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Review

Does the relationship between sow body composition change in lactation and re-breeding success still exist?

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Abstract. Sow body composition largely reflects the amount of lean and fat tissue stores in the body, and is measured, managed and reported because traditionally when sows mobilise body tissues in lactation to support piglet growth, adverse consequences in subsequent reproduction may be observed. These consequences are largely driven by metabolic changes exerting negative influences on the reproductive axes through luteinising hormone and follicle stimulating hormone and direct impact on the ovary. This results in sows that take longer to ovulate, have lower ovulation rates and shed poorer-quality oocytes, translating to delayed wean to service intervals, higher pregnancy failure and lower litter sizes. Sow management needs to meet both the needs of the piglet (adequate colostrum and milk intake for survival and growth) and the needs of the sow (successful re-breeding). The way pork producers tackle this is through diets designed to match sow requirements at different production stages. We have recently observed, despite efforts (nutritional challenges), that we are unable to induce fat or lean tissue mobilisation in lactating sows, which is a novel finding, although pig populations such as in the EU, UK and USA would appear to be experiencing similar outcomes. Despite our lower reproductive performance than in much of the rest of the world as a consequence of having a closed genetic herd, the specific genetic selection programs that exist within Australia, and the resultant leaner, more efficient sows, may be a potential explanation. This, coupled with the high lactation feed intakes now commonly reported, means that sows are less likely to become catabolic and so suffer from poor re-breeding outcomes. A conclusion from these findings may mean that we now have an opportunity to feed the lactating sow to better meet the growth and survival needs of piglets, with the knowledge that we will not compromise subsequent reproduction.

Additional keywords: sow, body composition, back-fat, protein deposition, genetic selection, nutrition.

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Introduction

Sow body composition consists of the amounts of muscle (or lean, mostly in skeletal depots), adipose (fat) tissue, bone and water, and when lean and fat are mobilised in lactation, generally negative consequences on subsequent re-breeding have been reported (Aherne and Kirkwood 1985). However, there is increasing evidence that this link between lactational catabolism and subsequent reproduction may not be as strong as previously reported, and, in some cases, may be completely uncoupled (Patterson *et al*. 2011). In this review, we discuss how body composition (lean and fat) is measured in sows and explore why the historical link between tissue mobilisation and impaired reproduction exists. We present new Australian data that would suggest that sows are more resistant to lactation pressure and demonstrate that this is supported in part by work conducted internationally. We also explain why the modern sow is more resilient and suggest ways in which sow reproduction can be exploited further by advancements in nutrition.

Sow body composition and its impact on reproductive performance

Measurement of sow body composition

Body condition scoring is widely used by producers and involves a visual and tactile assessment of breeding stock (Mitchell and Scholz 2000) to provide quick assessment of bone prominence as an indicator of body and rib fat (Russel *et al*. 1969; Otto *et al*. 1991). Sows are subjectively scored on a scale of 1 (thin) to 5 (fat), but the method is susceptible to measurement error, often referred to as herd blindness, when visual scoring is performed in the same herd over time (Maes *et al*. 2004). Additionally, scorers with different levels of prior experience have been shown to over- or under-estimate body condition score, with variance among the individual scoring rounds being 70.6% in one study (Fitzgerald *et al*. 2009).

After careful assessment of anatomical joints, it was shown that body fat could be estimated with a high degree of accuracy from a measure of back-fat depth taken at the thinnest point above the loin muscle, the P2 location, and the depth of the loin muscle was highly correlated with the weight of the total carcass muscle (McMeekan 1940). Shortly afterwards, the use of real-time linear array ultrasonic scanners allowed for *in vivo* measurement of back-fat and loin muscle depth (Kliesch *et al*. 1957). Fat depth at the P2 site was then shown to give a reliable estimate of carcass lean tissue (Kempster and Evans 1979), showing a high correlation with the weight of muscle in the carcass and the eye muscle area when compared with using measures of the forearm or *psoas* (McMeekan 1940). While the diversity of pig breeds used commercially has diminished (Bunter and Hermesch 2017), the selection emphasis applied in the past 40 years has seen divergence in the proportion of lean to fat in different populations, resulting in variation in the reported accuracy of predicting body composition from ultrasound measurement. With the reported accuracy of these equations ranging from an R^2 of 0.36 to R^2 of 0.83 (Mitchell and Scholz 2009). Thus, even when using a more objective measure of body composition such as ultrasound, variability is still inherent through the operator, breed, gender, age and size of the animal.

