IPVS2022

26th international pig veterinary society congress - rio de janeiro - brazil

Proceedings IPVS2022

RIO DE JANEIRO/RJ, BRAZIL

/ipvs2022
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IPVS2022

26th international pig veterinary society congress - rio de janeiro - brazil

ISBN: 978-65-5941-698-1

RIO DE JANEIRO
2022

Precision Feeding during Gestation for High Producing Sows: a breakthrough towards sustainability and productive efficiency

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Introduction

Advances in pig production have brought many benefits for producers, such as higher number of piglets/ sows per year, higher farrowing rates per year, decreased age at slaughter, increased feed efficiency and higher lean gain (Ball et al., 2008). Nevertheless, negative characteristics, such as within-litter birth weight variation have developed, resulting in economic losses and lower profits to the producer (Wolf et al., 2008). The establishment of a proper nutrition program for modern sows, should consider the genetic material of the farm, nutritional needs, factors that affect these needs, and should have the understanding of the various aspects of the metabolic interaction between genotype, nutrition and reproduction in sows. This understanding is essential so that we can achieve productivity and longevity at the same time. The gestating sow's energy state can directly influence its performance during lactation. Excessive energy can cause obesity at birth, leading to reduced voluntary intake, resulting in high physical losses during lactation (Sinclair et al., 1998; and Kim et al., 2009). The reduction in voluntary intake is to be an even bigger problem when it comes to the gilt and second parity sow in relation to adult sows. Young sows generally have a lower voluntary intake capacity, at around 20% lower (Young et al. 2004) compared to adult sows. A severe energy deficiency can result in sows being thin at farrowing, which can lead to problems during lactation with reduced capacity to produce milk and reduction in litter weight at weaning. To control the energy consumption of the gestating sows, restricted and/or controlled feeding strategies are put into practice more efficiently. The maternal gain should be recognized as the net gain in weight of the sow during the gestation period, disregarding the weight gain attributed to the uterus, placenta, placental fluids, foetuses and mammary gland. The contribution of maternal gain to the energy requirement of the sow is variable and is related to the growth phase, which is higher in primiparous sows. The total energy demand of the pregnant sow would also depend on the body condition of the animal at the time of insemination. Therefore, sows with lower body fat reserves require more energy to reach the body condition recommended for the time of farrowing.

Current Feeding Strategies for Gestating Sows and Their Impacts on Nutritional Requirements

Due to the fact that sows are fed restrictively during gestation, they may become deficient in amino acid intake, especially towards end of gestation. Thus, when considering a limited supply of feed to restrict energy consumption, it is important to provide a diet that allows a high efficiency in the utilization of the protein. Amino acids are not only building blocks of protein synthesis but are also used as precursors for nitrogenous substances essential for whole-body homeostasis (Wu et al., 2010). There is strong evidence that the members of the arginine family of amino acids have an important role in placental vascularization and development, especially during the middle of pregnancy (Wu et al., 2007). This theory is supported by Mateo et al. (2007) who supplemented 1% L-arginine to a corn and soybean meal-based diet after day 30 of gestation to gilts and found that supplementation increased the number of pigs born alive by 22%. There is more information available on lysine requirements than other essential amino acids. However, if we apply the ratio that makes ideal use of the proposed need of lysine by Samuel et al. (2008a), the need for methionine would be 40% higher than current recommendations. Methionine plays a key role during pregnancy, including DNA methylation during development of pregnancy, which makes it extremely important for the regulation of gene expression. Dourmad and Etienne (2002) concluded that the need for threonine during pregnancy in modern sows is greater than the value proposed by most published references on sow's requirements, the authors attribute this difference to a greater daily nitrogen retention found in modern sows during gestation. These results corroborate the hypothesis that the amino acid requirements are larger for current genotypes, due to a greater lean tissue deposition and protein turnover capacity. For foetal growth and development of mammary tissue to occur rapidly during the final stage of gestation, the amino acid requirements tend to be higher. Therefore, muscle growth must also be considered in younger sows as part of their reproductive needs. While analysing recent studies with modern genotype sows, particular attention has been given to foetal growth (McPherson et al., 2004) and development of the mammary gland (Ji et al., 2006). The results obtained by these authors indicate an exponential growth of both the foetus tissue as well as the mammary gland mainly after 70 days of gestation. These results are higher than those observed in similar studies in the '80s and the '90s. Wu et al. (1999) assessed the amino acid composition of pig fetuses during the different stages of gestation and observed that this variable changes significantly during the progress of gestation. The changes in the rate and composition of the tissue gain affect the individual needs for amino acids for fetal and mammary gland growth during gestation. From the amino acid composition of various tissues (mammary gland, uterus, fetus, placenta) and the changes that occur during pregnancy, it is possible to develop models based on the productive profile of the modern genotypes, through which we can obtain the real daily nutrient requirements for sows. Based on the results of recent studies, the establishment of nutritional programs using more diets and no longer a single diet throughout the entire gestation period may have not only several benefits for the sows and foetal development (McPherson et al., 2004) but also reducing the excretion of total N and ammonia emissions, which may contribute to higher animal productivity and create a more sustainable environmental system (Clowes et al., 2003a).

