November 2021
Volume 9 Issue 6

NDS Dynamics

Welcome to the NDS Dynamics newsletter!

Dear readers,

For the last issue of the year, we have Professor Mike Van Amburgh (Cornell University, USA) discussing calves feeding management, paying particular attention to the starter formulation.

In addition, Dr. Giulia Esposito (RUM&N, R&D), gives an overview of the effect of dietary strategies during pregnancy on the critical developmental windows which will determine the future performance of the offspring.

RUM&N consulting wishes all the readers a happy and safe festive season looking forward to 2022 full of advancement in ruminant nutrition and precision feeding.

Please continue to follow us on our channels to receive updates on what is new and what is happening at RUM&N and NDS North America.

The Editor
Ermanno Melli

Calf starter formulation discussion

*By M. Van Amburgh**
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A feed management objective is to encourage dry feed intake to develop the rumen and supply nutrients. It is essential that the calf learn to consume starter and develop a functional rumen by the time the weaning process is completed. Basic requirements for starter intake before complete weaning are that calves be consuming at least 1 to 1.3 kg of starter by the time liquid feed is removed. The amount of starter intake, however, before weaning is confounded by the level of milk fed, so an absolute value is not really appropriate. It is most important that the calf consume enough to develop the rumen and establish a robust microbial population to ensure good digestion and rumen function. Under most of the conditions that dairy calves are managed, barriers to learning can affect how the calf views and accepts starter grain as a food source. Our way of managing that learning has been to limit the nutrients from milk or milk replacer in an effort to enhance hunger so they are encouraged to consume nutrients from other sources. Having calves of somewhat varying ages in housing conditions that allow for interaction or at least visual observation helps with the learning process because the older calves provide lessons in eating behavior for the calves not yet experienced enough to understand where and what the starter grain might be. Creating an environment that allows calves to teach each other about starter grain intake is essential to enhance nutrient delivery and weaning efficiency in dairy calves and help avoid post-weaning nutrient balance problems (de Paula Viera et al., 2012). Furthermore, starter grain formulation has relied heavily on the use of starch, either from corn or oats and high inclusion levels of starch might be counter-productive for efficient weaning and rumen development. Many starters on the market range from 32% to 59% starch and those levels have been formulated to ensure moderate energy intake at reduced dry matter intakes and provide adequate fermentable carbohydrates to promote rumen fermentation, microbial yield and rumen development. These levels of starch, however, are quite high and might inhibit feed intake because of potential effects on rumen pH in calves transitioning to a ruminant state. The pH effect of high starch starters is equivocal in published studies (Castells, et al., 2013; Laarman et al. 2012). Several studies have been conducted evaluating the addition of forage on weaning efficiency. Those studies have been modestly successful most like by diluting the starch content and providing fiber for chewing, rumination, resulting in increased saliva production to buffer the pH (Kahn et al., 2011; Terre et al., 2013). Adding forage fiber might be an option but is difficult to do under practical conditions. There are alternatives to this approach and those alternatives require rethinking the ingredients used in starter grains.

To extend this discussion, under conditions of pasture rearing (a more natural environment), calves would suckle the dam and eventually consume some young, immature pasture forage in addition to their milk. That pasture forage likely would be low in fiber (29 to 32% NDF), moderate in protein (17 to 20%), moderate in sugars (14 to 20%), nearly void of starch, and very high in carbohydrate and NDF digestibility compared with many of the forages currently fed to calves. Sugars, such as sucrose and fructose found in the pasture forage would promote good fermentation, tend not to ferment to lactic acid, and promote both butyrate and propionate production to enhance rumen development. And a modest amount of NDF would be provided from the forage, thus providing chewing and rumination for proper buffering. Thus, a starter formulation consistent with this type of forage would be lower in starch, higher in sugar, would provide NDF in a form that is highly digestible and can be included in the starter pellet.

An example starter formulation is found in the table below and represents a starter that provides some starch, greater than average protein, moderate NDF levels, and greater than average sugar levels to promote fermentation and rumen development. The beet pulp could be replaced with citrus pulp as both would supply very modest sugar levels and more importantly, soluble fiber (pectin) that digests rapidly and has reasonably digestible NDF. It can be pelleted or processed in a form that can be included in the starter grain mix. It is important that these conditions be met in an economical manner that is easy to implement and ensures adequate intake by the calf. No matter the nutrient profile or density, the primary criteria for the first dry feed offered to the calf is palatability and intake potential.