The relationship between body condition scoring and fat measured by ultrasound is poorly associated. Young *et al*. (2001) measured body condition score and back-fat depth of 700 sows, with the back-fat depth of condition score 1 sows ranging from 6 to 14 mm, and condition score 3 sows ranging from 7 to 23 mm. In this study, the two methods were poorly correlated ($R^2 = 0.18$), even when assigned by the same scorer. These two systems appear to be fraught with within- and across-user error, requiring further development in the accurate measurement of sow body composition.

Much work has been conducted to refine the measurement of lean and fat tissue in sows. Dourmad *et al*. (1997) conducted a study dissecting and chemically analysing multiparous sows at various stages of reproduction to develop prediction equations for fat and protein mass. Prediction equations for Australian sows have been determined by King *et al*. (1986) and more recently by Smits *et al*. (2017). The inclusion of additional information into predictions over and above weight and ultrasound fat depth, such as parity and loin muscle depth, improves the accuracy of the equation (Miller *et al*. 2018). However, estimating the fat and protein mass of sows using these prediction equations relies on measures of ultrasound back-fat and loin muscle depths at the P2 site coupled with weight. This would pose obvious issues if the accuracy and practicality of measures that feed into prediction equations are questioned as discussed above, and (or) sows cannot be weighed; so, novel means of estimating sow body composition are worthwhile exploring to see whether accuracy can be improved.

Bioelectrical impedance analysis (BIA) is a non-invasive, inexpensive and portable method of measuring a change in body composition, which can be used for repeated-measures to monitor growth and development of a single animal. Initial studies have found BIA measurements to have good potential to predict body fat mass and fat-free mass in live pigs (Daza *et al*. 2006) and carcasses (Swantek *et al*. 1992). Bioelectrical impedance analysis is based on the principle of differentials in the conductance of an electrical current through different body tissues/fluids. We have recently conducted studies to validate this method against a 'gold standard' (deuterium dilution), and alongside the aforementioned prediction equations (Muller *et al*. 2021). While we recognise that results may differ across different genotypes and management, we were able to conclude that some prediction equations, based on bodyweight (BW) and back-fat depth, are still better estimates of sow body composition than is BIS. This was most likely explained by population assumptions that were incorporated into individual BIA analyses; hence, this still needs refinement.

Computer vision systems are currently being developed as a non-invasive means of pig body composition and BW measurement (Fernandes *et al*. 2020), while reported accuracies for BW are high, R^2 of 0.86, the accuracy of muscle depth and back-fat are low (R^2 of 0.50 and 0.45 respectively). Further work is therefore required before BIS or other more reliable and accurate approaches can be applied to replace ultrasound as a reliable assessment of sow body composition.

The impact of body composition changes on reproductive performance

Sows will typically mobilise body tissues during lactation to offset deficiencies in energy and nutrient intake to meet the demands of the litter. It is common for sows with low feed intakes and excessive tissue mobilisation during lactation to show subsequent reproductive failure (Vinsky *et al*. 2006). Sow BW losses exceeding 9–12% in a lactation have been associated with declines in milk protein concentration and piglet growth and impaired ovarian function (Clowes *et al*. 2003), and negative impacts on wean to service interval have been reported (Thaker and Bilkei 2005) in Parity 1 sows when weight loss exceeds just 5%, but greater than 10% losses were needed in Parity 2 or higher sows. A parity effect has also been observed in total born litter sizes at losses greater than 10% in Parity 1 versus Parity 2–5 sows. Schenkel *et al*. (2010) showed the biggest impacts on subsequent reproductive performance were realised when protein was mobilised, indicating a change in body composition, rather than a change in BW *per se*. Hoving (2012) reported that for every kilogram of BW loss during lactation, subsequent litter size was reduced by 0.04 piglets, but for every millimetre of loin muscle depth loss, subsequent litter size was reduced by 1.8 piglets.