The simplest method of meeting the increasing energy and amino acid requirements of sows during late gestation is increasing the level of feed supplied during late gestation. It is proposed that simply increasing feed intake better meets the increasing nutrient demands of the sow. NRC (2012) outlined a 400 g/day (about 20%) feed intake increase after day 90 of gestation based on energy requirements, while this increase should be about 40% based on lysine requirements. A cooperative research study by Cromwell et al. (1989) concluded that additional feed supplied during late gestation improved reproductive performance. The study involved 1,080 litters where multiparous sows in the treatment group were fed 1.82 kg/d of a corn and soybean meal-based diet (3.2 Mcal ME, 14% CP) in addition to the levels received by the control group (summer 1.82, winter 2.27 kg/d) from day 90 of gestation until farrowing. Sows fed extra feed in late gestation farrowed an average of 0.35 more pigs/litter, as well as slightly heavier pigs at birth (1.48 kg vs 1.44 kg) and at weaning (18 days) (Cromwell et al., 1989). A more recent study by Shelton et al. (2003) yielded slightly conflicting results when 0.9 kg/d of extra feed (corn/soybean meal-based diet containing 3.26 Mcal ME, 0.57% SID lysine) was given after day 90 of gestation (2.09 vs 2.95 kg/d,). These authors found that increasing feed intake during late gestation led to a decrease in piglet birth weight in multiparous sows, but an increase in piglet birth weight in gilts. Additionally, gilts offered extra feed had an increase in subsequent conception rate compared to the control, whereas sows fed extra feed had reduced conception rate in subsequent parities. Only in second parity sows did an increased feeding level during late gestation slightly increase litter weight at weaning. We also have to consider that extra feed supplied during late gestation can result in over-conditioning of sows at farrowing, which can compromise sow reproductive performance (Young et al., 1991; NRC, 2012). Research focusing on relating patterns of intake of total feed, energy or protein (i.e., amino acids) during gestation to sow reproductive performance has yielded varying results. In an extensive review of the scientific literature, Campos et al. (2012) reported that providing extra feed or energy during late gestation only marginally improved piglet birth weight, and effects were not consistent between different studies. Several studies demonstrated no effect, while others indicated improvements in various aspects of production, such as litter size, gestation sow BW gain, lactation sow BW loss and feed intake during lactation. Differences in results amongst these studies could be attributed to different levels of energy and nutrients supplied, as well as different durations of time and periods of supplementation. Another important factor to consider is the use of primiparous sows compared to multiparous sows, which are known to have differences in nutrient partitioning. Current commercial gestation sow feeding strategies do not consider the sow as an individual; they are generally based on using a single gestation diet for all sows regardless of parity or stage of gestation. Computer controlled electronic sow feeders (AIPF) allow precision feeding (PF) of individual, gestating sows according to parity order and gestation stage housed in groups. Based on the above observations, it is clear that increasing dietary amino acid levels is more beneficial than increasing feed intake, especially during late gestation, as it does not contribute to excess maternal body lipid deposition which may reduce subsequent sow reproductive performance. While studies have clearly demonstrated that the amino acid demands of gestating sows change throughout gestation, more research is needed to clarify if more closely meeting these changing amino acid and energy requirements will improve sow reproductive performance and ultimately, profitability.

