Fetal Programming in Dairy Cattle

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Abstract

It has been widely known that maternal nutrition may play a role in the development of the fetus in mammalians. Many studies have been conducted on the study of fetal programing in sheep and beef cows, but there is not much research on the area in dairy cows. In 2013 at the Tristate Dairy Conference, Dr. Schoonmaker presented a review on the same topic showing a lot of possible areas of research for fetal programing in dairy cows. Our idea is not to cover again his perspectives but to show some results and future research on the area. On this review, we will show some data on the effect of increasing number of parity, days in milk, milk yield, and milk energy output at the time of conception and their effect on the offspring performance and longevity. At this time, there is not much information on the role of different nutrients impact on fetal programing. However, there are some physiological aspects of the fetal and placenta development that may be considered important for future research on the impact of different nutrients during gestation. The current data on dairy cows suggest that cow health may be more important than milk yield or milk energy output. The main reason of this may be due to the possible, but unknown, increase in requirements on subacute inflammatory states.

Introduction

The study of fetal programing in animal production became relevant after the study of Godfrey and Baker (2001). This study shows the effect of adult undernutrition and its impact on the health of their offspring. Since then, there are thousands of publications in many species that look on how nutritional or endocrine changes during gestation impact offspring health or performance. Considering large farm animals, sheep is used as a model for human health (Vuguin, 2007). For this reason, there are many studies looking into fetal programing in sheep. In beef cows, the type of production system and the outcome makes the study of fetal programming a very important tool to improve productivity. The reason for this is during the last third of gestation in US cow-calf operation systems, the cows receive some type of supplementation, most of the times as hay or they were grazing poor quality forage. The strategic supplementation during this period of time improves performance in the cow and in the offspring (Larson et al., 2009; Funston et al., 2012). In dairy cows, diet composition is more controlled than in cow-calf operation systems and generally diets are formulated to meet or exceed the known nutrient requirements. Also, the main objectives in lactating dairy cow diets are to cover lactation requirements at the different physiological stages. In our opinion, the main reason why there are more studies

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conducted on fetal programing in sheep and beef cows than in dairy cows is because the different production systems and the expected outcomes on the production in each system. However, we know that lactating dairy cows' metabolism changes a lot during lactation, somewhat similiar to milk production. Because of that, we thought it would be logical to expect an imprinting effect of milk production and physiological stage on fetal development.

Description of the Model

Lactating dairy cows are unique models in which conception may coincide with the higher maternal nutrient and energy requirements. In early lactation, the cow enters a negative energy balance that leads to mobilization of body energy reserves. During the last part of this negative energy balance is when we want the cow to conceive. However, we need to consider that nutrients must be partitioned between the mammary gland and the placenta. Therefore, our starting hypothesis was that milk production will play a role in fetal development.

Fetal Program Effect

As mentioned earlier in the manuscript, there is not much research on fetal programing in dairy cows. However, there are some research that looks into it. One of the first studies that looked into the role of maternal performance on their offspring performance was conducted by Pryce et al. (2002). They use two genetic lines as maternal treatments and evaluate the effect that the genetic line has on reproductive performance. In this study they did not find difference on maternal genetic line and reproductive performance, neither in milk yield, body condition score, nor dry matter intake on the first 180 days of lactation (Pryce et al., 2002). However, the study did not have a large number of animals and there were various management systems. This may result in not enough experimental units to test their proposed objective.

Another interesting study on fetal programming was carried out by Berry et al. (2008). In this study, they evaluated maternal milk production in their offspring. They used a large data base of more than 20,000 cows. Despite the objective to evaluate the effect of milk production, they separated the dams only by milk yield, without talking in consideration other variables, such as days in milk. From this study, they observed that milk yield at the time of conception had a negative impact on milk yield of the offspring and survival of the offspring to the second lactation. Also, increased dam milk yield increases somatic cell counts on the offspring (Berry et al., 2008).

However, it is known that milk yield changes depending on the days in milk of each cow. For that reason, we used a large data base (more than 150,000 dams and 200,000 offspring) and added into the model the effect of milk yield at the time of conception, number of parity, days in milk at conception, and their interaction (Chiarle et al., 2015). We did not observe an effect of the interactions of the explanatory variables. Considering milk yield at the time of conception, there was no effect of milk yield or energy yield on the dam at the time of conception or the offspring's milk yield in the first lactation. This is different from the results of Berry et al. (2008), but it is possible that the difference is due to the inclusion of days in milk in our model. When we evaluated days in milk (**DIM**), we observed a quadratic effect of DIM at conception on the offspring's milk yield (Figure 1). The offspring conceived from cows in early lactation produced less than offspring conceived at later DIM, and it plateaued at day 150. When we evaluated the effect of number of parity on the offspring's milk yield, we observed a decrease in the offspring's milk yield when the dam had increased number of lactations (1st, 2nd, 3rd or subsequent, Figure 2). This model does not take in consideration the bull or the genetic improvement on each parturition; therefore, the response may be bigger if we add those variables in the model. Within in each cow, milk yield and DIM are confounded, and for that reason, it may be possible why our results in milk yield differ from those presented by Berry et al. (2008).

