growth in late gestation is unknown, although it is known that mammary growth is faster before parturition than after (Kim *et al.*, 1999b; Noblet *et al.*, 1985). For late gestating sows, the unknown dynamics of nutrient requirements are of minor importance from an energetic point of view because most of the energy is required by the sow body and not by reproductive tissues. In contrast, the production of colostrum is important for evaluating the requirements of protein and essential amino acids.

After parturition, nutrients are required for milk production, maintenance, mammary growth and heat loss associated with these reproductive traits. The regressing uterus has a considerable impact on the amounts of amino acids and protein required by the sow. Since no information is available in the literature on how fast regression of the uterus occurs, it is assumed in this mathematical model that the uterus regresses during the first week of lactation. The assumptions that colostrum is being produced uniformly over 10 d and that the uterus regresses over 7 d are clearly too simple and further research is needed to better evaluate the timing of these processes.

7.4.2 Energy requirement

Sow maintenance is the major contributor to the energy requirement in late gestation (Figure 7.5). From d 105 to 115 of gestation, sows require approximately 39 MJ/d of metabolizable energy (Feyera and Theil, 2014) and, by far, the highest proportion (79%) is lost as heat (30.5 MJ/d; Noblet *et al.*, 1985, Theil *et al.*, 2002). The remaining 21% is retained in reproductive tissues or products, such as colostrum (3.6 MJ/d), fetal growth

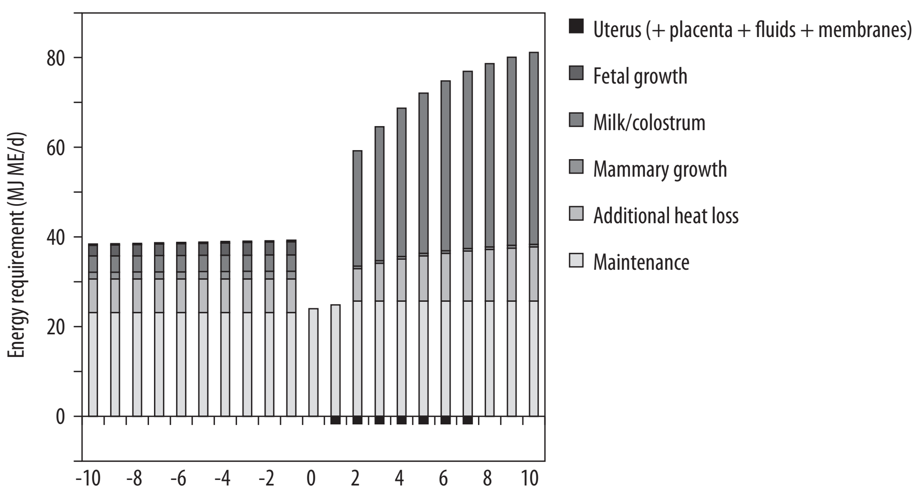

Figure 7.5. Energy requirement of transition sows. ME = metabolizable energy.

(2.6 MJ/d), mammary growth (1.6 MJ/d), and uterus, placenta, fluids and membranes (0.3 MJ/d). Heat loss is required for maintenance purposes and for colostrum production, fetal growth, mammary growth and growth of uterine tissues. The energy requirement is fairly constant in late gestation and hardly increases from d 105 to parturition because the metabolic live weight (kg$^{0.75}$) of sows increases only slightly. After parturition, the energy requirement is low for a couple of days mainly because no nutrients are retained in fetuses, placenta or uterine tissues, and because large quantities of colostrum and milk likely are not synthesized during the first 1.5 d after parturition. From d 2 of lactation onwards, the energy requirement increases substantially each day due to a greater milk production (Hansen *et al.*, 2012b) and to increasing amounts of heat associated with milk production. On d 10 of lactation, sows require approximately 81 MJ/d of metabolizable energy, of which 53% is secreted in milk (42.8 MJ/d), another 12 MJ/d is lost as heat due to milk production and the remaining 25.7 MJ/d is lost as heat due to maintenance. The regressing uterus supplies only a minor amount of energy during the first week of lactation and this contribution slightly reduces the daily energy requirement (-1.6 MJ/d). Finally, the energy required for mammary growth (0.6 MJ/d) is negligible (Kim *et al.*, 1999b). It is interesting to note that the proportion of additional heat lost (heat loss exceeding that required for maintenance) is 19 to 20% prior to parturition, whereas it is only 13 to 15% after parturition. The greater proportion lost before parturition is likely explained by a greater level of physical activity in late gestation vs. early lactation (6 vs. 4 h of standing activity; Theil *et al.*, 2002, 2004), but it may also be speculated that conversion of metabolizable energy to colostrum is less efficient than utilizing metabolizable energy for milk production.