Changes in metabolic hormone concentrations when sows are in a state of negative energy balance are believed responsible for adverse impacts on reproduction. Catabolism during peak milk yield in late lactation negatively affects levels of insulin and insulin-like growth factor 1 (IGF-1) (Zak *et al*. 1997), and this influences follicular development via changed patterns of luteinising hormone and follicle-stimulating hormone secretion (Pettigrew *et al*. 1993). Clowes *et al*. (2003) found that ovarian function was suppressed, with fewer medium-sized follicles and less follicular fluid, in sows that had mobilised high levels of protein in lactation. The number of live embryos has also been shown to be reduced in pregnant sows that did not receive adequate energy levels in the previous lactation (Vinsky *et al*. 2006), with embryo survival rather than ovulation rate being affected. The survival of the embryo is influenced by the quality of both the embryo and the uterus, with the synchrony between embryonic and uterine development largely being influenced by progesterone (Pope 1988). Hoving *et al*. (2012) showed a delayed progesterone peak in sows with heavy weight loss in lactation, suggesting an impaired number of implantations. The negative impacts of catabolism in sows on reproductive axes cause an extended period between weaning and oestrus (Koketsu *et al*. 1996; Zak *et al*. 1997), increased chance of pregnancy failure, and reduced litter size (Schenkel *et al*. 2010), leading to more non-productive days in the herd.

A typically realised example of the negative impact on tissue mobilisation is reported when first-parity sows are weaned. First-parity sows are highly likely to mobilise body tissues during lactation as they are still growing, wean higher numbers of pigs, and cannot physically ingest sufficient feed to meet all these demands (Pluske *et al.* 1998), with even low BW losses of 5% increasing wean-to-service intervals in first-parity sows (Thaker and Bilkei 2005). Consequently, this population of sows often experience ‘second-parity syndrome’. This is typified by delayed wean-to-service intervals, reduced farrowing rates and lower litter sizes, which can occur independently or in combination (Soede *et al*. 2013) and persist into subsequent parities (Hoving *et al*. 2011), although high litter size in the first parity can reduce the impact on subsequent litter of sow’s that experience ‘second-parity syndrome’. The outcome of this suboptimal reproductive performance of second-parity sows is premature culling, with repeat breeders exiting the herd two parities earlier (Hoving *et al*. 2011), which distorts the parity distribution of the herd and has large economic ramifications.

Feeding the lactating sow

Sow management in lactation needs to meet both the needs of the piglet (enhanced survival, high growth rates to achieve optimum weaning weights) and subsequent successful re-breeding. Feeding sows correctly during lactation is therefore crucial, and lactation diets focus on supplying optimum levels of nutrients and energy for maintenance requirements, optimum milk production and maintenance of body condition. Nutrient requirements may also be influenced by the rate of piglet growth, litter size and stage of lactation, and environmental conditions. Litter growth forms part of the basis for determining the energy and lysine requirements of the sow, with the energy to lysine balance critical for nutrient specification, and lysine being the first limiting amino acid. If the ratio of energy to lysine is unbalanced, the sow mobilises body reserves (Ball *et al*. 2008). For example, and at the time for a 175 kg sow, a 25% reduction in dietary energy and protein intake below requirements over a 28-day lactation was calculated to cause mobilisation of 4.4 kg lean and 11.6 kg fat from maternal tissues (Close and Cole 2000).