Another study was conducted by Gonzalez-Recio et al. (2012). This study supported the effect of dam parity on the offspring's milk yield. Also, it revealed that dam parity or number of lactations has an impact on the offspring's longevity and milk composition. If the offspring is born in the first parturition, it has a longer lifespan and a greater fat/protein ratio. Gonzalez-Recio et al. (2012) also looked at the effect of dam subclinical mastitis and the effect on offspring milk yield and longevity. Despite there not being a significant difference, dam subclinical mastitis trended to decrease milk yield and lifespan on the offspring.

So far, there are no studies that can explain the physiology mechanism of these results; however, we suggest that the uterine environment may play a big role on the fetal development. It is possible that in cows with more parities or in early stages of production, the uterus is healing form injuries produced by calving and aging. This may lead to changes in expression of genes, endocrine responses, or even an increase in immune response.

A study presented by Valour et al. (2014) showed on 18 day embryos, difference in genes occurred that are involved in energy and lipid metabolism, depending the physiological stage of the cow. They compared 2 different physiological stages (heifers, early lactation, and late lactation). These group of dams presented different endocrine and metabolite plasma profiles, such as changes in plasma insulin, non-esterified fatty acids (**NEFA**), glucose, and insulin-like growth factor-1 (**IGF-1**) concentrations. In their conclusion, they stated that energy nutrient availability in the dam may have an effect on endometrium physiology.

Conclusions and Future Research

Despite there not being much research on fetal programing in dairy cows, there is evidence that physiological stage of the dam has an impact on the productivity of the offspring. Because of the genetic selection for milk yield and the effects on mammary development, dam milk production does not seem to be the most important factor regulating fetal programing.

There are some things that we have to consider for future research in this area. Some of those are the association of embryonic and fetal development and the association with placenta physiology. This will help us to understand at what particular time a particular nutrient is required. Also to evaluate if we can nutritionally, through endocrine changes, manipulate the placenta physiology to improve the availability of nutrients to the fetus, in particular periods of development.

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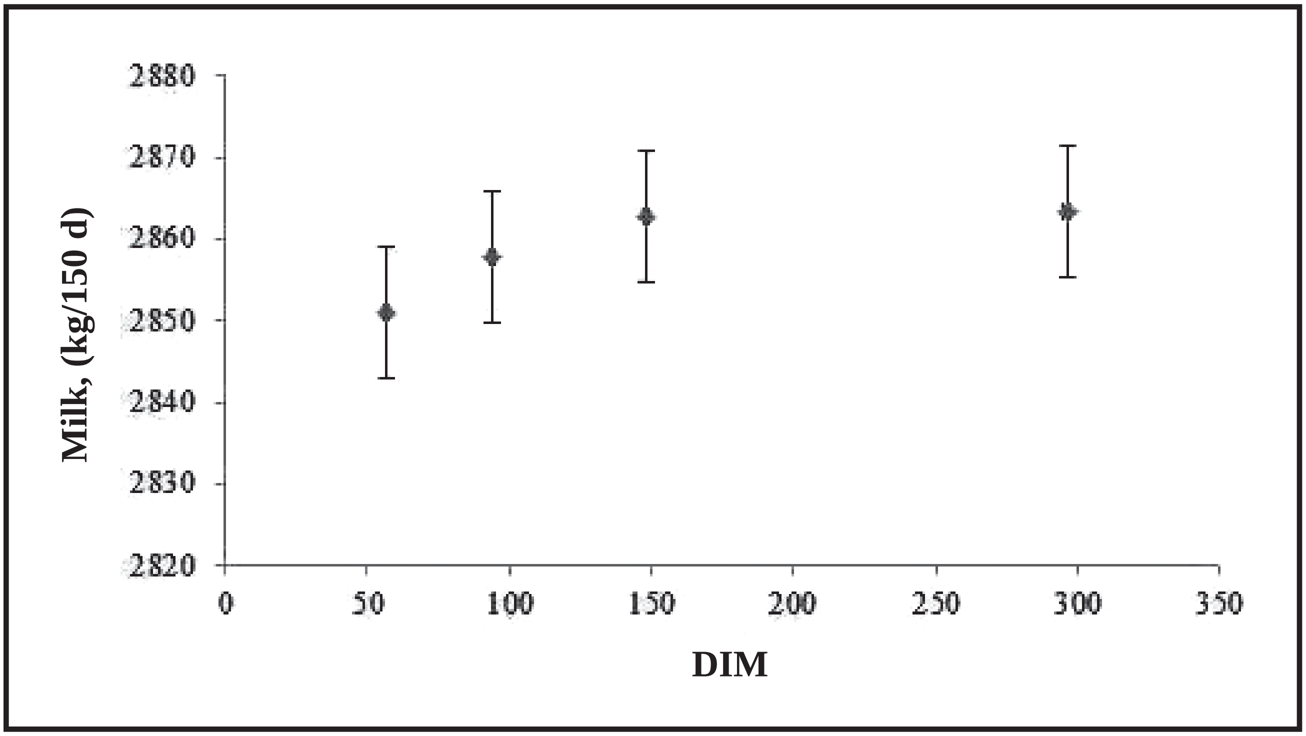