Use of AIPF (artificial intelligent precision feeding) Technology

The welfare of farm animals is important for producers, consumers and society as a whole (CORNISH et al., 2016). Modern hyperprolific sows are often fed restrictively for efficient reproduction and to increase longevity (MANU, 2020) and/or are fed only once a day, for reasons such as reduced farm management or the feeding system. Gestating sows that are fed restrictively may experience stress and impact on their behavior (BERNARDINO et al., 2016). Increased and sustained stress is associated with impaired well-being. The hypothalamic-pituitary-adrenal (HPA) axis is one of the physiological systems almost always activated by stress. In research carried out, it was possible to observe that the availability of food stimulates the rhythmicity of cortisol in such a way that food restriction or starvation increases the average levels of glucocorticoids in humans and rats (GARCIA-BELENGUER et al., 1993; KENNY et al., 2014). Cortisol is a steroid hormone secreted by the adrenal gland and has a circadian rhythm with highest concentration around 8:30 am, gradually decreasing to the lowest levels around midnight (CHAN and DEBONO, 2010; SUNAINA et al., 2016). In studies carried out by Amdi (2013), it was possible to observe that food restriction in pregnant gilts elicited higher levels of salivary cortisol than gilts used in the control treatment, which had higher feeding levels. When an animal is pregnant, the prolonged stress response, the hyperactivation of the HPA axis and the excess of glucocorticoids pose risks to normal development, reproduction, emotional balance, physiological health and the well-being of newborns (COULON et al. al., 2013; PETIT et al., 2015).

With regard to feeding frequency, Verdon et al. (2018) found that increasing feeding frequency allowed the performance of natural behavior to improve welfare compared to less frequently fed sows. According to Meunier-Salaün et al., (2001), pregnant females are fed about 2.5 kg of feed per day, which represents 50% of their *ad libitum* feed intake. Dividing limited feeding into two or three meals or feeding these animals several times a day did not change basal cortisol concentrations, which is consistent with findings from other studies (TERPSTRA et al., 1978; LEVAY et al., 2010). In view of this, according to Manu (2020), in his study it was not expected to find any difference in basal cortisol levels when all treatment groups had similar energy intake per kilogram of metabolic body weight. However, it was observed that twice-daily feeding reduced the area under the curve (AUC) of cortisol compared to control sows. Farmer et al. (2002) also reported that feeding pregnant sows a concentrate diet twice daily reduced cortisol AUC compared to single-feeding sows.

Increasing feeding frequency for pregnant females can improve satiety and their well-being because energy for stereotyped behaviors can decrease and increase productivity. The increase in activity can be attributed to inadequate intestinal filling due to the lower amount of energy and/or volume of food received in each feeding. In support of this theory, Lawrence et al. (1988) explained that the conventional diet of North American sows is concentrated in nutrients and, although it is sufficient for good health and performance, it may not meet the animal's other needs. In addition, the small amount of food is unlikely to give a feeling of satiety (VERDON et al., 2018).

When the amount of the meal is too small to induce satiety, “non-eating activities” persist (TERLOUW et al., 1993; ROBERT et al., 2002). The behavioral activities that precede feed provision are termed “food anticipatory activity” (FAA) (JOHNSTON, 2014). A balanced diet guarantees adequate nutrients for each phase, but this is not synonymous with satiety of the sows, and this lack of satiety may reflect on stress and behavior (MEUNIER-SALAÜN et al., 2001; DE LEEUW et al., 2004). The fact that sows are hungry reflects in abnormal behaviors, arising from the absence of satiety and the presence of motivation to feed. This motivation is represented by behaviors such as rubbing the muzzle on the empty feeder and biting bars in the cell (DOUGLAS, 1998; JENSEN, 1980). Furthermore, these changes in motivation can alter the performance, the immune function and also the behavior of these animals, factors of extreme importance in productivity, economic viability and longevity of the sow (DOUGLAS et al., 1998).