7.4.3 Lysine requirement

During transition, lysine is mainly required for reproduction whereas minor amounts are required for sow maintenance (Feyera and Theil, 2014; Figure 7.6). During the last 10 d of gestation, the lysine requirement increases by approximately 24% due to the exponential increase in fetal growth (Noblet *et al.*, 1985). The increase in lysine requirement may be even greater than 24% if mammary growth follows an exponential growth curve like fetal growth in late gestation. However, it is currently unknown how the requirements for mammary growth and colostrum production change in the pre- and post-farrowing period. If we assume that all colostrum is produced uniformly during the last 10 d of gestation, it can be calculated that as much as 59% (d 106) and 48% (d 115) of the daily lysine requirement is needed for mammary growth and colostrum synthesis. At parturition, the lysine requirement drops abruptly because most of the lysine is needed for reproduction and only sparse amounts are required for sow maintenance. The lysine requirement then increases dramatically from d 2 and throughout the transition period, because sows have a very high requirement of lysine for milk production. Wu and Knabe (1994) reported that milk contains 29 mmol/l of lysine, which is equivalent to 4.12 g of lysine per kg of milk (assuming that milk density is 1.029 kg/l). However, after parturition the regressing uterus supplies approximately 2.6 g/d of lysine, and this amount is higher than the amount required for sow maintenance. In total, the uterine supply accounts for approximately 13% of the total requirement for lysine on d 2 and 8% on d 7 of lactation. These quantities are valid only if the uterine degradation after parturition happens

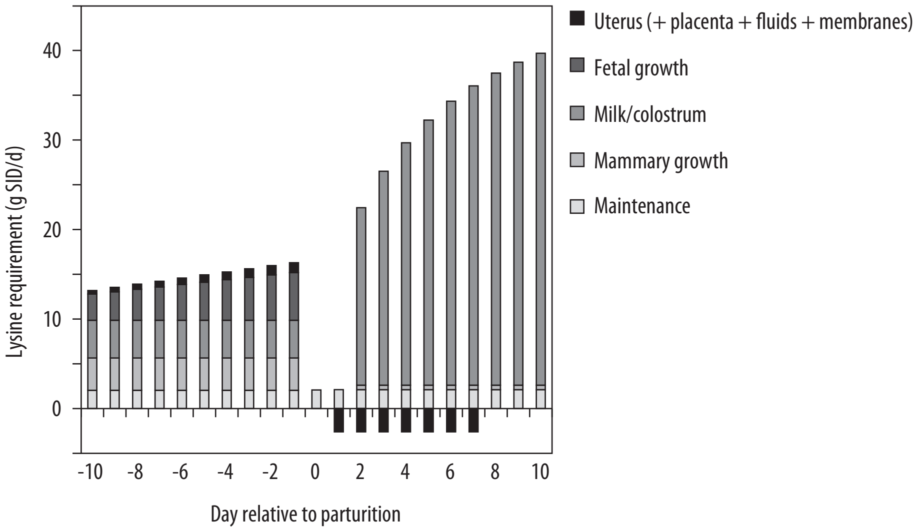

Figure 7.6. Lysine requirement of transition sows. SID = standardized ileal digestible.

uniformly (which is unlikely the case), but the amounts emphasize that the contribution of the uterus should be considered when optimizing nutrient supply to sows since it provides substantial amounts of lysine and other amino acids.

7.4.4 Nitrogen requirement

Nitrogen (as both essential and non-essential amino acids) is also required for sow maintenance and reproductive traits but, in contrast to energy and lysine, the nitrogen requirement for sow maintenance is not well defined. Reasons for this are that the requirements for many essential amino acids are unknown. Furthermore, any excess (imbalances relative to lysine) dietary amino acid is deaminated in the liver, converted into urea, and secreted as urine, whereas the carbon skeletons may be used as an energy source or as glycogenic precursors. Consequently, it is more appropriate to quantify the amount of nitrogen lost in the urine than to evaluate the amount of nitrogen required for maintenance (Hansen *et al.*, 2014), but the urinary loss of nitrogen depends on nitrogen intake. The numbers presented here (Feyera and Theil, 2014) are based on the fact that the amount of nitrogen lost in the urine depends on dietary intake (36% is lost in late gestation and 28% in lactation; Theil *et al.*, 2002, 2004), because it is widely accepted that the protein turnover increases with the level of dietary nitrogen supplied. Even though the maintenance requirement cannot be quantified exactly, the term daily nitrogen requirement is used here to describe the demand for nitrogen.

The percentage of nitrogen lost in the urine ranges from 36 to 48% of the calculated nitrogen requirement in late gestation (Feyera and Theil, 2014). The amount of nitrogen required for fetal growth, colostrum production and mammary growth are roughly similar and account altogether for 50 to 62% of the daily nitrogen requirement in late gestation. After parturition, the amount of nitrogen lost in the urine increases along with feed intake and the amount of nitrogen required increases with milk yield throughout the transition period. Concomitantly, the uterine degradation contributes 19% of the calculated daily nitrogen requirement on d 2, whereas the uterine supply decreases to 11% on d 7 (Figure 7.7). It is noteworthy that the calculated daily nitrogen requirement increases much less from gestation to lactation than does the requirement for lysine. This could indicate that protein may be a limiting factor for sow productivity in late gestation and that lysine may be limiting after parturition.