Figure 1. Effect of dam days in milk (DIM) on their offspring's accumulated milk yield in the first 150 days of lactation of the first lactation (P value for linear effect < 0.01, quadratic < 0.01, cubic > 0.10).

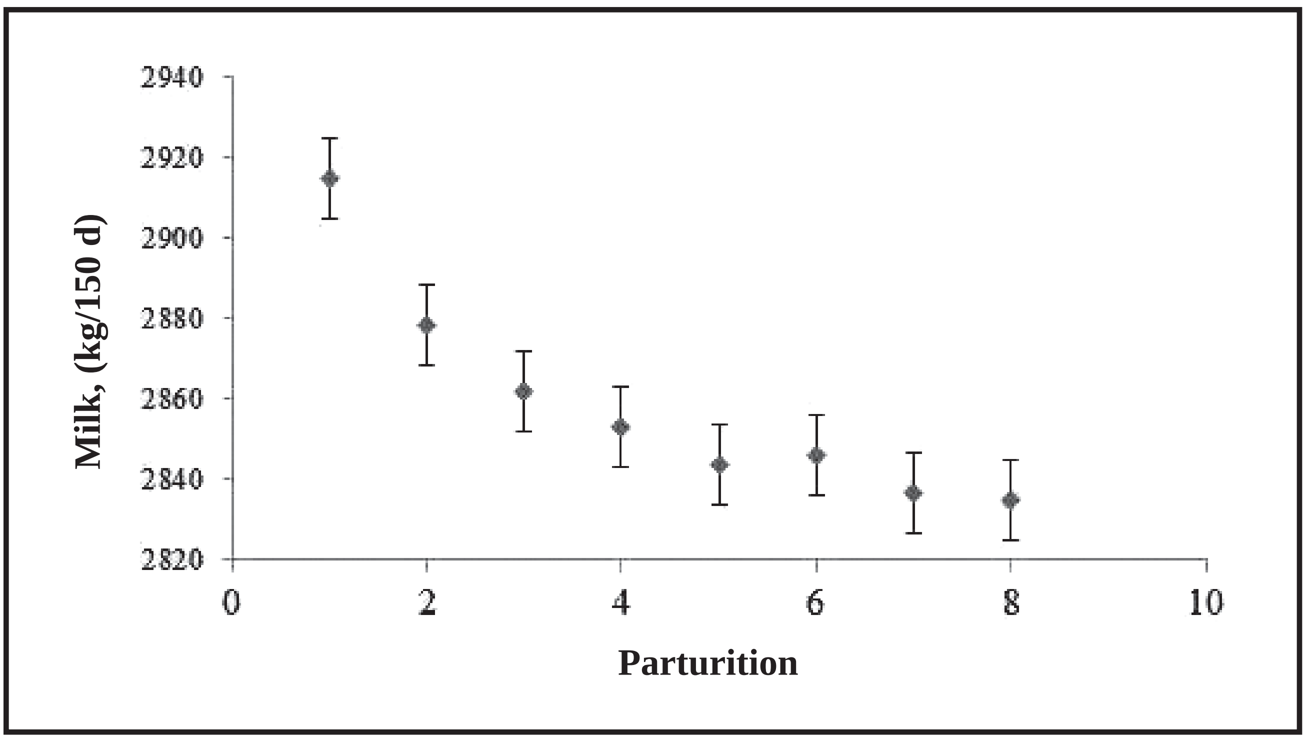

Figure 2. Effect of dam number of partuirtions on their offspring's accumulated milk yield in the first 150 days of lactation of the first lactation (P value for linear effect < 0.01, quadratic = 0.05, cubic > 0.10.