According to Samuel (2019), there is a trio of “rights” in the precise feeding of modern and hyperprolific sows: the right diet, in the right amount and at the right time. Feeding levels for sows during pregnancy are normally based on maintenance requirements, desired body condition, weight and litter weight gains (NATIONAL RESEARCH COUNCIL, 1998; SPOOLDER and VERMEER, 2015; BUNTER et al., 2018). However, the amount of food is normally less than the amount that sows would voluntarily consume (VAN BARNEVELD et al., 2007). In electronic feeding systems, pregnant sows are usually fed only once a day, which has been shown to increase the efficiency of energy use, however, it has reduced the efficiency of protein use and, unfortunately, we still observe a scarcity of information. recent studies on feeding sows at the right time (SAMUEL, 2019). Previous research has not shown significant productivity and performance advantages when feeding sows more than once a day. According to Fabry (1969), feeding sows once a day seems to result in greater energy storage efficiency. The improvement in energy utilization efficiency was also attributed to reduced energy expenditure related to the consumption of a single meal compared to several meals (Baird, 1970). On the other hand, it was possible to observe that the reduction of feeding frequency has an effect on lipid metabolism. As an adaptive mechanism for storing large energy intakes, lipogenesis is stimulated by infrequent feeding of meals (LEVEILLE and HANSON, 1965). The result of increased lipogenesis is an increase in body fat and plasma lipid concentrations (FABRY, 1969). While animals fed a single meal tend to retain excess energy primarily as fat, animals fed more frequently tend to store excess carbohydrates as glycogen rather than converting them to lipids (LEVEILLE and HANSON, 1965). As a result, we can predict the composition of body weight gain among animals fed more frequently compared to those fed a single meal. Therefore, the effect of feeding on energy metabolism must be considered, mainly due to its impact on dietary needs and body composition of sows. Samuel (2019), investigating the energy and protein metabolism of pregnant and non-pregnant females (through simultaneous energy measurements using open circuit calorimetry and protein metabolism as protein turnover), showed that the frequency of feeding has a opposite impact on female metabolism. Therefore, while single-feeding improved energy retention efficiency, protein utilization efficiency was reduced (SAMUEL, 2008). More recently, Manu et al. (2019) reported that when sows fed in the afternoon instead of being fed in the morning, should changes in energy and nutrient metabolismo by increasing backfat thickness.

Currently, a very important goal within the swine industry is to achieve precision feeding. One of the objectives in this regard is to reduce the crude protein content of the swine diet. Potential advantages of low crude protein diets include savings on expensive protein ingredients, reducing dietary costs, lowering nitrogen emissions, lowering the impact on the environment, thus improving gut health and production efficiency. Probably, dietary requirements for amino acids are higher due to single-meal feeding, where protein utilization is reduced (SAMUEL, 2019). In addition, reductions in the crude protein content of the diet will require higher levels and mixtures of synthetic amino acids in the diets. Therefore, the potential for infrequent feeding can negatively impact amino acid utilization due to nutrient asynchrony. Amino acid asynchrony refers to the delayed digestion and absorption of protein-bound amino acids compared to synthetic amino acid sources. However, there may be potential implications for increasing the inclusion of synthetic amino acids, such as in low crude protein and single-meal diets.

Using AIPF technology can accommodate the unique and dynamic changes in energy and amino acid requirements of individual sows throughout gestation. Still there are challenges concerning the implementation of this technology. The limitations of the application of a production system in a commercial farm are not only related to theory (making mathematical models), but the work to be performed with the animals must be treated with great care. In addition, the adaptations in the facilities for the application of this system, as well as the acquisition of such technologies, can impact on production costs if not properly managed.

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