Example calf starter formulation that provides lower starch, higher sugar, and adequate NDF to promote rumen fermentation, chewing and rumination and rumen development along with adequate nutrients to meet 1 kg/day gain

Pellet ingredients	Amount (kg)	% of DM
Wheat mids	0.6	0.199
Rumen protected soybean	0.6	0.199
Canola meal	0.2	0.066
Sugar	0.1	0.033
Dried whey	0.18	0.060
Blood meal	0.12	0.040
Metasmart dry[1]	0.022	0.007
Minerals	0.02	0.007
Vitamins ADE	0.01	0.003
Rumensin premix	0.01	0.003
Flavor enhancer	0.01	0.003
Molasses	0.1	0.033
Fat	0.02	0.007
Yeast cell wall product	0.02	0.007
External ingredients		
Beet pulp shreds	0.4	0.132
Flaked corn	0.61	0.202

[1]Isopropyl ester of hydroxy analogue of methionine (hMBI), Addiseo, Alpharetta, GA

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Dam nutrition during pregnancy affect future offspring performance

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Allocation of energy and nutrient requirements for dairy cows during the dry period tends to focus on the transition period, because it represents the moment of higher metabolic demands, coinciding with the accelerated growth of the foetus and the beginning of lactogenesis.
This practice has led to neglect of cows 'requirements during late lactation and early dry period, when the female is regarded as unproductive while, in fact, is gestating a calf that will represent an income for the enterprise, either as an abattoir-sell or as a replacement for the herd.
Moreover, most of the time, these negative effects are carried over to the next generation as epigenetic modifications often occur.
In recent years the concept of foetal programming has been developed, stressing, even more, the need for highly fine-tuned diets. According to Nathanielsz and collaborators (2007), foetal programming can be defined as "The response to a specific challenge to the mammalian organism during a critical developmental time window that alters the trajectory of development qualitatively, quantitatively, or both, with resulting persistent effects".
In animal and biomedical science, there is growing evidence that fetal programming can alter the postnatal development, growth, and disease susceptibility of the offspring.

During pregnancy, the main "critical windows" have been identified as follow:

1. Placentation
2. Immune system development
3. Growth and attainment of puberty
4. Muscle and fat development

Placentation

The placenta is a transient unique organ of pregnancy that provides an interface for metabolic exchange between the dam and the foetus (Senger et al., 2003). This develops after maternal recognition of pregnancy in mammals (Schlafer et al., 2000), and it is fully developed by 40 days in cattle. While most foetal growth occurs during late gestation (Bach et al.,2012), inadequate nutrition during early gestation can have profound effects on placental development, vascularization, and embryo organogenesis (Funston et al., 2010). Placental surface growth, vascularisation, and secretion of growth factors never cease during pregnancy paralleling increasing foetal demands. Thus, nutrient restrictions during this phase can dramatically affect placentation and foetal development. In fact, nutrient restriction during early gestation, followed by re-alimentation during d 125 to 250 affected placental angiogenesis, caused decreased development in the cotyledonary and caruncular portions (Vonnahme et al. 2007). Compromised placental development translates into reduced vascularity and uteroplacental perfusion, thus increasing the risk of impaired embryo development (Mc Gready et al.,2019). Uteroplacental blood flow affects the transport of nutrients through the placenta. In large animal models, it has been demonstrated that nutrient transport increases throughout gestation primarily because of increased uteroplacental blood flow rather than increased nutrient extraction from each unit of blood (Reynolds et al., 2010). Thus, supporting the hypothesis that uteroplacental perfusion plays a central role in foetal growth.

Immune system development

Although the ruminant immune system forms during foetal development, the passive transfer of immunity depends mainly on the quality and quantity of colostrum available and the absorption capacity of the newborn (Tizard, 2013; Moreno-Indias et al., 2012). However, nutrient-restricted cattle have decreased colostrum tri-iodothyronine concentration which plays an important role on IgG absorption at the calf intestinal level (Kennedy et al., 2019; Boland et al., 2008). Thus, the ability of the offspring to acquire immunoglobulins G (IgG) seems to be affected by the nutrition of the dam during late gestation (Quigley et al., 1998). A decrease in protein intake during the last trimester of gestation results in impaired serum IgG concentration in the calf. Furthermore, calves born to cows fed a balanced diet, but fed colostrum from dams fed restricted diets have less serum IgG concentrations at 24 h of life than the calves receiving colostrum from well-nourished cows (Quigley et al., 1998).

