Feedstuffs Reprint

Research on fetal programming covers multiple disciplines

THE fetal pig's development is influenced by many factors that can alter lifelong muscle structure and growth performance. This area of science is referred to as "fetal programming" and is being studied across many disciplines, such as nutrition, reproduction, muscle development and health.

This article will attempt to discuss a few of these areas of research to introduce the basics of fetal programming. This article will relate more to muscle development, the effects nutrition can have on fetal development and a discussion of why variation might exist across different research projects.

As a start to this discussion, a few comments regarding muscle biology and development are used as a baseline:

1. A pig is born with the maximum number of muscle fibers it will have for life. Over the course of its lifetime, the total number will decrease.

2. "Hyperplasia" occurs in the period prior to birth and refers to an increase in the number of muscle fiber cells.

3. "Hypertrophy" occurs primarily after birth, when the pig is growing, and refers to growth in the size of a muscle fiber.

4. Satellite cells are undifferentiated cells that can fuse into muscle fiber cells during hypertrophy and allow for growth and repair of muscle cells. Many satellite cells reside alongside the muscle fibers.

5. Control of muscle fiber hypertrophy postnatally is influenced by muscle function and locomotion, nutrition, environment, genetic base and health.

Figure 1 demonstrates the periods of fetal muscle development *in utero*. The first stage is development of the primary muscle fibers — the structural scaffolding around which the muscle develops. As the proliferation of the primary muscle development slows, the beginning of the secondary muscle development starts to occur in bundles of fibers surrounding the already-developed primary fibers. These secondary fibers will develop more prolifically in the fetal pig. The ratio of primary-to-secondary muscle fiber cells differs between muscle groups (semitendinosus muscle versus longissimus dorsi, as an example), but the number of secondary fibers is 20-fold or more greater than primary fibers.

Figure 2 illustrates a signaling pathway for mammalian transcript of rapamycin (mTOR), which is the major signaling pathway that stimulates muscle cellular development. The insulin-like growth factor-1 (IGF-1) receptor affects the phosphorylation of the mTOR pathway, resulting in the stimulation of muscle protein synthesis (proliferation and/or differentiation, depending on timing).

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Bottom Line

with
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From a practical standpoint, understanding these realities of development demonstrates the difficulty of balancing fetal development and sow condition at the sow farm. When considering the events that occur in the daily feeding of sows transitioning from lactation with different body conditions and the variance that exists in parity distribution of the sow herd, it is easy to see that some activities can conflict with periods of fetal development.

As an example, a farm with an overconditioned sow might choose to reduce the amount of feed provided to that sow during a period when fetal development is occurring; this will affect the long-term performance of the offspring.

In most research evaluating the effects of nutrition during gestation on subsequent progeny performance, severe feed changes have affected fetal development, altering muscle development and postnatal growth characteristics.

Research by Dwyer et al. (1994) illustrated that doubling feeding intake during gestation at the critical time of days 25-80 resulted in a 5% increase in the number of muscle fibers, an increase in the secondary:primary fiber ratio and faster average daily gain (ADG) in the offspring (Table).

As the area of nutritional effects on fetal programming is explored, it is important to ensure that differences of *in vitro* (benchtop) and *in vivo* (animal) work are not used individually to determine the true mechanism of action but are used together to identify conceptual pathways that may be influenced.