Current nutrient requirements for sows in lactation are modelled from previous research (NRC 2012), while commercial companies have extended these models to adjust for phenotypical differences (e.g. PIC 2016; DanBred 2020). From the previous NRC (NRC 1998) recommendations to 2012, sow maintenance requirements have fallen from 106 kcal ME/kg $BW^{0.75}$ to 100 kcal ME/kg $BW^{0.75}$. The current recommendations by the NRC (2012) for standardised ileal digestible (SID) lysine required for maximum litter growth (270 g per nursing pig per day, 11.5 litter size) in a multiparous sow (Parity 2+, 210 kg post-farrowing weight) is 52.6 g/day, while commercial recommendations sit ~20% higher for similar litter growth (PIC 2016). In Danish studies, litter growth has been shown to be optimal when multiparous sows consumed 54.1 g/day (Hojgaard *et al*. 2019) or 57.9 g/day (Feyera *et al*. 2020) of SID lysine, whereas higher lysine intake levels were required to optimise litter growth in Chinese (65.4 g/day; Liu *et al*. 2020) and US studies (63.0 g/day; Greiner *et al*. 2020). This variation in optimal lysine requirement is high, and likely due to differences in milk production and, given the fact that Australian sows are a unique population (explored later), perhaps this work is required locally.

Does the modern sow still mobilise body tissues in lactation?

Results from Australian studies

Recent data from this research group (T. L. Muller, K. J. Plush, J. R. Pluske and R. J. van Barneveld, unpubl. data), and other research within Australia (Craig 2021; Liu *et al*. 2021) based on commercial genotypes, suggest that sows raised under Australian conditions are not mobilising fat or lean tissue in lactation. An experiment was conducted using 153 multiparous sows allocated to a 2 × 2 factorial design, with respective factors being (1) diet type (gestation, 13.0 MJ digestible energy (DE)/kg, 0.42 g SID lysine/MJ DE vs lactation, 14.3 MJ DE/kg 0.62 g SID lysine/MJ DE) and (2) feed allowance (*ad libitum* vs an overall allowance of 7.5 kg/day, representing a 15% reduction on *ad libitum* intake in this herd). Overall, feed intakes were higher than those in previous reports on Australian sows (Hermesch 2010). Dietary treatments did not result in significant changes in sow BW, back-fat depth, or the estimated sow body fat and body protein changes (Table 1), nor was piglet growth affected by treatment. This lack of impact occurred despite sows experiencing a calculated negative lysine balance in some treatments where SID lysine intakes were ~35 and 42 g/day, well below NRC (2012) recommendations. Similarly low levels of lysine intake (44.5 g/day) have not resulted in BW loss in other studies (Liu *et al*. 2020), and while it remains unclear as to the cause of this lack of impact, significant gains in the efficiency of protein deposition have been achieved through genetic selection.

In this regard, it is possible in commercial systems that feed to appetite in lactation, that there is a period of lysine oversupply in early lactation, followed by undersupply later in lactation that may have impacts on milk yield and litter growth in those periods (Feyera and Theil 2017). Sows may

Table 1. Effects of diet type (gestation, lactation) and feed allowance (*ad libitum*, restricted) on average daily feed intake (ADFI), digestible energy (DE) and/or standardised ileal digestible lysine (SID Lys) intake and balance during lactation (Days 1–21) on the change in sow body composition from the day after farrowing (Day 2) to weaning (Day 21). Data are presented as means with a pooled standard error (s.e.m.)

Data are presented as means with a pooled standard error (s.e.m.). Means within rows with different letters differ significantly (at $P = 0.05$)