Growth and attainment of puberty

Several studies in cattle have demonstrated the importance of dam nutrition on the growth, attainment of puberty, and reproductive performance of the offspring. The major factors controlling the onset of puberty are body weight and growth rather than age (Perry, 2016). For instance, although heifers born to dams supplemented with protein during the last third of pregnancy had similar birthweight to calves born from non-supplemented dams, these animals, had higher pregnancy rates (Martin et al., 2007). In addition, restricted nutrition in beef cattle decreases birth weights and reduces postnatal growth (Robinson et al., 2001). Although the effect of global nutrient restrictions and /or excess has been extensively investigated, individual nutrients hinder offspring wellbeing if deficient. For example, methionine supplementation in Holstein cows changes the transcriptome of flushed embryos, including genes involved in embryonic development and immune responses (Peñagaricano et al., 2013; A Sánchez-Garrido et al., 2013). Furthermore, maternal nutrition modulates the hypothalamic pathways controlling GnRH release and, therefore, affects the programming of puberty in the female offspring (Cardoso et al., 2020; Iwasa et al.,2010). In cattle, any nutritional and metabolic change occurring from foetal life to puberty can impact the hypothalamic pathways controlling GnRH secretion and pubertal maturation (Cardoso et al., 2020). In fact, maternal nutrition meeting the animal requirements during gestation, together with high body weight gain rates during early postnatal development, results in increased circulating levels of leptin, insulin, and IGF1; reduced neuropeptide Y (NPY) mRNA abundance and NPY (inhibitory) inputs to GnRH neurons.

Muscle and fat development

Skeletal muscle development is initiated in the embryonic stage during primary myogenesis (first trimester of pregnancy), with the formation of primary myofibers (Cossu and Borello, 1999). During this phase, maternal nutrition has negligible effects on fetal skeletal muscle development. In cattle, the majority of muscle fibers form during the secondary myogenesis (between the 2nd and 7th/8th months of gestation; Russel and Oteruelo, 1981). This period is crucial because there will be no net increase in the number of muscle fibers after birth (Thornton et al., 2019; Paradis et al.,2017).

Post-natal muscle growth occurs mainly due to an increase in muscle fiber size rather than new muscle fiber formation (Thornton et al., 2019; Karunaratne et al., 2005). Adipogenesis is initiated around mid-gestation (Muhlhansler et al.,2007), overlapping with the period of secondary myogenesis. The amount of intramuscular fat is determined by the number and size of intramuscular adipocytes within foetal skeletal muscle. Skeletal muscle and fat are less of a priority in terms of nutrient partitioning during foetal development when compared with organs development. As a result, skeletal muscle development is particularly vulnerable to nutrient availability (Zhu et al.2006). It has been reported that calves from nutrient-restricted beef cows have decreased average daily gain and fatter carcasses at 30 months of age (Cafe et al., 2009; 2006). However, in calves from dams fed nutrient-restricted diets during early pregnancy, but that was realigned during late gestation; muscle fiber size and muscle progenitor cell numbers could be rescued (Gonzales et al., 2013). Furthermore, it has been reported

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that improving the dams' diet by increasing forage quality during mid to late gestation, results in leaner calves and with better yielding carcasses compared to offspring from dams fed a negative energy diet (Mohrhauser, et al 2013; Du et al., 2010).

Seizing the opportunity

The best strategy to obtain highly productive offspring is to provide adequate dam nourishment. However, several strategies, when applied timely, can be used to aid in preventing or compensating the negative effects induced by undernourishment of dams during pregnancy.

Protein supplementation of the maternal diet, for instance, proved to have a positive effect on neonates' birth weight, further attainment of puberty, and first pregnancy rate when provided over the last trimester to grazing beef dams (Martin et al., 2007); Arginine and Methionine and/or B vitamins improve blood flow into organs and stimulate tissue growth (Kwon et al., 2004).

Therefore, taking advantage of pregnancy as the first available and possibly most influential developmental window by providing and/or reinforcing adequate nutritional and energy requirements will positively impact future offspring performance by unlocking full genetic potential. Improvement in carcass quality in the case of beef production or mammary gland development and milk production capability in dairy cattle plus the enhancement of reproductive performance in both cases are amongst the effects to look forward to.

Send us your comments on this topic! Emiliano Raffrenato is at emiliano.raffrenato@rumen.it; Giulia Esposito is at giulia.esposito@rumen.it; Dave Weber is at rumendvm@gmail.com

Note that the features and utilities developed by the NDS team are not components of the underlying CNCPS model. None of the original CNCPS structures or equations have been changed in the NDS platform. NDS does provide sub-models and utilities to provide enhanced predictions based on the original CNCPS model. *Questions about the use of these features should be directed to the NDS support team, and not to the CNCPS group at Cornell.*

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