7.4.5 Nutrient balances during transition

Transition sows fed a standard gestation diet until one week prior to parturition are exposed to minor negative balances of lysine and nitrogen, but to a slightly positive energy balance (Figure 7.8; Feyera and Theil, 2014). If the gestation diet is replaced by a standard lactation diet at the onset of the transition period, all three balances become positive until the feed supply is eventually lowered (for instance during the last 3 d before parturition), as recommended in Denmark. This decreased feed supply leads to negative balances of lysine, nitrogen and energy until parturition. After parturition, the nitrogen balance is constantly positive, the lysine balance is close to zero and the energy balance is negative initially but becomes zero after approximately one week. The slightly positive balances of energy, lysine and nitrogen after the dietary shift in late gestation indicate that nutrient requirements of sows are met quite well by the feed composition and feeding level prior to parturition. In contrast, the positive nitrogen balance along with the negative energy balance in early lactation indicates that the lactation diet is not well balanced with nutrients required to support milk production.

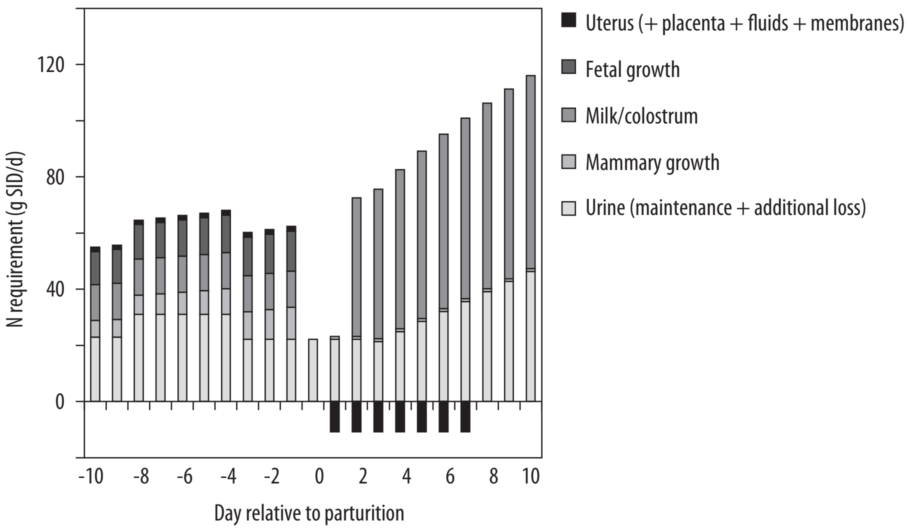

Figure 7.7. Nitrogen requirement of transition sows. SID = standardized ileal digestible.

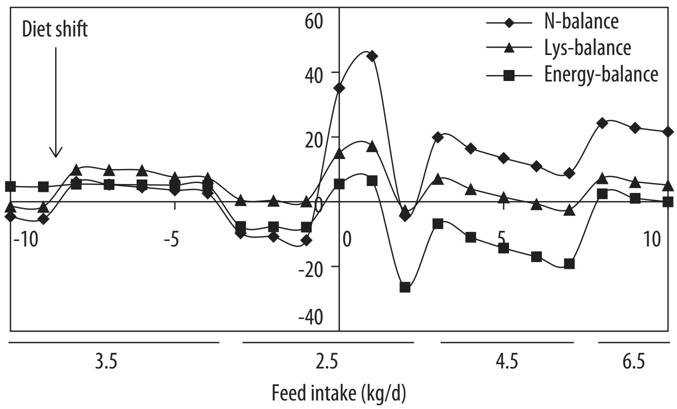

Figure 7.8. Balances of energy, lysine and nitrogen of transition sows fed a common gestation diet until one week prior to farrowing and then fed a lactation diet. The feed supply is adjusted in steps as shown in the figure.

7.5 Future perspectives

Ideally, the nutrient requirements of sows should be expressed with respect to day of gestation or lactation and not on a feed basis. This is particularly true during the transition period, when requirements change substantially and rapidly and it is therefore impossible to feed sows optimally with a single diet. Since the requirements for energy and protein change independently of each other, it makes little sense to express the nutrient requirements on a feed basis, whether on a kg or on an energy basis. Development of new feeding strategies in order to match the rapidly changing nutrient requirements for transition sows is an avenue which needs to be considered in the future in order to improve feed utilization and productivity of sows. This will likely increase sow longevity and reduce mortality of piglets and even of sows. Undoubtedly, energy, crude protein, and lysine supplies around parturition are essential for sow productivity and requirements must be met, but it is important to stress that other dietary nutrients (other amino acids, vitamins and minerals) may indeed be the limiting factor(s) for sow productivity during the transition period.

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