Item	Gestation		Lactation		s.e.m.	*P*-value		
	Ad libitum	Restricted	*Ad libitum*	Restricted		Diet type	Feed allowance	Interaction
ADFI (kg/day)	7.7a	6.4c	6.7b	6.3c	0.1	0.009	<0.001	0.015
DE intake (MJ/day)	100.0a	82.6c	95.5a	90.0b	28.2	0.596	<0.001	0.023
DE balance[A] (MJ/day)	29.1	11.1	22.5	15.6	53.2	0.781	<0.001	0.384
SID Lys intake (g/day)	41.9	34.6	59.7	56.2	7.4	<0.001	<0.001	0.149
SID Lys balance[A] (g/day)	–8.6	–17.0	5.5	1.0	16.4	<0.001	0.002	0.896
Bodyweight change (kg)	3.7	–1.4	7.9	4.8	2.4	0.135	0.236	0.769
Fat depth change (mm)	–1.7	–1.6	–2.2	–2.3	0.6	0.124	0.941	0.821
Body fat change[B] (kg)	–2.2	–2.8	–1.6	–2.8	5.4	0.782	0.452	0.775
Body lean change[B] (kg)	1.2	0.3	1.0	1.2	2.5	0.683	0.690	0.480

[A]Energy and lysine balance requirement was calculated on the basis of the total requirement of the sow for maintenance and milk production from farrowing to weaning (Close and Cole 2000; Dourmad *et al*. 2008; NRC 2012).

[B]Fat and lean tissue mass estimated using bodyweight and subcutaneous fat depth at the P2 site (Dourmad *et al*. 2008).

therefore be depositing protein before its mobilisation during peak lactation, offering a possible reason for sows maintaining or gaining condition when evaluated over the entire lactation period. Under the design of this particular experiment where sow body composition was assessed only after farrowing and at weaning, this could not be tested. Future work should determine whether sow body composition changes during different stages of lactation, such that energy and nutrient supply may be better matched to needs of the piglet and feed intake of the sow. Regardless and not surprisingly, there was no treatment impact on litter growth and subsequent reproductive success as measured by wean to service interval and litter size at next farrowing. These findings point to the modern Australian sow, at least of this genotype, being more resilient to nutritional impositions during lactation; however, more work is required to determine whether this holds true for all parities, populations and/or genotypes.

Results from international studies

One of the first studies to suggest that primiparous sows were more resistant to metabolic change in lactation was reported from Canada, where Patterson *et al*. (2011) employed a 60% reduction in feed allowance during the final week of lactation, and while there was an ~8 kg difference in sow weight at weaning relative to *ad libitum*-fed control sows, no difference in ultrasound back-fat was observed despite the nearly 50% reduction in energy intake in restricted versus control sows. Models incorporating energy intake from feed and output of piglet growth did suggest that sows from the restricted treatment mobilised more body tissues than did control sows, but this resulted in no change in wean-to-service interval, pregnancy rate, ovulation rate, embryo survival and live embryos at Day 30 of gestation. The authors concluded that sow biology in lactation had most likely changed, with higher resilience to lactation catabolism. De Bettio *et al*. (2016) confirmed these results in mixed-parity sows from Brazil, with a reduction in feed intake from 6.4 kg/day to 4.1 kg/day causing increased protein and fat mobilisation, resulting in a 13% loss in sow BW, without negative impacts on re-breeding indices.

Contrasting this, in Dutch studies, Costermans *et al*. (2020) showed that first-parity sows restricted from 6.5 kg/day to 3.25 kg/day for the final 2 weeks of lactation lost weight, mobilised protein but no fat tissue, and displayed reduced *in vitro* oocyte development, maturation and fertilisation, in line with the results of previous work (Zak *et al*. 1997; Clowes *et al*. 2003).

Manipulating energy levels in the feed from 13.8 to 15.9 MJ DE/kg had little impact on weight and back-fat change in lactation in the UK, and, in fact, despite multiparous sows losing on average 3 mm of fat, sows gained ~15 kg from farrowing to weaning (Rooney *et al*. 2020). There was no impact of energy density on subsequent litter size in this investigation either.