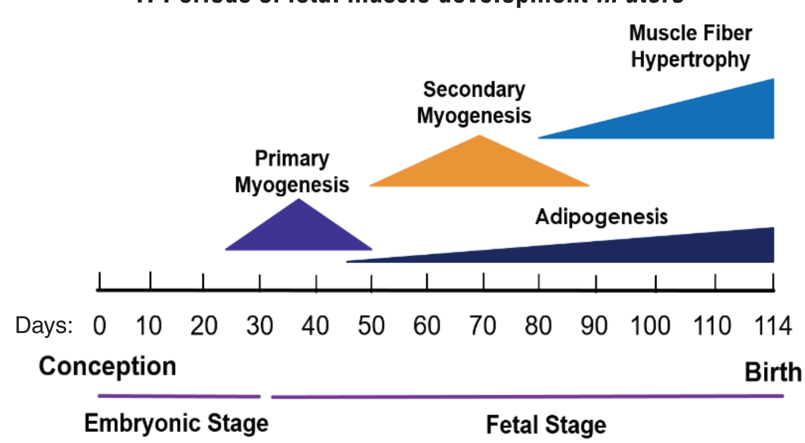
Over the past several decades, a better understanding of the impact of IGF-1, IGF-1 binding proteins and regulatory factors — such as pyruvate dehydrogenase kinase 1 (PDK1), phosphoinositide 3-kinase (PI3K), My5, Pax7, AKT and others — has allowed researchers to determine more of the direct ties into the mTOR pathway.

This knowledge is critical for understanding the regulation of myoblast proliferation and differentiation, as well as a great deal of other protein synthesis functions. Today, several nutritional options are being investigated to understand the effects they can have on mTOR and signaling proteins, and some research groups are now starting to demonstrate these effects in *in vitro* experiments.

As technologies continue to validate the action through these pathways and demonstrate clear effects in offspring characteristics and performance, the potential to improve animal production will be exciting.

Research in the area of maternal gestation management and its influence on long-term progeny performance is certainly of interest to practical animal pro-

1. Periods of fetal muscle development *in utero*



duction, but it is complex and difficult to conduct this type of research.

It is known that response variations in this area can exist and may be influenced by several key factors, such as nutrient requirements for the gestating sow not being clearly defined for parameters outside the reproduction rate, weight gain and lactation performance. Very little work has been done to evaluate maternal nutrient exposure on postnatal performance of the progeny. Relatively little is understood regarding how this type of research should even be conducted, including how consistent the maternal effect may be on all progeny within a litter, which affects how progeny should be subsampled.

Clearly, other factors such as parity, baseline nutrition of the dam as well as total number born all add to the variation that makes this type of research extremely complex.

The Bottom Line

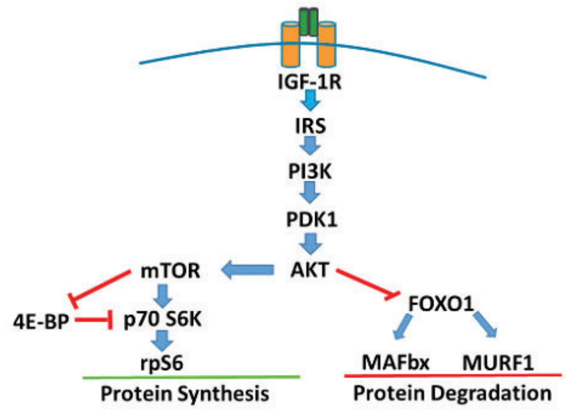
The goal here is to illustrate that many practices often employed in the daily production of pigs might be creating responses that are not considered as they relate to the long-term productivity of the animals raised to feed the world.

This is also intended to encourage nutritionists, researchers and animal caregivers to communicate across disciplines as they plan protocols for research or develop standard operating procedures for swine production.

Effect of doubling sow feed intake during gestation at days 25-80

	Control sows	High-intake sows	P-value
Intake, kg/day	2.5	5.0	—
Number of muscle fibers	370,970	389,950	>0.05
Ratio of secondary: primary fibers	23.2	25.2	<0.05
Offspring ADG, days 70-130, g/day	840.1	924.4	<0.05

2. Signaling pathway for mTOR



Source for Figures: Matt Vaughn, Muscle Biology Lab, Kansas State University.

Reference

Dwyer, C.M., N.C. Stickland and J.M. Fletcher. 1994. The influence of maternal nutrition on muscle fiber number development in the porcine fetus and on subsequent postnatal growth. J. Anim. Sci. 72:911-917. ■