Hojgaard *et al*. (2019) showed that increasing SID lysine intakes from 39.4 to 63.9 g/day had no impact on wean-to-service interval, farrowing rate and subsequent litter size in multiparous Danish sows. While there was a significant linear impact of SID lysine intake on sow BW loss, the lowest lysine intake-level treatment, and so the highest sow BW loss, was only 5.6%, which some could argue is nominal. Additionally, there was no impact on back-fat loss. In a series of experiments targeting lysine intakes across sow parity in a US commercial herd, Greiner *et al*. (2020) showed that when sows were given access to feed *ad libitum*, a range of lysine intake levels from 52.1 to 77.3 g/day for Parity 1 sows and from 62.5 to 88.0 g/day for multiparous sows had no impact on sow weight change, wean-to-service interval or subsequent litter size. The lysine intakes were substantially higher than NRC recommendations as the average daily feed intake of the sows was unexpectedly greater than anticipated. So, in a follow-up series of experiments, feed intake was restricted (5.3–5.6 kg/day) to reduce lysine intakes. First-parity sows showed shorter wean-to-service intervals with an increasing intake level, but no impact on litter size was observed, while lysine intakes had no impact on the reproductive output of older-parity sows. These findings mirror those of Gourley *et al*. (2017), who showed that the proportion of sows bred within 7 days of weaning increased with an increasing lysine intake from 48 to 70 g/day only in first-parity sows. Again, this highlighted the sensitivity of first-parity sows to lactation pressures, and, in addition to this, probably demonstrated that in older parities, culling strategies that remove sows with poor reproduction skew the population to higher resilience and prolificacy. Interestingly, lower lysine intake levels (44.5–61.2 g/day) have been shown to have no impact on weight and back-fat loss (which was negligible), or wean-to-service interval on a Chinese population of first-parity sows (Liu *et al*. 2020), which contrasts the US findings.

Given all of this, it would appear that the Australian findings are in line with those of work conducted overseas. Sows are not mobilising body tissues in lactation to support milk production and piglet growth to the same degree as has been historically reported. Even if lean and fat tissues are mobilised, negligible impacts on reproductive traits such as wean-to-service interval, farrowing rate and litter size are identified, and this is especially true for multiparous sows. Perhaps in their recent review, Tokach *et al*. (2019, p. 2967) correctly summarised the current status of sows when they stated they 'are resilient and, with proper nutrient intake, can withstand the rigorous demands of increased productivity'.

Why are sows more resilient to impacts of lactation catabolism?

Recent work would suggest that restrict-fed sows are more efficient with regards to performance, i.e. they consume less feed for milk output, piglet growth and re-breeding, and, so, potentially, genetic selection for efficiency is an explanation for why our sows were less likely to mobilise body tissues in lactation (Patterson *et al*. 2011; De Bettio *et al*. 2016), while improvements in environment within the farrowing house, feeding management in both gestation and lactation and feed formulation have increased voluntary feed intake (Tokach *et al*. 2019). In a successful strategy to keep diseases of great economic impact out, Australia has been a closed genetic herd since the late 1980s, and in combination with breeding goals to suit our market and economic environment, we have made slower progress in maternal traits than have the hyper-prolific sows of Europe and northern America. However, our sows have still demonstrated significant increases in litter size, producing fast-growing, lean and efficient progeny. From 2014 to 2019, total litter size increased by 0.24 piglets per litter per year (PIC 2020), while body lean tissue percentage increased as indicated by an increase in loin muscle depth (0.29 mm/year), with back-fat depth increasing by 0.01 mm/year over the same period. Similarly, Hermesch (2010) demonstrated that as selection for desirable progeny traits occurs (growth and back-fat), sow BW and composition will change as back-fat depth measures between growing pigs and sows have a high positive genetic correlation (Bunter and Lewis 2010). In addition to compositional changes, it would appear that selection for efficiency results in a decreased requirement for basal metabolism (Gilbert *et al*. 2012). Last, large gains have been made in the genetic potential for piglet growth (Bunter *et al*. 2010), but these are yet to be realised in commercial herds.

Opportunities in nutrition to improve sow performance

So, taken collectively, our sows have greater protein reserves and are more efficient, perhaps because of lower basal metabolic requirements, due to genetic improvement. As a result, catabolism is no less common in sows during lactation, and even when experienced, it is un-coupled from re-breeding success. The genetic potential for our piglets to grow is not being captured in commercial herds; so, rather than aiming to feed the sow to limit body tissue mobilisation, we now have an opportunity to feed the sow to maximise piglet growth, such as staged lactation diets (Pedersen *et al*. 2016).

Staged lactation diets

Advances in feeding programs have been developed to better meet the requirements of the sow at specific gestational stages (Ball *et al*. 2008). Cadogan *et al*. (2019) demonstrated that supporting the specific increases in essential amino acids during late gestation led to better fetal development, as evidenced by a 3.5% increase in average piglet birthweight. This shows the potential for nutritional programs to meet specific developmental stages, but less attention has been paid to lactation feeding programs. Energy requirements increase from Week 1 to Week 3 of lactation, before decreasing into Week 4, while lysine requirements start to increase only in Week 2 (van der Peet-Schwering and Bikker 2019). Stage of lactation affects litter growth rate and influences the SID lysine requirements. Clowes *et al*. (2003) found no impact of SID lysine intake on litter growth rate until after Day 20 of lactation when sows started to mobilise body protein. Litter growth rates vary considerably, ranging from 100 to 236 g/day before Day 10 of lactation, before reaching 275–350 g/day by Day 25 (Close and Cole 2000; Theil *et al*. 2002; Hojgaard *et al*. 2020). These data are dependent on sow feed intake, body size and litter size. Hence, daily energy and protein requirements are expected to change throughout lactation. Sows are expected to require more energy and less protein in early lactation as lactation becomes a priority and energy is partitioned for milk fat secretion (Rosero *et al*. 2016). As the sow attempts to increase her feed intake to support the demands of litter growth when progeny are rapidly growing, protein requirements increase. Not all agree with this approach, given the concentration of protein could be argued to ideally increase in early lactation, while feed intake is low (Strathe *et al*. 2015).

Theil (2017) was able to demonstrate that large metabolic shifts occur from 3 days before to 3 days post-farrowing, and continue into lactation, concluding sows lack dietary energy in early lactation more than protein. This would suggest that a two-stage lactation diet has its benefits, such as increasing milk yield and litter growth and reducing sow weight loss in early lactation (Pedersen *et al*. 2016). Indeed, when a two-component feeding strategy was applied to Danish sows, litter growth rate achieved 3.5 kg/day, which exceeded previous reports of growth between 3.0 to 3.2 kg/day from the same research group (Feyera *et al*. 2020), and is exceptional when compared with the 2.2 kg/day achieved by some Australian sows (*unpublished*). The two-component feeding strategy consisted of a basal diet formulated and fed to meet the daily maintenance requirement of the sow, and a lactation supplement designed to meet the lysine and energy requirements for milk production that was delivered on the basis of expected milk yield each day. There are of course logistical issues with milling, transport, storage and delivery of two diets during lactation. Thus, we are currently evaluating whether the diet commonly fed to gestational sows can be continued into the initial stages of lactation, to limit lysine intake, yet encourage feed (and energy) intake, used in combination with a lactation feed in later lactation to meet the increased lysine requirement. Allowing us to better meet the needs of the sow and her litter.

Conclusions

It would appear that sows are not mobilising muscle and adipose tissues to the same degree as traditionally observed, both in Australia and overseas, through a combination of better nutrient intake and changed metabolic requirements due to genetic improvements, and so carry-over effects of lactation performance on subsequent rebreeding success are now minor, if present at all, in multiparous sows. This is likely to be due to genetic selection influencing sow body composition and efficiency, as well as on-farm culling decisions that remove sows susceptible to high levels of mobilisation early in life. Nutritional requirements during lactation are not consistent over time, and so, perhaps, we now have the opportunity to test diets that better meet the needs for milk production and, so, piglet growth.

Data availability

The data that support this study are available in the article and accompanying online supplementary material.

Conflicts of interest

The authors declare no conflicts of interest.

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